NASA SP-7037 (297)
November 1993

AERONAUTICAL ENGINEERING

A CONTINUING BIBLIOGRAPHY WITH INDEXES

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A CONTINUING BIBLIOGRAPHY WITH INDEXES

National Aeronautics and Space Administration
Scientific and Technical Information Program
Washington, DC 1993

This publication was prepared by the NASA Center for AeroSpace Information,
800 Elkridge Landing Road, Linthicum Heights, MD 21090-2934, (301) 621-0390.

INTRODUCTION

This issue of *Aeronautical Engineering — A Continuing Bibliography with Indexes* (NASA SP-7037) lists 825 reports, journal articles, and other documents recently announced in the NASA STI Database.

Accession numbers cited in this issue include:

Scientific and Technical Aerospace Reports (STAR) (N-10000 Series)	None for this issue
International Aerospace Abstracts (IAA) (A-10000 Series)	A93-47551 — A93-49080

The coverage includes documents on the engineering and theoretical aspects of design, construction, evaluation, testing, operation, and performance of aircraft (including aircraft engines) and associated components, equipment, and systems. It also includes research and development in aerodynamics, aeronautics, and ground support equipment for aeronautical vehicles.

Each entry in the publication consists of a standard bibliographic citation accompanied in most cases by an abstract. The listing of the entries is arranged by the first nine *STAR* specific categories and the remaining *STAR* major categories. This arrangement offers the user the most advantageous breakdown for individual objectives. The citations include the original accession numbers from the respective announcement journals.

Seven indexes—subject, personal author, corporate source, foreign technology, contract number, report number, and accession number—are included.

A cumulative index for 1993 will be published in early 1994.

Information on availability of documents listed, addresses of organizations, and CASI price schedules are located at the back of this issue.

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TYPICAL REPORT CITATION AND ABSTRACT

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ACCESSION NUMBER → **N93-10098** *# Old Dominion Univ., Norfolk, VA. Dept. of Mechanical Engineering and Mechanics. ← CORPORATE SOURCE

TITLE → **NAVIER-STOKES DYNAMICS AND AEROELASTIC COMPUTATIONS FOR VORTICAL FLOWS, BUFFET AND AEROELASTIC APPLICATIONS Progress Report, 1 Oct. 1991 - 30 Sept. 1992**

AUTHOR → OSAMA A. KANDIL Sep. 1992 38 p ← PUBLICATION DATE

CONTRACT NUMBER → (Contract NAG1-648)

REPORT NUMBER → (NASA-CR-190692; NAS 1.26:190692) Avail: CASI HC A03/MF A01 ← AVAILABILITY AND PRICE CODE

The accomplishments achieved during the period include conference and proceedings publications, journal papers, and abstracts which are either published, accepted for publication or under review. Conference presentations and NASA highlight publications are also included. Two of the conference proceedings publications are attached along with a Ph.D. dissertation abstract and table of contents. In the first publication, computational simulation of three-dimensional flows around a delta wing undergoing rock and roll-divergence motions is presented. In the second publication, the unsteady Euler equations and the Euler equations of rigid body motion, both written in the moving frame of reference, are sequetially solved to simulate the limit-cycle rock motion of slender delta wings. In the dissertation abstract, unsteady flows around rigid or flexible delta wings with and without oscillating leading-edge flaps are considered. L.R.R.

TYPICAL JOURNAL ARTICLE CITATION AND ABSTRACT

NASA SPONSORED

ACCESSION NUMBER → **A93-12007** * National Aeronautics and Space Administration. Langley Research Center, Hampton, VA. ← CORPORATE SOURCE

TITLE → **NUMERICAL SIMULATIONS OF HIGH-SPEED FLOWS ABOUT WAVERIDERS WITH SHARP LEADING EDGES**

AUTHORS → KEVIN D. JONES and F. C. DOUGHERTY (Colorado Univ., Boulder) ← AUTHORS' AFFILIATION

JOURNAL TITLE → Journal of Spacecraft and Rockets (ISSN 0022-4650) vol. 29, no. 5 Sept.-Oct. 1992 p. 661-667.

PUBLICATION DATE → Research supported by Univ. of Colorado and DLR refs

CONTRACT NUMBER → (Contract NAG1-880)

A procedure is developed for the numerical simulation of stagnation-free inviscid supersonic and hypersonic flows about waveriders with sharp leading edges. The numerical approach involves the development of a specialized grid generator (named HYGRID), an algebraic solution-adaptive grid scheme, and a modified flow solving method. A comparison of the results obtained for several waverider geometries with exact solutions, other numerical solutions, and experimental results demonstrated the ability of the new procedure to produce stagnation-free Euler solutions about sharp-edged configurations and to describe the physics of the flow in these regions. I.S.

AERONAUTICAL ENGINEERING

A Continuing Bibliography (Suppl. 297)

November 1993

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AERONAUTICS (GENERAL)

A93-48554
ANALYSIS ON SPACE SHAPE AND TENSION DISTRIBUTION OF TOWED FLEXIBLE CABLES
TONGLI ZHOU (Research Inst. of Pilotless Aircraft, China) Nanjing University of Aeronautics and Astronautics, Journal (ISSN 1000-1956) vol. 25, no. 3 June 1993 p. 391-398. In CHINESE refs

This paper comprises a study of the theoretical analytical method by which to calculate the shape and tension distribution of the flexible flying cable towed by aircraft. The study takes account of the influences of gravity and aerodynamic force on the towed cable and on its shape and tension distribution. Also taken into account is the influence of the acceleration when the aircraft is accelerating in different directions. The analytical method suggested in this paper is one of the essential tools by which to study the problems with respect to the movement of the aircraft-towed cable-target dynamic system.

A93-49331
WILL AEROSPACE PLANE DEVELOPMENT GO INTERNATIONAL?
JERRY GREY Aerospace America (ISSN 0740-722X) vol. 31, no. 7 July 1993 p. 16-19, 41.
Copyright

An evaluation is made of current prospects for the pooling of various nations' efforts toward aerospaceplane (ASP) development into a single. more economical international program. The existing ASP efforts are (1) NASA/DOD's NASP and X-30, (2) Britain's HOTOL, and (3) Germany's Saenger. The most important of the barriers to cooperation on this scale is the engineering of numerous interfaces among constituent systems that are developed and manufactured according to distinctive national standards. Attention is drawn to the prospects for the use of NASP's development-coordination mechanism as a model for an international cooperative effort. AIAA

A93-50353
IMPLICATIONS OF EUROPEAN LEGISLATION POST 1992; PROCEEDINGS OF THE CONFERENCE, LONDON, UNITED KINGDOM, MAR. 12, 1992
London Royal Aeronautical Society 1992 51 p. No individual items are abstracted in this volume
(ISBN 1-85768-015-4) Copyright

The present conference discusses the liberalization of commercial aviation regulatory policies in the European Community (EC), the harmonization of maintenance regulations, standards of competence and qualifications, and a new domestic route for flying across Europe. Also discussed are the certification of nondestructive testing personnel in the 1990s, prospective aviation standards for the EC, and the prospective benefits of Eastern European airlines' involvement in EC regulatory efforts. AIAA

A93-50486
AIRCRAFT SAFETY EVALUATION
Aerospace Engineering (ISSN 0736-2536) vol. 13, no. 7 July 1993 p. 7-9.
Copyright

One of the most critical steps taken toward determining the structural airworthiness of a new aircraft is the assessment of the *structural load spectrum associated with its intended use*; this information forms the basis for future service life evaluations and inspection programs. Attention is here given to several representative load-spectra determination methods, each of which has distinctive features and advantages. While the FAA AFS-120-73-2 and NCR LR-516 spectra are easy to use,and yield conservative results, the ESDU 69023 and NASA SP-270 spectra are more sensitive to altitude. AIAA

A93-51727
COST EFFECTIVE PROCESS SELECTION FOR COMPOSITE STRUCTURE
W. T. DOMINY, JR. (Grumman Aircraft Systems, Bethpage, NY) Jan. 1993 9 p. In RUSSIAN Society of Manufacturing Engineers, Conference on Composites in Manufacturing '93, Pasadena, CA, Jan. 19, 20, 1993
(SME PAPER EM93-100) Copyright

The selection of a manufacturing process for a complex design composite structure has a direct impact on the cost of the tooling and manufacturing of that structure. The decision to cocure or integrally cure a structure has an impact on the economics of the program. Using an aileron as a target cost model the cost impact of cocuring versus integrally curing is examined. All of the cost considerations of the target cost model are investigated as they relate to the process selection. This will include the cost trades and manufacturing technical considerations.

A93-51732
DESIGN AND MANUFACTURE FOR PRODUCIBILITY OF CARBON FIBER/EPOXY COMPOSITE AIRCRAFT SKINS
VINCENT C. YUHAS (Northrop Corp., Aircraft Div., Hawthorne, CA) Jan. 1993 14 p. In RUSSIAN Society of Manufacturing Engineers, Conference on Composites in Manufacturing '93, Pasadena, CA, Jan. 19, 20, 1993
(SME PAPER EM93-104) Copyright

The baseline design of the F/A-18 E/F fuselage skins utilizes carbon fiber/epoxy composite technologies developed at Northrop over the past 10 years through research and development on previous projects. An Integrated Product Development team used this knowledge base to conceptualize and produce a design of significant cost and weight savings, with producibility as the main objective. As part of the effort to design and manufacture for producibility, Northrop undertook a manufacturing risk reduction project with the primary focus centering around the fabrication of a representative F/A-18 E/F hat stiffened, composite fuselage skin.

A93-52548
ASPECTS OF FATIGUE AFFECTING THE DESIGN AND MAINTENANCE OF MODERN MILITARY AIRCRAFT
S. A. BARTER, J. Q. CLAYTON, and G. CLARK (Defence Science and Technology Organisation, Aeronautical Research Lab.,

Melbourne, Australia) International Journal of Fatigue (ISSN 0142-1123) vol. 15, no. 4 July 1993 p. 325-332. refs
Copyright

The various approaches used in the design and maintenance of modern military aircraft are discussed, with particular attention given to those used by the Royal Australian Air Force fleet. Aircraft design and maintenance standards are examined, with consideration given to the approaches to safe-life, the fail-safe design, the durability and damage tolerant design, and safety by inspection. Examples are presented of Australian applications of safety by inspection to safe-life aircraft. AIAA

A93-52614
ABOVE THE SKY
DOUG STEWART Air & Space (ISSN 0886-2257) vol. 8, no. 3 Aug.-Sept. 1993 p. 22-30.
Copyright

An account is given of the remote sensing activities and the mission-preparation and maintenance-related operations of NASA's ER-2 high altitude aircraft. These have been developed from a variant of the U-2 'spyplane' once intended for carrier operations. The ER-2s carry more than a ton of remote-sensing instrumentation to altitudes of as much as 78,000 ft. One of the instruments of this sensor suite, the Airborne Visible/IR Imaging Spectrometer, was recently employed to map the entire eastern shoreline of the U.S. Ground-related, marine, and atmospheric studies may be conducted by various combinations of ER-2 sensors. AIAA

02

AERODYNAMICS

Includes aerodynamics of bodies, combinations, wings, rotors, and control surfaces; and internal flow in ducts and turbomachinery.

A93-48042
NORMAL SHOCK WAVE OSCILLATIONS IN SUPERSONIC DIFFUSERS
K. MATSUO and H.-D. KIM (Kyushu Univ., Fukuoka, Japan) Shock Waves (ISSN 0938-1287) vol. 3, no. 1 1993 p. 25-33. refs
Copyright

The present paper describes experimental investigations for shock oscillations caused by normal shock wave/turbulent boundary layer interaction in a supersonic diffuser. An array of wall-mounted transducers and especially a line image sensor for the nonintrusive detection of shock displacements were employed to investigate the interactions at low supersonic speeds. The line image sensor was collimated with a conventional Schlieren optical system and was a good indicative of capturing the shock oscillating motions in the present configuration. This study shows that the amplitude of the shock motions increases with approaching flow Mach number, and the cause of oscillation of the shock wave can, however, be independent of the Mach number. In addition, the present system employed to determine the shock wave positions and displacements can be effectively applied to a variety of practical problems.

A93-48043* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
INVESTIGATION OF A HYPERSONIC CROSSING SHOCK WAVE/TURBULENT BOUNDARY LAYER INTERACTION
N NARAYANSWAMI, D. D. KNIGHT (Rutgers Univ., Piscataway, NJ), and C. C. HORSTMAN (NASA, Ames Research Center, Moffett Field, CA) Shock Waves (ISSN 0938-1287) vol. 3, no. 1 1993 p. 35-48. refs
(Contract AF-AFOSR-86-0266)
Copyright

A combined theoretical and experimental study is presented for the interaction between crossing shock waves generated by (10 deg, 10 deg) sharp fins and a flat plate turbulent boundary layer at Mach 8.3. The theoretical model is the full 3D mean compressible Reynolds-averaged Navier-Stokes (RANS) equations incorporating the algebraic turbulent eddy viscosity model of Baldwin and Lomax (1978). A grid refinement study indicated that adequate resolution of the flow field has been achieved. Computed results agree well with experiment for surface pressure and surface flow patterns and for pitot pressure and yaw angle profiles in the flow field. The computations, however, significantly overpredict surface heat transfer. Analysis of the computed flow field results indicates the formation of complex streamline and wave structures within the interaction region. Author (revised)

A93-48116#
TRAJECTORY MAPPING OF QUASI-PERIODIC STRUCTURES IN A VORTEX FLOW
J. P. HUBNER and N. M. KOMERATH (Georgia Inst. of Technology, Atlanta) Jul. 1993 11 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 Research supported by USAF refs
(AIAA PAPER 93-2914) Copyright

Steady vortex flows over swept wings develop quasi-periodic velocity fluctuations. The nature of such fluctuations was explored using a 59.3 deg delta wing set at 25 deg angle-of-attack in a low-speed wind tunnel. Cross-spectral analysis of velocity fluctuations sensed by two hot-wire sensors was used to track these phenomena to the region of their origin as well as study the evolution and growth of the fluctuations. The power spectral density of the fluctuations was mapped in several regions of interest. Results show the existence of narrow, dominant frequency bands in which the majority of the fluctuation energy is contained. This frequency band narrows and the peak frequency decreases while the peak magnitude increases as the sensors are moved downstream from the apex. The coherence between the signals from the two sensors and the spectral density at the peak frequency are used to determine the trajectory of the flow structures responsible for the fluctuations. Investigations along the leading-edge of the model show that the quasi-periodicity first originates at the 30 percent chord region. The structures then appear to follow a helical trajectory around the core of the vortex system. Convection speeds of the structures responsible for the quasi-periodicity, determined from cross-correlation shifts, are on the order of 50 percent of the freestream speed.
Author (revised)

A93-48122*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
INTERPRETATION OF WAVERIDER PERFORMANCE DATA USING COMPUTATIONAL FLUID DYNAMICS
CHARLES E. COCKRELL, JR. (NASA, Langley Research Center, Hampton, VA) Jul. 1993 12 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-2921) Copyright

A computational study was conducted to better understand experimental results obtained from wind tunnel tests of a Mach 4 waverider model and a comparative reference configuration. The experimental results showed that the performance of the reference configuration was slightly better than that of the waverider model. These results contradict waverider design theory, which suggests that a waverider optimized for maximum lift-to-drag should provide better performance than any other non-waverider configuration at a given design point, especially at hypersonic speeds. The computational results showed that the predicted surface pressure values and the integrated lift and drag coefficients from the pressure distributions were much lower for the reference model than for the flat-top model, due to the reference model bottom surface having a slight expansion. The lift-to-drag ratios for the flat-top model were higher due to a relatively low drag for the same amount of lift. These results indicate that the performance advantage of the reference model was due to the shape of the bottom surface and not due to the flat top surface. The results also showed that the reference model exhibited the same shock attachment characteristics as the waverider because the planform shapes were identical. CFD predictions show that the planform

shape gives the waverider an advantage in performance over conventional hypersonic vehicles and that altering the bottom surface of a waverider does not cause significant performance degradation.

A93-48124#
AN EXPLORATORY WIND TUNNEL STUDY OF SUPERSONIC TIP VORTICES
FRANK Y. WANG and PASQUALE M. SFORZA (Polytechnic Univ., Brooklyn, NY) Jul. 1993 8 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-2923) Copyright

Results of recent tests conducted at Polytechnic University on supersonic tip vortices generated by a small aspect ratio, rectangular half-wing in a Mach 3 stream are presented. Surveys were made for two angles of attack at a station approximately two chords downstream of the half-wing. Time-averaged vortex position, Mach number, velocity, pressure and density were estimated by combining pitot pressure readings and a shadowgraph-based visualization technique. Some very low frequency vortex trajectory oscillations were observed. In many respects, the observed supersonic tip vortex behaved much like its low speed counterpart with a compressibility correction, that is, a two-dimensional vortex superimposed on a uniform freestream velocity. The downstream convection of the vortex appeared to proceed with negligible diffusion in the near field studied. It was also found that the trailing supersonic tip vortices, although estimated to be weak in terms of swirl, appear to include a substantial stagnation pressure deficit. On the other hand, it appears that the axial component of velocity and the temperature are constant across the profile, within the spatial resolution possible. Suggestions on vortex modeling are provided to aid in formulating initial conditions for numerical studies involving supersonic tip vortices.

A93-48125#
SUPERSONIC BASE FLOW EXPERIMENTS IN THE NEAR-WAKE OF A CYLINDRICAL AFTERBODY
J. L. HERRIN and J. C. DUTTON (Illinois Univ., Urbana) Jul. 1993 12 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(Contract DAAL03-90-G-0021)
(AIAA PAPER 93-2924) Copyright

The near-wake of a circular cylinder aligned with a uniform Mach 2.5 flow has been experimentally investigated in a wind tunnel designed solely for this purpose. Mean static pressure measurements were used to assess the radial dependence of the base pressure and the mean pressure field approaching separation. In addition, two-component laser Doppler velocimeter (LDV) measurements were obtained throughout the near-wake including the large separated region downstream of the base. The primary objective of the research was to gain a better understanding of the complex fluid dynamic processes found in supersonic base flowfields including separation, shear layer development, reattachment along the axis of symmetry, and subsequent development of the wake. Results indicate relatively large reverse velocities and uniform turbulence intensity levels in the separated region. The separated shear layer is characterized by high turbulence levels with a strong peak in the inner, subsonic region which eventually decays through reattachment as the wake develops. A global maximum in turbulent kinetic energy and Reynolds shear stress is found upstream of the reattachment point which is in contrast to data from the reattachment of a supersonic shear layer onto a solid wall.

A93-48127#
CFD STUDY OF THE FLOWFIELD DUE TO A SUPERSONIC JET EXITING INTO A HYPERSONIC STREAM FROM A CONICAL SURFACE. II
S. C. CHAN and R. P. ROGER (Teledyne Brown Engineering, Huntsville, AL) Jul. 1993 10 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-2926) Copyright

Steady-state CFD analyses are compared to wind tunnel measurements for a large center of gravity (c.g.) thruster firing from a triconic configuration. Computations are performed to investigate the angle of attack dependence for the extent of the recirculation region upstream of the lateral c.g. thruster. CFD predictions are compared to Schlieren photographs and surface pressure measurements. Results show that proper grid resolution of the separated region upstream of the thruster is critical to obtaining predictions which closely match test measurements. Symmetry plane computations (only 180 degrees of the full configuration) have been performed which necessitated the use of over 2M computational grid points. Flowfield differences between a zero angle of attack case and a sixteen degree angle of attack case (jet on lee side) are emphasized.

A93-48128*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
A NUMERICAL INVESTIGATION OF SUPERSONIC STRUT/ENDWALL INTERACTIONS IN ANNULAR FLOW WITH VARYING STRUT THICKNESS
K. E. WILLIAMS (Washington Univ., Seattle), G. J. HARLOFF (Sverdrup Technology, Inc., Brook Park, OH), and F. B. GESSNER (Washington Univ., Seattle) Jul. 1993 12 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(Contract NAG3-376; NAS3-25266)
(AIAA PAPER 93-2927) Copyright

A full 3D Navier-Stokes numerical investigation has been conducted of the shock-wave/boundary-layer flow interactions caused by four diamond-shaped struts, of varying thickness, in an annular duct with Mach 3 core flow and turbulent boundary-layers on both walls. Secondary flows caused by weak-to-strong interactions are examined in the vicinity of a strut which is bounded by curved endwalls. The duct endwall boundary-layer separated for the strongest interaction. The struts studied had maximum thickness-to-chord ratios of 0.125, 0.188, 0.250, and 0.500. The duct gap height is 0.7 strut chords, the duct inner-to-outer wall radius ratio is 0.7, and the Reynolds number is 3 x 10 exp 5 based on the strut chord length which was held constant for all interactions considered. The effects of strut thickness on the secondary flows are discussed, including: trajectories for the leading and trailing edge horseshoe vortices, strut/endwall corner vortices, and boundary-layer separation. The line of coalescence discussed in the literature, previously ascribed to boundary-layer separation, is shown to be caused by the leading edge horseshoe vortex convecting along the shock front. Author (revised)

A93-48130#
SOLUTION OF THE EULER EQUATIONS FOR AIRFOILS USING ASYMPTOTIC METHODS
A. VERHOFF and D. STOOKESBERRY (McDonnell Douglas Corp., Saint Louis, MO) Jul. 1993 11 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-2931) Copyright

A method for analytic solution of the two dimensional Euler equations for airfoils is presented. This method forms the basis for a very efficient design procedure in which aerodynamic sensitivities are determined analytically. Analytic solution of the Euler equations is accomplished by a sequence of transformations, mappings, and asymptotic methods. The basic solution procedure consists of a corrective iteration process using Green's function with an initial approximation provided by the solution of a linear, homogeneous system which incorporates a compressibility transformation. Entropy effects produced by shock waves can be included in this asymptotic process. The analysis is formulated in natural streamline (rectilinear) coordinates which leads to significant simplification. Results are presented for subsonic flow which compare the analytic solutions and computational fluid dynamics (CFD) Euler predictions in terms of accuracy and cost. Significant reduction in cost is achieved by the analytic procedure for both the baseline solution and aerodynamic sensitivity derivatives.

A93-48131#
NUMERICAL SOLUTION OF THE EULER EQUATIONS FOR COMPLEX AERODYNAMIC CONFIGURATIONS USING AN EDGE-BASED FINITE ELEMENT SCHEME
HONG LUO, JOSEPH D. BAUM (Science Applications International Corp., McLean, VA), and RAINALD LOEHNER (George Washington Univ., Washington) Jul. 1993 12 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 Research supported by DNA and USAF refs
(AIAA PAPER 93-2933)

This paper describes the development, validation and application of a new finite element scheme for the solution of the compressible Euler equations on unstructured grids. The implementation of the numerical scheme is based on an edge-based data structure, as opposed to a more traditional element-based data structure. The use of this edge-based data structure not only improves the efficiency of the algorithm, but also enables a straightforward implementation of upwind schemes in the context of finite element methods. The algorithm has been tested and validated on some well documented configurations. A flow solution about a complete F-18 fighter is shown to demonstrate the accuracy and robustness of the proposed algorithm.

A93-48133#
EFFECTS OF JUNCTION MODIFICATIONS ON SHARP-FIN-INDUCED SHOCK WAVE/BOUNDARY LAYER INTERACTION
S. KOIDE and J. L. STOLLERY (Cranfield Inst. of Technology, United Kingdom) Jul. 1993 12 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 Research supported by Japanese Defense Agency refs
(AIAA PAPER 93-2935)

The effects of junction modifications on the shock wave/turbulent boundary layer interaction generated by a sharp fin placed on the wall of a supersonic wind tunnel were examined experimentally at a Mach number of 2.46 and a Reynolds number of 2.59 x 10 exp 6/m. The interactions between a turbulent boundary layer on the wall and shockwave systems caused by a fin with a fillet and three fins with different strakes were examined individually. The flow features obtained by oil flow visualization and surface pressure measurements were compared with the data from an unmodified fin to evaluate the effects of the modifications. The comparison indicated that a 'strake-type' modification had a weakening effect on the interaction-induced separation. Flowfield surveys were made using laser-light-sheet flow visualization and schlieren photography to obtain the 3D flow structures. Based on these observations, the necessary geometric requirements to prevent separation were predicted. Author (revised)

A93-48134#
REYNOLDS STRESS TRANSPORT MODELLING OF SHOCK/BOUNDARY-LAYER INTERACTION
LARS DAVIDSON (Chalmers Univ. of Technology, Goteborg, Sweden) Jul. 1993 12 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-2936)

A second-moment Reynolds Stress Transport Model (RSTM) is used to compute a transonic flow in a 2D channel with a bump and is implemented in an existing explicit Runge-Kutta time-marching finite volume code. The equations of turbulent quantities are solved with an implicit solver which, unlike the Runge-Kutta solver, is very stable and reliable for solving source dominated equations. The RSTM is coupled with a one-equation model in the viscosity dominated region near the wall. Good agreement is found between the model predictions and measurements. The interaction between the boundary layer and the external supersonic layer is found to be stronger than in experiments, which is explained by two factors: the predicted boundary layer is thicker than in the experiments ahead of the shock, and oscillations in the shock wave are found in the experiments. AIAA

A93-48136#
SHOCK-WAVE/BOUNDARY LAYER INTERACTIONS AT HYPERSONIC SPEEDS BY AN IMPLICIT NAVIER-STOKES SOLVER
PENELOPE LEYLAND (Lausanne, Ecole Polytechnique Federale, Switzerland) Jul. 1993 14 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-2938)

An implicit Navier-Stokes solver has been used to calculate steady state solutions for several typical hypersonic geometries. Particular attention was paid to the resulting complex interactions between shock waves and the boundary layers. The numerical method was based on either an upwind Galerkin finite volume approach or a symmetric TVD extension for the convective fluxes, with a centered Galerkin finite element solution of the viscous fluxes. The computational grid consisted of structured finite elements within the boundary layer region and unstructured triangular elements elsewhere. Results are presented for the case of a compression ramp in two different flow situations. The first concerns a high Reynolds number flow while the second is at a higher Mach number but lower Reynolds number. Comparisons with experimental data are given. Subsequently computed results for two generic canopy flows over a double ellipse are also presented. These have been calculated for wind tunnel conditions at zero angle of attack. Comparisons show that skin heat transfer and pressure coefficients are in agreement with the shape of those found in the experiments. The importance of calculating equilibrium conditions in order to establish maximal margins is clearly indicated.

A93-48137#
INTENSE STUDIES ON UNSTEADY SECONDARY SEPARATIONS AND OSCILLATING SHOCK WAVES IN THREE-DIMENSIONAL SHOCK WAVES/TURBULENT BOUNDARY LAYER INTERACTION REGIONS INDUCED BY SHARP AND BLUNT FINS
SHIGERU ASO, SYOZO MAEKAWA, SATOSHI OKUYAMA (Kyushu Univ., Fukuoka, Japan), KEIICHI KARASHIMA, and KIYOSHI SATO (Inst. of Space and Astronautical Science, Sagamihara, Japan) Jul. 1993 10 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 Research supported by Inst. of Space and Astronautical Science refs
(AIAA PAPER 93-2939)

This paper discusses the secondary separations and oscillating shock waves in shock wave/turbulent boundary layer interaction region in supersonic flows. In the experiments, sharp and blunt fins are selected as shock generators and the unsteady interaction region is investigated by using flow visualization techniques, such as oil flow method, schlieren photography, and shadowgraphy. Also pitot pressure distribution is measured. For detailed visualization, a color oil flow method, various colored oil come oozing through many holes in surface, has developed improving conventional oil flow method. Using this new technique, we have visualized the secondary separation in the interaction region. In addition, oscillating shock waves are captured using instantaneous shadowgraphy and the high-speed video camera system.
Author (revised)

A93-48139#
IMPROVEMENT OF CONICAL SIMILARITY RULE IN SWEPT SHOCK WAVE/BOUNDARY LAYER INTERACTION
XUEYING DENG, JINHUA LIAO, and HUA ZHANG (Beijing Univ. of Aeronautics and Astronautics, China) Jul. 1993 7 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 Research supported by NNSFC and Aeronautical Science Foundation of China refs
(AIAA PAPER 93-2941)

In order to improve and extend the conical similarity rule by Settles et al. extensive experiments of conical interaction have been performed with four families of shock generators: unswept and swept sharp leading-edge fins, semicones and swept compression corners at low freestream Mach numbers of 1.79, 2.04 and 2.50. Based on the detailed inviscid flow field experiments

and analyses, a concept of effective shock strength parameter effective shock wave angle was proposed for the shock wave with nonuniform strength by swept compression corner as a measure of shock strength responsible for interaction. The region with conical correlative flow behaviors is limited in the flow field upstream of inviscid shock wave. Based on these concepts, the present correlative results of flow behaviors in the conical region reveal an universal conical similarity rule: correlated flow behaviors are dependent on inviscid shock strength only and independent of the curvature of shock wave and the compressibility of turbulent boundary layer. Author (revised)

A93-48142#
NAVIER-STOKES CALCULATIONS FOR TRANSPORT WING-BODY CONFIGURATIONS WITH NACELLES AND STRUTS
T. J. KAO, T. Y. SU, and N. J. YU (Boeing Commercial Airplane Group, Seattle, WA) Jul. 1993 10 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-2945) Copyright

A simplified multiblock grid generation method, together with a Navier-Stokes solver, has been developed for the analysis of a transport wing-body configuration with underwing-mounted nacelles and struts. Boeing 747-200 configurations with only inboard engines and with both inboard and outboard engines have been analyzed to assess interference effects of engine installation on airplane aerodynamic characteristics. Preliminary results show that the code is highly efficient and can be used to evaluate engine installation effects at both cruise and off-design conditions.

A93-48143#
A CFD-BASED DESIGN STRATEGY FOR ADVANCED TRANSONIC WING CONCEPTS WITH PRACTICAL RAMIFICATIONS FOR SUBSONIC TRANSPORTS
A. SHMILOVICH, F. T. LYNCH, and R. A. PELKMAN (McDonnell Douglas Transport Aircraft Unit, Long Beach, CA) Jul. 1993 12 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-2946) Copyright

A strategy for improving the aerodynamic performance of advanced transonic wings for subsonic transports is presented. The study utilizes a CFD-based flow analysis method in conjunction with an inverse design approach to identify the cause for the formation of the double shock-wave system attendant at certain flow conditions. A cure for eliminating this undesirable flow phenomenon is prescribed and its applicability is demonstrated for an advanced wing-fuselage configuration at full-scale Reynolds number.

A93-48144#
APPLICATION OF PARABOLIZED NAVIER-STOKES TECHNIQUE FOR HIGH-L/D, HYPERSONIC VEHICLE DESIGN
JAMES E. DAYWITT (Martin Marietta Astro Space, King of Prussia, PA), BILAL A. BHUTTA, and CLARK H. LEWIS (VRA, Inc., Blacksburg, VA) Jul. 1993 14 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 Research supported by General Electric Co refs
(AIAA PAPER 93-2948) Copyright

New wind-tunnel data, obtained on a wide variety of high lift-to-drag configurations, is used to systematically assess a novel parabolized Navier-Stokes (PNS) code as well as inviscid, boundary-layer, and approximate aerodynamic prediction techniques. The wind-tunnel data, spanning a range of supersonic Mach numbers, is used to support the design of a candidate flight configuration. Extensions of the PNS code are developed to enable design applications including predictions of yaw-stability and the pitch-and-roll control characteristics of deflected elevons. Comparisons with the wind-tunnel data are used to assess confidence in the PNS technique for the flight environment. The approximate techniques, calibrated with the ground-test data, are also applied at design critical flight conditions. Applications of the PNS code for aerodynamic tailoring are used to assess its potential as a design tool.

A93-48149#
A VISCOUS FLOW BASED MEMBRANE WING MODEL
RICHARD SMITH and WEI SHYY (Florida Univ., Gainesville) Jul. 1993 14 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-2955) Copyright

A computational procedure has been developed which extends previous work on membrane wing aerodynamics to include the effects of viscosity in the fluid. The present membrane wing model is derived by combining an incremental, continuum based, finite element formulation of the elastic membrane problem with a control volume formulation of the Navier-Stokes equations written in general curvilinear body-fitted coordinates. The model yields solutions for membrane shape, membrane stress. and the surrounding viscous flow field variables simultaneously. The results of the viscous flow based model are qualitatively in agreement with flow visualization studies reported in the literature. The effect of viscosity in the fluid leads to substantially different membrane surface pressures compared with the surface pressures predicted by an inviscid flow model.

A93-48150*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
NUMERICAL SIMULATION OF UPSTREAM DISTURBANCE ON FLOWS AROUND A SLENDER BODY
DAVID DEGANI (Technion - Israel Inst. of Technology, Haifa) and MURRAY TOBAK (NASA, Ames Research Center, Moffett Field, CA) Jul. 1993 11 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 Research supported by Technion - Israel Inst. of Technology refs
(Contract NCA2-578)
(AIAA PAPER 93-2956) Copyright

Numerical solutions of the thin-layer approximation of the compressible Navier-Stokes equations have been obtained for flows around an ogive-cylinder body with and without a small fixed disturbance placed upstream of the body tip. Locating the disturbance at positions in the flow field upstream of the tip provokes the same range of behavior of the asymmetric flow that was numerically produced earlier by use of a geometrical disturbance on the body tip. Results remain consistent with the presence of a convective instability mechanism, and demonstrate the potential for a precise mapping of the body's receptivity to fixed disturbances in the flow field. Numerical solutions were also obtained for the flow-field responses to impulsive upstream disturbances to determine whether there is a growing response to an asymmetric impulsive disturbance that is consistent with presence of a convective instability mechanism. Results for surface pressure are interpreted with the aid of a mathematical model. The model suggests that the observed growth of surface pressure gradient with time and distance along a ray in response to an asymmetnc impulsive disturbance is in accord with the solution of a Ginzberg-Landau equation, with distinguishing features of the solution being consistent with the convective instability mode of behavior.

A93-48151#
ASYMMETRIC VORTICAL SOLUTIONS IN SUPERSONIC CORNERS - STEADY 3D SPACE-MARCHING VERSUS TIME-DEPENDENT CONICAL RESULTS
G. DEGREZ, P. G. SPAZZINI (von Karman Inst. for Fluid Dynamics, Rhode-St.-Genese, Belgium), R. MARSILIO, and M. PANDOLFI (Torino, Politecnico, Turin, Italy) Jul. 1993 14 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-2957) Copyright

Computational solutions of inviscid flows in symmetrical corners formed by intersecting wedges are presented. The incoming flow Mach number is 10 and the wedge deflection ranges between 5 and 20 degrees. Numerical solutions were obtained by two different approaches, namely a space marching solution of the 3D Euler equations and an iterative solution of the conical Euler equations, using upwind finite volume methods in both cases. Above a critical wedge deflection, vortical solutions appear, first symmetric and then asymmetric when the wedge deflection is increased further.

This is observed independently of the computational method used. Numerical dissipation is shown to strongly influence the range of asymmetric solutions, asymmetric solutions appearing at lower wedge deflections for smaller numerical dissipation (finer grids). Finally, all solutions were found to be truly steady and conical, proving the stable character of the asymmetric solutions observed.

A93-48152*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ACTIVE CONTROL OF ASYMMETRIC CONICAL FLOW USING SPINNING AND ROTATORY OSCILLATIONS
OSAMA A. KANDIL, HAZEM H. SHARAF EL-DIN (Old Dominion Univ., Norfolk, VA), and C. H. LIU (NASA, Langley Research Center, Hampton, VA) Jul. 1993 15 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(Contract NAG1-994)
(AIAA PAPER 93-2958) Copyright

The effectiveness of active control on asymmetric flows around circular cones is investigated computationally using cone spinning and rotatory oscillation around its axis. The investigation uses the time-accurate solution of the unsteady, compressible, full Navier-Stokes equations with the implicit, upwind, flux-difference splitting, finite-volume scheme. The present solutions are obtained under the locally-conical-flow assumption in order to understand the flow physics using very fine grids for reasonable flow resolution at low computational cost. For all the computational solutions, a grid of 241 x 81 x 2 points in the wrap-around, normal and axial directions, respectively, is used. The grid is spinning or oscillating rigidly with the cone according to its motion and the kinematical and dynamical boundary conditions are modified accordingly. The computational applications include the effects of uniform spinning rates and periodic rotatory oscillations at different amplitudes and frequencies on the flow asymmetry.

A93-48155*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
EFFECTS OF AFT GEOMETRY ON VORTEX BEHAVIOR AND FORCE PRODUCTION BY A TANGENTIAL JET ON A BODY AT HIGH ALPHA
G. I. FONT (MCAT Inst., Moffett Field, CA) Jul. 1993 11 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(Contract NCC2-729)
(AIAA PAPER 93-2961) Copyright

Explored in this study are the physical effects of the numerical treatment of the aft geometry on the vortex behavior and force production due to a tangential jet on a body at a high angle of attack. The study is conducted numerically by solving the three-dimensional, compressible-flow, Reynolds-averaged Navier-Stokes equations. Two tangent-ogive cylinder configurations are used. The first configuration locates the computational exit plane at the end of the body, while the second caps the end of the body with a hemisphere and locates the exit plane far downstream. In both configurations, a blowing slot is located at the cylinder-ogive junction. Comparisons are made between results for the two configurations for cases with and without the jet present. Results indicate that inclusion of the wake of the body in the computations, while altering the flow in small details, does not change the character of the flow. The vortex behavior remains unaltered and the force distribution, while changing to some degree in magnitude, does not change in shape.

A93-48156*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
EFFECT OF FOREBODY TANGENTIAL SLOT BLOWING ON FLOW ABOUT A FULL AIRCRAFT GEOMETRY
KEN GEE (MCAT Inst., Moffett Field, CA), YEHIA M. RIZK, and LEWIS B. SCHIFF (NASA, Ames Research Center, Moffett Field, CA) Jul. 1993 12 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(Contract NCC2-657)
(AIAA PAPER 93-2962) Copyright

The effect of forebody tangential slot blowing on the flowfield about an F/A-18 aircraft is investigated numerically using solutions of the Navier-Stokes equations. Computed solutions are obtained for a full aircraft geometry, including the fuselage, wing with deflected leading-edge flap, empennage, and a faired-over engine inlet. The computational slot geometry corresponds to that used in full-scale wind tunnel tests. Solutions are computed using flight test conditions and jet mass flow ratios equivalent to wind tunnel test conditions. The effect of slot location is analyzed by computing two non-time-accurate solutions with a 16 in. slot located 3 in. and 11 in. aft of the nose of the aircraft. These computations resolve the trends observed in the full-scale wind tunnel test data. The flow aft of the leading edge extension (LEX) vortex burst is unsteady. A time-accurate solution is obtained to investigate the flow characteristics aft of the vortex burst, including the effect of blowing on tail buffet.

A93-48157*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
THE HEMISPHERE-CYLINDER IN DYNAMIC PITCH-UP MOTIONS
E. C. PANZER, O. K. REDINIOTIS, and D. P. TELIONIS (Virginia Polytechnic Inst. and State Univ., Blacksburg) Jul. 1993 9 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(Contract NAS1-18471)
(AIAA PAPER 93-2963) Copyright

Laser-Doppler velocimetry and seven-hole probes were employed to map out the velocity and vorticity field along a plane downstream of a hemisphere-cylinder. Steady flow data were obtained over a fixed model at a range of angles of attack, as well as over a model pitching through ramp motions to a final angle of attack. Attention was focused on the dynamic development of induced vortex asymmetry. It was found that the wake develops first in a symmetric fashion and asymmetry is generated with some time delay.

A93-48158*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
SOME PRACTICAL TURBULENCE MODELING OPTIONS FOR REYNOLDS-AVERAGED FULL NAVIER-STOKES CALCULATIONS OF THREE-DIMENSIONAL FLOWS
TRONG T. BUI (NASA, Lewis Research Center, Cleveland, OH) Jul. 1993 37 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-2964) Copyright

New turbulence modeling options recently implemented for the 3D version of Proteus, a Reynolds-averaged compressible Navier-Stokes code, are described. The implemented turbulence models include: the Baldwin-Lomax algebraic model, the Baldwin-Barth one-equation model, the Chien k-epsilon model, and the Launder-Sharma k-epsilon model. Features of this turbulence modeling package include: well documented and easy to use turbulence modeling options, uniform integration of turbulence models from different classes, automatic initialization of turbulence variables for calculations using one- or two-equation turbulence models, multiple solid boundaries treatment, and fully vectorized L-U solver for one- and two-equation models. Good agreements are obtained between the computational results and experimental data. Sensitivity of the compressible turbulent solutions with the method of y(+) computation, the turbulent length scale correction, and some compressibility corrections are examined in detail. Test cases show that the highly optimized one- and two-equation turbulence models can be used in routine 3D Navier-Stokes computations with no significant increase in CPU time as compared with the Baldwin-Lomax algebraic model. *Author (revised)*

A93-48161*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
A NUMERICAL STUDY OF THE EFFECT OF GEOMETRY VARIATION, TURBULENCE MODELS, AND DISSIPATION ON THE FLOW PAST CONTROL SURFACES
DENNY S. CHAUSSEE (NASA, Ames Research Center, Moffett

Field, CA) Jul. 1993 14 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-2967) Copyright

The steady 3D viscous flow past the ONERA M6 wing and a slender delta wing-body with trailing edge control surfaces has been computed. A cell-centered finite-volume Navier-Stokes patched zonal method has been used for the numerical simulation. Both diagonalized and LUSGS schemes have been implemented. Besides the standard nonplanar zonal interfacing techniques, a new virtual zone capability has been employed. For code validation, the transonic flow past the ONERA M5 wing is calculated for angles-of-attack of 3.06 deg and 5.06 deg and compared with the available experiments. The wing-body computational results are compared with experimental data for both trailing-edge flaps deflected. The experimental flow conditions are M subinfinity = 0.4, a turbulent Reynolds number of 5.41 million based on a mean aerodynamic chord of 25.959 inches, adiabatic wall, and angles-of-attack varying from 0 deg to 23.85 deg. The computational results are presented for the 23.85 deg angle-of-attack case. The effects of the base flow due to a model sting, the varying second and fourth order numerical dissipation, and the turbulence model are all considered. Author (revised)

A93-48162#
NUMERICAL SOLUTION OF NAVIER-STOKES EQUATIONS AND K-OMEGA TURBULENCE MODEL EQUATIONS USING A STAGGERED UPWIND METHOD
XIAOQING ZHENG and FENG LIU (California Univ., Irvine) Jul. 1993 12 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 Research supported by California Space Inst., Univ. of Califonia, and NNSFC refs
(AIAA PAPER 93-2968) Copyright

A staggered finite volume upwind algorithm for solving the compressible Navier-Stokes equations and the k-omega turbulence model equations has been developed for computing cascade flows. Roe's upwind scheme is used to discretize the convective terms of the Navier-Stokes equations while a third-order upwind scheme is used for the convective terms of the k-omega equations. All the diffusion terms are discretized with central difference method. By the use of a combination of cell-centered and cell-vertex schemes, the method maintains a small stencil for all the diffusion terms and makes the Navier-Stokes equations and k-omega equations strongly coupled. The algorithm was first tested for a flat-plate flow, the results compare well with empirical correlations. Further investigations are conducted on a supersonic wedge cascade flow and a low-pressure turbine cascade flow at design and off-design conditions. They provide good test cases for the algorithm on the ability of shock capturing and the prediction of separation. Author (revised)

A93-48163*# National Aeronautics and Space Administration, Washington, DC.
HYPERSONIC FLOW PAST OPEN CAVITIES
ALAGACYR MORGENSTERN, JR. and NDAONA CHOKANI (North Carolina State Univ., Raleigh) Jul. 1993 11 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 Research supported by Inst. de Aeronautica e Espaco refs
(Contract NAGW-1331)
(AIAA PAPER 93-2969) Copyright

The hypersonic flow over a cavity is investigated. The time-dependent compressible Navier-Stokes equations, in terms of mass averaged variables, are numerically solved. An implicit algorithm, with a subiteration procedure to recover time-accuracy, is used to perform the time-accurate computations. The objective of the study is to investigate the effects of Reynolds number and cavity dimensions. The comparison of the computations with available experimental data, in terms of time mean static pressure, heat transfer, and Mach number show good agreement. In the computations large vortex structures, which adversely affect the cavity flow characteristics, are observed at the rear of the cavity. A self-sustained oscillatory motion occurs within the cavity over a range of Reynolds number and cavity dimensions. The frequency spectra of the oscillations show good agreement with a modified semi-empirical relation.

A93-48164#
COMPARISON OF ENO AND TVD SCHEMES FOR THE PARABOLIZED NAVIER-STOKES EQUATIONS
A. M. STURMAYR, J.-M. MOSCHETTA (Ecole Nationale Superieure de l'Aeronautique et de l'Espace, Toulouse, France), and A. LAFON (ONERA, Centre d'Etude et de Recherche de Toulouse, France) Jul. 1993 10 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-2970) Copyright

A side-by-side comparison of high-order accurate ENO and TVD schemes applied to the parabolized Navier-Stokes equations is presented. Convection terms are modelled using non-MUSCL extensions of Roe's upwind scheme to second and third order accuracy. The construction of the ENO schemes is based on Harten and Yang using reconstruction via primitive function approach. Numerical results presented include hypersonic flow past a 15 deg compression corner and supersonic flow with crossflow separation past a cone at angle of attack. The advantages and disadvantages of the different schemes are discussed in terms of accuracy and stability. Special attention is paid to the resolution of shock waves and contact discontinuities. Author (revised)

A93-48165#
PRECISE PITCHING AIRFOIL COMPUTATIONS BY USE OF DYNAMIC UNSTRUCTURED MESHES
ROLAND RICHTER and PENELOPE LEYLAND (Lausanne, Ecole Polytechnique Federale, Switzerland) Jul. 1993 12 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-2971) Copyright

Pitching airfoil calculations are presented using a dynamical auto-adaptive mesh refinement/derefinement strategy with unstructured meshes. An explicit time accurate finite volume centered scheme in space is used to calculate the flow over a harmonically pitched NACA 0012 airfoil. The oscillating shock structure is well captured by the method, for a reduced but optimal number of discretization points. The instantaneous pressure coefficients, and the lift and moment coefficients agree with those obtained by other authors.

A93-48166#
TIP VORTEX, STALL VORTEX, AND SEPARATION OBSERVATIONS ON PITCHING THREE-DIMENSIONAL WINGS
PETER F. LORBER (United Technologies Research Center, East Hartford, CT) Jul. 1993 15 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 Research supported by United Technologies Research Center and USAF refs
(Contract DAAL03-89-C-0013)
(AIAA PAPER 93-2972) Copyright

Experimental results on unsteady separation and separated flow characteristics for a pitching three-dimensional wing are described. New results are presented in three areas. The measured surface pressures and airloads are used to examine the loads induced by the tip vortex and to infer the effects of pitch rate, Mach number, and geometry on vortex strength. Leading edge dynamic stall vortex propagation patterns are obtained from the surface pressure minima, revealing strong effects of sweep and spanwise position. The leading and trailing edge separation phenomena are investigated using surface pressures and gradients, and pitch rate and Mach number limits for Stratford's turbulent boundary layer separation criterion are identified.

A93-48167*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
SHOCK-VORTEX INTERACTION OVER A 65-DEGREE DELTA WING IN TRANSONIC FLOW
OSAMA A. KANDIL, HAMDY A. KANDIL (Old Dominion Univ., Norfolk, VA), and C. H. LIU (NASA, Langley Research Center, Hampton, VA) Jul. 1993 14 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 Research supported by USAF

refs
(Contract NAG1-994)
(AIAA PAPER 93-2973) Copyright

Transonic flow over a 65-deg swept-back, sharp-edged, cropped delta wing is investigated computationally using the time-accurate solution of the unsteady, compressible, full Navier-Stokes equations with an implicit, upwind, flux-difference splitting, finite-volume scheme. Coarse and fine O-H grids are used to obtain the solution. The grid consists of 125 x 85 x 84 points in the wrap-around, normal, and axial directions, respectively. The results are presented for an angle of attack of 20 deg Mach number of 0.85 and Reynolds number of 3.23 x 10 exp 6. With the fine grid, the results show that a system of shocks has been captured over the upper wing surface and that the leading-edge vortex core experiences an unsteady supersonic vortex breakdown after passing through a spanwise shock near the wing trailing edge. The computed results at a certain time are in good agreement with the experimental data. Topological aspects of the vortex breakdown flowfield are also presented and discussed. Author (revised)

A93-48168#
COMPUTATIONAL STUDY OF VORTEX BREAKDOWN ON A PITCHING DELTA WING
MIGUEL R. VISBAL (USAF, Wright Lab., Wright-Patterson AFB, OH) Jul. 1993 19 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 Research supported by USAF refs
(AIAA PAPER 93-2974)

Computational results are presented describing the onset and initial stages of vortex breakdown above a pitching delta wing. The flow is simulated by solving the full unsteady 3D Navier-Stokes equations on a moving grid using the implicit Beam-Warming algorithm. An assessment of the effects of numerical resolution and the good agreement with recent experimental measurements indicate that the calculations duplicate the basic dynamics of this transient breakdown. A detailed description of the evolution of the vorticity field during the onset of breakdown is provided. At the early stages, the structure of the vorticity field is fairly axisymmetric and is characterized by a shear layer of negative azimuthal vorticity which surrounds the reversed-flow region. Subsequently, regions of concentrated vorticity appear accompanied by loss of axial symmetry. Ultimately, a bubble-type breakdown emerges with a complex 3D vortical structure. This structure consists of a bulbous region of high vorticity immediately downstream of axial stagnation, followed by a tail which spirals downstream. This convoluted structure is open and allows the convective transport of vorticity across the bubble breakdown. Author (revised)

A93-48169#
COMPUTATION OF DELTA-WING ROLL MANEUVERS
RAYMOND E. GORDNIER (USAF, Wright Lab., Wright-Patterson AFB, OH) Jul. 1993 16 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-2975)

This paper presents computations of delta-wing roll maneuvers for an 80 deg sweep delta-wing at 30 deg angle of attack. Three constant roll-rate maneuvers are considered. Two of the maneuvers consist of a roll from 0 deg to 45 deg at non-dimensional roll rates of Phi = 0.1325 and Phi = 0.265. The third roll maneuver computed starts at a 45 deg roll angle and rolls back to a -45 deg roll angle at a roll rate, Phi = -0.265. The governing unsteady 3D Navier-Stokes equations are solved using the implicit, approximately-factored, diagonal form of the Beam-Warming algorithm. Subiterations are used to provide a consistent means of implementing the diagonal form of the algorithm for unsteady flows. The effects of roll-rate and differing initial roll angles on the dynamical behavior of the vortices positions and strengths as well as their corresponding effect on surface pressure and roll moment coefficient are described. A motion-induced 'bubble'-type vortex breakdown of the upward moving edge vortex is observed during a portion of the roll maneuver with an initial roll angle of 45 deg. Roll-rate induced camber effects, convective time lags along the vortex core, and the initial roll angle all contribute to promoting the breakdown of this vortex. Author (revised)

A93-48170#
THREE-DIMENSIONAL UNSTEADY SEPARATING FLOWS AROUND AN OSCILLATORY FORWARD-SWEPT WING
H. Q. YANG and A. J. PRZEKWAS (CFD Research Corp., Huntsville, AL) Jul. 1993 11 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(Contract F496200-91-C-0042)
(AIAA PAPER 93-2976) Copyright

A pressure-based Navier-Stokes equation solver is applied to study flow physics around stationary and oscillating 30 deg forward swept wings. It is found that the leading edge vortex, which initiates from the wing root, interacts with the tip vortex. The leading edge vortex convects downstream with variable speed at different span locations, whereas the tip vortex forms over the upper surface at the wing tip and simply increases or decreases in size during the cyclic motion. Three-dimensional particle traces and flow ribbons are used to reveal the general flow structure during the periodic pitching. The results show favorable agreement with the experiments. Author (revised)

A93-48171*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
TRANSITION EFFECTS ON COMPRESSIBLE DYNAMIC STALL OF TRANSIENTLY PITCHING AIRFOILS
M. C. WILDER (U.S. Navy-NASA Joint Inst. of Aeronautics; MCAT Inst., San Jose, CA), M. S. CHANDRASEKHARA (U.S. Navy-NASA Joint Inst. of Aeronautics; U.S. Naval Postgraduate School, Monterey, CA), and L. W. CARR (U.S. Army, Aeroflightdynamics Directorate; NASA, Ames Research Center, Moffett Field, CA) Jul. 1993 14 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 Research supported by USAF and U.S. Army refs
(AIAA PAPER 93-2978)

Experimental results and analysis of the effects of boundary layer tripping on dynamic stall of a transiently pitching airfoil are presented. At low Mach numbers, the tripped airfoil exhibits qualitative similarity with the behavior of the untripped airfoil. However, the local supersonic flow at Mach numbers greater than 0.3 is significantly modified by the trip leading to vastly different shock/boundary layer interactions, dynamic stall onset and vortex formation angles. The formation of the laminar separation bubble is found to have a favorable influence in delaying dynamic stall on the untripped airfoil flow. In both Mach number regimes, the tripped flow actually stalls at slightly lower angles of attack. Further experimentation with three trips on an oscillating airfoil showed that the dynamic stall process is very sensitive to the state of the turbulence in the boundary layer. This sensitivity points to a need for finer turbulence modeling techniques for use in dynamic stall computations.

A93-48172#
DRAG MEASUREMENTS ON BLUNTED CONES AND A SCRAMJET VEHICLE IN HYPERVELOCITY FLOW
L. M. PORTER, D. J. MEE, and A. PAULL (Queensland Univ., St. Lucia, Australia) Jul. 1993 7 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 Research supported by Australian Research Council and Queen Elizabeth II Fellowship Scheme refs
(AIAA PAPER 93-2979) Copyright

This paper reports some applications of the deconvolution force balance for measuring drag in hypervelocity impulse facilities where test times are of the order of 1 ms. Two basic model geometries are considered. The first is a 5 deg semivertex angle cone with varying degrees of nose bluntness. The influence of bluntness on drag on this slender conical body in a Mach 5.2 air stream at a stagnation enthalpy of 14 MJ/kg is presented. The second application is to the drag measurement on the more complex geometry of a scramjet powered vehicle. The drag on the vehicle bas been measured at stagnation enthalpies in the range of 3-14 MJ/kg. Author (revised)

A93-48173#
EXPERIMENTAL STUDY OF SHOCK WAVE AND HYPERSONIC BOUNDARY LAYER INTERACTIONS NEAR A CONVEX CORNER
R. J. HAWBOLDT, P. A. SULLIVAN, and J. J. GOTTLIEB (Toronto Univ., Downsview, Canada) Jul. 1993 13 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 Research supported by USAF, Johns Hopkins Univ., and NSERC refs
(AIAA PAPER 93-2980) Copyright

Data on the interaction of a Mach 8 laminar boundary layer with an externally generated shock wave impinging in the neighborhood of a convex corner was obtained using a hypersonic gun tunnel. Surface static pressure measurements and schlieren photographs were taken from planar models with matching shock generator and convex corner angles of 5 deg and 10 deg. The results are compared with data obtained in the same tunnel for two related interactions: an externally generated shock impinging on a flat plate boundary layer, and a boundary layer interacting with a corner expansion wave. The shock-corner interactions fall into three flow categories, depending on the location of separation and reattachment with respect to the corner. The 5 deg and 10 deg interactions are similar when separation and reattachment both occur upstream or downstream of the corner but differ markedly when the separation and reattachment points are separated by the corner. Boundary layer separation is less severe when the shock impinges close to the convex corner, and it is minimized when the separation point is located at the corner, corresponding to shock impingement 2-4 boundary layer thicknesses downstream of the corner. Author (revised)

A93-48174#
AN ANALYTICAL DESCRIPTION OF HYPERSONIC BOUNDARY LAYER STABILITY
DANIEL R. BOWER and CHING S. LIU (New York State Univ., Buffalo) Jul. 1993 7 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-2981) Copyright

The neutral modes of a hypersonic boundary layer flow over an adiabatic flat plate are considered. A formulation of the governing second order linear equation for the pressure disturbance is developed that lends itself to the application of the WKB method over the entire boundary layer. This formulation provides analytic eigenvalues and eigenfunction relations for the pressure disturbances and is applicable to flows at moderate Mach numbers as well. Solutions are determined for the cases of the wave speed $c = 0$ and $c = 1$ and show good qualitative agreement with the numerical computations of Mack (1984), as well as the high Mach number results of Smith and Brown (1990). Author (revised)

A93-48175#
NONLOCAL VS. LOCAL INSTABILITY OF COMPRESSIBLE FLOWS INCLUDING BODY METRIC, FLOW DIVERGENCE AND 3D-WAVE PROPAGATION
MARTIN SIMEN and UWE DALLMANN (DLR, Goettingen, Germany) Jul. 1993 17 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 Research supported by Dornier Luftfahrt GmbH/Deutsche Aerospace AG, BMFT, and DLR refs
(AIAA PAPER 93-2982) Copyright

Instabilities of compressible flows over cylindrical and conical surfaces are investigated. The indirect effect of viscous-inviscid interaction within the basic flow modelling and the direct effect of body curvature and divergence within the disturbance flow modelling are studied using local linear stability theory. Conical divergence is shown to have a stabilizing effect on first- and second-mode disturbances which can be of the same order as nonparallel flow effects. Hence a nonlocal stability theory for convectively unstable flows is introduced, which in a generalized formulation takes into account the spatial variation of the body curvature and divergence of the nonparallel flows and of the 3D wave propagation. Nonlocal effects are found to be quantitatively significant on first-mode and weak on second-mode disturbances for unstable compressible flows over cylindrical surfaces. A qualitative effect is found for flows over conical surfaces. Conical body curvature and divergence reduces local first-mode growth rates, whereas nonlocal growth rates are increased, supporting the need for a generalized theory. Longitudinal convex surface camber stabilizes, whereas concave camber destabilizes first- and second-mode disturbances according to local as well as nonlocal stability analysis. Due to longitudinal concave surface curvature an increasingly unstable region develops merged with the second-mode region. Author (revised)

A93-48176#
INSTABILITY OF HYPERSONIC FLOW PAST BLUNT CONES - EFFECTS OF MEAN FLOW VARIATIONS
EWALD KUFNER, UWE DALLMANN (DLR, Goettingen, Germany), and JOACHIM STILLA (DLR, Braunschweig, Germany) Jul. 1993 29 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-2983) Copyright

Hypersonic (freestream Mach number = 8.0), laminar, axisymmetric mean flows past blunt, circular cones at zero angle of attack are calculated. The stability analysis based on local, primary, and linear stability theory reveals that an Euler/boundary layer (EUBL) model is an efficient tool for computing hypersonic laminar mean flows. Mean flow computations are performed using the thin-layer Navier-Stokes method and the EUBL model and agree very well with thin-layer Navier-Stokes results (Esfahanian, 1991, 1992). There is a shift in downstream direction of the calculated flow properties compared to experimental data. AIAA

A93-48177#
AERODYNAMIC HEATING WITH BOUNDARY LAYER TRANSITION AND HEAT PROTECTION WITH MASS ADDITION ON BLUNT BODY IN HYPERSONIC FLOWS
SHIGERU ASO, YUICHI KUMAMOTO, NOBUYUKI KONDO (Kyushu Univ., Fukuoka, Japan), YOSHIKO NAKAMURA, MASAYUKI KATAYAMA, and RYUJIRO KUROSAKI (Mitsubishi Electric Corp., Kamakura, Japan) Jul. 1993 8 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-2984) Copyright

Aerodynamic heating due to boundary layer transition and heat protection due to mass addition on blunt bodies are investigated experimentally and computationally. For the experiments on boundary layer transition a tripping wire method is used. Numerous experiments are conducted with tripping wire by changing the location by using a conventional shock tunnel. The results show a quite remarkable increase of aerodynamic heating due to boundary layer transition. The results predict a sudden change of aerodynamic heating quite well. For the experiments on heat protection with mass addition a semisphere model is used with a mass addition device at the top of the model. By changing the quantity of mass addition, heat flux distributions are measured. The results show the mass addition is quite significant in reducing aerodynamic heating at the nose of the blunt body.
Author (revised)

A93-48178#
HYPERSONIC, TURBULENT VISCOUS INTERACTION PAST AN EXPANSION CORNER
BEHZAD BIGDELI and FRANK K. LU (Texas Univ., Arlington) Jul. 1993 9 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-2985) Copyright

Turbulent, viscous interaction theory is used to understand the hypersonic flow past an expansion corner. By assuming a pressure law, the boundary layer properties of the flow are obtained through simultaneous solution of a displacement thickness relationship and a coupling equation relating the effects of incidence and displacement thickness to the effective body shape. The pressure law is obtained through examination of available experimental data. The form of the pressure law is found to depend on the incidence. The pressure decay is dependent on both viscous and incidence effects. For weak incidence, viscous effects are important throughout the interaction and they produce a gentle pressure decay. For strong incidence, viscous effects are important only

near the front of the corner. In this latter case, the pressure decays rapidly followed by a long asymptotic downstream region; the overall pressure distribution then appears more similar to the inviscid case.

A93-48179#
A FINITE ELEMENT AND SYMBOLIC METHOD FOR STUDYING LAMINAR BOUNDARY LAYERS OF REAL GASES IN EQUILIBRIUM AT MACH NUMBERS TO 30
AUGUSTO C. M. MORAES, JOSEPH E. FLAHERTY, and HENRY T. NAGAMATSU (Rensselaer Polytechnic Inst., Troy, NY) Jul. 1993 12 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 Research supported by CAPES and USAF refs
(Contract DAAL03-91-G-0215)
(AIAA PAPER 93-2986) Copyright

Laminar boundary layers at high Mach numbers and stagnation temperatures, which are conditions that the National Aerospace Plane and future hypersonic vehicles will encounter on flights to orbit, are studied. The Prandtl laminar boundary layer equations for an adiabatic flat plate are solved using finite element matrices for three different assumptions. The latter include a perfect gas with constant properties and unit Prandtl number, a perfect gas with viscosity and thermal conductivity variation according to Sutherland's law, and a real gas with equilibrium properties. Results for each flow regime are given in terms of streamwise and transverse velocity profiles, temperature and density distributions, and gas property distributions. AIAA

A93-48180*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
AN OVERVIEW OF RECENT SUBSONIC LAMINAR FLOW CONTROL FLIGHT EXPERIMENTS
F. S. COLLIER, JR. (NASA, Langley Research Center, Hampton, VA) Jul. 1993 25 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-2987)

This paper presents an overview of wind-tunnel investigations and flight research activities in the United States and Europe devoted to advancing the state-of-the-art and reducing the risk associated with the application of laminar flow control (LFC) technology. The paper highlights LFC research conducted within the last five years.

A93-48181*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
A LAG MODEL FOR TURBULENT BOUNDARY LAYERS DEVELOPING OVER ROUGH BLEED SURFACES
J. LEE, M. L. SLOAN, and G. C. PAYNTER (Boeing Commercial Airplane Group, Seattle, WA) Jul. 1993 10 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(Contract NAS3-25963)
(AIAA PAPER 93-2988) Copyright

Boundary layer mass removal (bleed) through spanwise bands of holes on a surface is used to prevent or control separation and to stabilize the normal shock in supersonic inlets. The addition of a transport equation lag relationship for eddy viscosity to the rough wall algebraic turbulence model of Cebeci and Chang was found to improve agreement between predicted and measured mean velocity distributions downstream of a bleed band. The model was demonstrated for a range of bleed configurations, bleed rates, and local free stream Mach numbers. In addition, the model was applied to the boundary layer development over acoustic lining materials for the inlets and nozzles of commercial aircraft. The model was found to yield accurate results for integral boundary layer properties unless there was a strong adverse pressure gradient.

A93-48182#
EFFECTS OF BOUNDARY LAYER BLEED ON SWEPT-SHOCK/BOUNDARY LAYER INTERACTION
TAKAAKI SHIZAWA, SHINJI HONAMI (Tokyo, Science Univ., Japan), FUMIO KOMIYAMA (Japanese Patent Office, Tokyo, Japan), YASUYUKI TANAKA (Fuji Xerox Co., Ltd., Kanagawa, Japan), KIMIO SAKATA, RYOJI YANAGI, SHIGEMI SHINDO, AKIRA MURAKAMI (National Aerospace Lab., Tokyo, Japan), ATSUSHIGE TANAKA, KAZUO SHIRAISHI (Ishikawajima-Harima Heavy Industries Co., Ltd., Tokyo, Japan) et al. Jul. 1993 10 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-2989) Copyright

New data are presented on the structure of flowfield of a wedge induced, swept-shock/turbulent boundary layer interaction. The effects of boundary layer bleed at the interacted flowfield are studied experimentally. The tests cover the free stream Mach number of 2.63 and 3.25 using 1 m x 1 m supersonic blow-down wind tunnel. Pitot pressure survey by a rake type of Pitot-probe and vapor screen technique are used to construct a physical model for the swept interaction flowfield structure with and without boundary layer bleed. The direction of surface shear stress is measured by the use of oil film method. The separation vortex induced by the swept-shock decreases in size as the boundary layer bleed rate at the upstream location of the shock wave is increased. But the location of the center of the separation vortex is unchanged with the bleed. The separation shock wave associated with the separation vortex caused by the weak interaction are almost annihilated by the bleed at both up- and downstream locations.

A93-48183#
THE EFFECT OF EXPANSION ON THE LARGE SCALE STRUCTURE OF A COMPRESSIBLE TURBULENT BOUNDARY LAYER
STEPHEN A. ARNETTE, MO SAMIMY, and GREGORY S. ELLIOTT (Ohio State Univ., Columbus) Jul. 1993 35 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 Research supported by NSF refs
(Contract AF-AFOSR-91-0412)
(AIAA PAPER 93-2991) Copyright

Initial results of an extended investigation of the expansion effects on high Reynolds number, compressible, turbulent layers are presented. The large-scale features of the boundary layer turbulence are studied using extensive flow visualizations with filtered Rayleigh scattering. The incoming flow with a Mach 3 fully developed boundary layer is considered. It is found that streamwise structures exist in the expanded boundary layers. Particular attention is given to the effect of expansions on the large-scale structures which increase in scale across the expansion region as the angle between the structures and the downstream wall also increases. The small scale motions in the incoming boundary layer appear to respond very quickly to the expansion region, and the large scale motions respond much more gradually. AIAA

A93-48184*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
AN INVESTIGATION OF SHOCK WAVE TURBULENT BOUNDARY LAYER INTERACTION WITH BLEED THROUGH SLANTED SLOTS
A. HAMED, J. J. YEUAN, and S. H. SHIH (Cincinnati Univ., OH) Jul. 1993 10 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 Research supported by NASA refs
(AIAA PAPER 93-2992) Copyright

Flow-field characteristics are simulated numerically in an oblique shock wave/turbulent boundary layer interactions with six different bleed slot configurations. The strong conservation-law form of the 2D compressible Navier-Stokes equations and the k-epsilon equations are solved throughout the interaction region and inside the bleed slot. The computed results are presented for a normal and 20-deg slanted bleed slots at three different locations, upstream, across and downstream of the impingement point of an oblique shock of sufficient strength to cause boundary layer separation without bleed. The detailed flow characteristics in the interaction zone and inside the bleed slot are compared for the different bleed slot configurations. The resulting surface pressure and shear stress distributions as well as the boundary layer

characteristics downstream of the interaction region are also presented for the mix bleed configurations at different bleed mass flows up to choking. Author (revised)

A93-48185#
COMPUTATION OF HYPERSONIC FLOW PAST BLUNT BODY FOR NONEQUILIBRIUM WEAKLY IONIZED AIR
ESWAR JOSYULA (USAF, Wright Lab., Wright-Patterson AFB, OH) Jul. 1993 17 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-2995)

Hypersonic flow in thermochemical nonequilibrium and weak ionization was numerically simulated for a flow past blunt bodies for the Mach number range from 16 to 35. A flux splitting procedure was based on the presence of additional eigenvalue due to the electron translational temperature. The additional eigenvalue made it possible to predict a 13 percent higher electron pressure on the body surface for the RAM-C II flight test case of Alt. = 61 km, and to better capture the electron temperature with fewer points along the shorter distance. Results show that, for the smallest radius considered, the numerical code gave excellent agreement between predicted and experimental stagnation point heat transfer. AIAA

A93-48187#
A HIGH-ORDER STREAMLINE GODUNOV SCHEME FOR STEADY HYPERSONIC EQUILIBRIUM FLOWS
J. Y. YANG, J. C. HUANG, and C. A. HSU (National Taiwan Univ., Taipei) Jul. 1993 11 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(Contract NSC-81-0210-E002-34)
(AIAA PAPER 93-2997) Copyright

A Godunov-type method with streamline meshes as control volumes for steady supersonic and hypersonic equilibrium flows is presented, and an equilibrium real gas Riemann problem is solved using density and internal energy as independent thermodynamic variables. Results for 2D steady hypersonic equilibrium flows indicate that the smooth flow can be accurately described and flow discontinuities can be solved. The use of streamline meshes makes it possible to adapt intrinsic flow, to obtain excellent resolution of slip lines, and facilitate the implementation of the Godunov method. AIAA

A93-48188#
THE PREDICTION OF VISCOUS NONEQUILIBRIUM HYPERSONIC FLOWS ABOUT ABLATING CONFIGURATIONS USING AN UPWIND PARABOLIZED NAVIER-STOKES CODE
KENNETH K. MURAMOTO (Lockheed Missiles & Space Co., Inc., Sunnyvale, CA) Jul. 1993 12 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 Research supported by Lockheed Missiles & Space Co., Inc refs
(AIAA PAPER 93-2998) Copyright

A three-dimensional parabolized Navier-Stokes code has been developed to compute the viscous nonequilibrium hypersonic flow about configurations with ablative surfaces. The code employs an implicit, finite-volume, upwind algorithm in which there is weak coupling between the fluid dynamic and species conservation equations. The mass loss rates and wall temperatures resulting from heatshield ablation are predicted from an empirical steady-state model. The gas mixture of air and ablation products is assumed to be under equilibrium conditions at the wall and to be chemically reacting at a finite rate throughout the shock layer. The ablation and nonequilibrium chemistry models are validated by making comparisons with existing computational data. Numerical results are presented for a generic hypersonic vehicle with an ablating graphite surface under mid-glide conditions.

A93-48189#
MULTI-BLOCK CALCULATIONS FOR FLOWS IN LOCAL CHEMICAL EQUILIBRIUM
CAREY F. COX, PASQUALE CINNELLA, and ABDOLLAH ARABSHAHI (Engineering Research Center for Computational Field Simulation, Mississippi State, MS) Jul. 1993 11 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 Research supported by NSF refs
(Contract F08635-89-C-0208)
(AIAA PAPER 93-2999) Copyright

The present study details the application of an approximate Riemann solver of the Roe type, derived for the simulation of flows in local chemical equilibrium, to the solution of problems involving multiple structured grid blocks in two and three space dimensions. Preliminary numerical results indicate that the present approach preserves continuity of the flow variables at block boundaries and does not require a significant increase in CPU requirements when compared with oneblock predictions.

A93-48190#
AN EXPERIMENTAL STUDY OF THE EFFECTS OF DEFORMABLE TIP ON THE PERFORMANCE OF FINS AND FINITE WINGS
T. W. CHIU, C. A. M. BROERS, A. H. C. WALKER, and C. R. BALLER (Exeter Univ., United Kingdom) Jul. 1993 9 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-3000) Copyright

In recent years, the reduction of aerodynamic induced drag (on finite wings) by passive means is a popular research topic. Among many drag reduction devices being investigated, flexible tip is of particular interest to nonaerospace application. In the wind-surfing industry, slender fins with flexible tips have shown high performance recently. The development of windsurfer fins, however, has been on a trial-and-error basis and the physics behind the improved performance has not been fully understood, although some suggest that the flexible tip helps to reduce the induced drag. At Exeter University, a series of experiments has thus been performed in order to help fully understand the effects of tip flexibility on the vortex wake and hence the performance as compared to similar fins with inflexible tips. Although the investigation was done on wind-surfer fins, the conclusions are equally valid for aircraft wings. Author (revised)

A93-48192#
SIMULATION OF DD-963 SHIP AIRWAKE BY NAVIER-STOKES METHOD
TSZE C. TAI (U.S. Navy, Naval Surface Warfare Center, Bethesda, MD) and DEAN CARICO (U.S. Navy, Naval Air Warfare Center, Patuxent River, MD) Jul. 1993 10 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 Research supported by U.S. Navy refs
(AIAA PAPER 93-3002) Copyright

The airwake about a DD-963 ship configuration is simulated by using a multizone, thin-layer Navier-Stokes method. The ship's superstructure is represented by two blocked structures, followed by a flight deck and a lower missile deck. Two test cases are considered: (1) atmospheric wind of 10 knots at wind angle of 30 deg, and (2) atmospheric wind of 30 knots at the same direction. The atmospheric wind is uniform wind corrected with an atmospheric boundary layer represented by a power-law profile. Both laminar and turbulent flows are simulated. In general, the flow is largely separated behind the superstructure. Major flow features including viscous-vortex interactions observed in the wind tunnel experiments are captured in the computed results. The computed mean velocities along a specified flight path compare well with wind tunnel data. No at-sea full-scale ship airwake data are currently available for comparison. Author (revised)

A93-48197#
EXPERIMENTAL STUDY OF 3-D SEPARATION ON A LARGE SCALE MODEL
D. BARBERIS and P. MOLTON (ONERA, Chatillon, France) Jul. 1993 11 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-3007; ONERA, TP NO. 1993-97) Copyright

Three-dimensional separation is studied by considering the flow past a large scale model consisting of an half prolate ellipsoid extended by a circular cylinder ending in a flat base at 45 deg

with respect to the cylinder axis. The flow past the model, including boundary-layer and vortical structures, is investigated in great detail by using a three-component LDV system and three-hole pressure probes actuated by a displacement system installed inside the model. This last device allows the probing of the separating 3D boundary-layer very close to the surface. We have observed how a boundary layer evolves as it gradually shears into a vortex rollup and then into an organized vortex. When skewing of the boundary layer grows, the difference of direction between velocity gradient vector and shear stress vector increases. For this type of flow, turbulence models based on the assumption of isotropic turbulent viscosity are inadequate for numerical modelization.
Author (revised)

A93-48198*# National Aeronautics and Space Administration, Washington, DC.
VORTEX DEVELOPMENTS OVER STEADY AND ACCELERATED AIRFOILS INCORPORATING A TRAILING EDGE JET
F. FINAISH, N. OKONG'O, and J. FRIGERIO (Missouri-Rolla Univ., Rolla) Jul. 1993 13 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 Research supported by Univ. of Missouri System-Weldon Springs Endowment, NASA Missouri Consortium, and Univ. of Missouri-Rolla refs
(AIAA PAPER 93-3008) Copyright

Computational and experimental studies are conducted to investigate the influence of a trailing edge jet on flow separation and subsequent vortex formation over steady and accelerated airfoils at high angles of attack. A computer code, employing the stream function-vorticity approach, is developed and utilized to conduct numerical experiments on the flow problem. To verify and economize such efforts, an experimental system is developed and incorporated into a subsonic wind tunnel where streamline and vortex flow visualization experiments are conducted. The study demonstrates the role of the trailing edge jet in controlling flow separation and subsequent vortex development for steady and accelerating flow at angles past the static stall angle of attack. The results suggest that the concept of the trailing edge jet may be utilized to control the characteristics of unsteady separated flows over lifting surfaces. This control possibility seems to be quite effective and could have a significant role in controlling unsteady separated flows.

A93-48199*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
A COMPUTATIONAL AND EXPERIMENTAL INVESTIGATION OF A DELTA WING WITH VERTICAL TAILS
SHERRIE L. KRIST, ANTHONY E. WASHBURN (Vigyan, Inc., Hampton, VA), and KENNETH D. VISSER (National Research Council, Hampton, VA) Jul. 1993 12 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(Contract NAS1-19672)
(AIAA PAPER 93-3009)

The flow over an aspect ratio 1 delta wing with twin vertical tails is studied in a combined computational and experimental investigation. This research is conducted in an effort to understand the vortex and fin interaction process. The computational algorithm used solves both the thin-layer Navier-Stokes and the inviscid Euler equations and utilizes a chimera grid-overlapping technique. The results are compared with data obtained from a detailed experimental investigation. The laminar case presented is for an angle of attack of 20 deg and a Reynolds number of 500,000. Good agreement is observed for the physics of the flow field, as evidenced by comparisons of computational pressure contours with experimental flow-visualization images, as well as by comparisons of vortex-core trajectories. While comparisons of the vorticity magnitudes indicate that the computations underpredict the magnitude in the wing primary-vortex-core region, grid embedding improves the computational prediction. Author (revised)

A93-48200*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
A COMPUTATIONAL STUDY OF WINGTIP VORTEX FLOWFIELD
JENNIFER DACLES-MARIANI, STUART ROGERS, DOCHAN KWAK (NASA, Ames Research Center, Moffett Field, CA), GREG ZILLIAC, and JIM CHOW (NASA, Ames Research Center, Moffett Field; Stanford Univ., CA) Jul. 1993 20 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-3010) Copyright

The near-field behavior of a wingtip vortex flow is studied computationally using an incompressible flow solver for the Navier-Stokes equations based on the artificial compressibility method. Inaccuracies in current computational studies are addressed, especially, the role of numerical errors and transition/turbulence modeling. A subset problem is devised in order to make the study of vortex preservation more tractable. As part of the numerical checks, the flow is first run laminar while performing a systematic grid refinement study for the subset problem. Further studies on the numerical errors are conducted with the measured Reynolds stresses introduced into the momentum equations as source terms. As a preliminary study of turbulent flows, the one-equation Baldwin-Barth turbulence model is implemented as well as the approximation of the production term. The full-geometry case is computed using 1.1 million grid points. The results are compared with experiment.

A93-48201*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
TURBULENT STRUCTURE OF A WINGTIP VORTEX IN THE NEAR FIELD
GREGORY G. ZILLIAC (NASA, Ames Research Center, Moffett Field, CA), JIM S. CHOW (Stanford Univ., CA), JENNIFER DACLES-MARIANI (NASA, Ames Research Center, Moffett Field, CA), and PETER BRADSHAW (Stanford Univ., CA) Jul. 1993 14 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-3011) Copyright

The turbulent rollup of a vortex generated by a rectangular wing has been investigated. Extensive mean and turbulence measurements of the flowfield on a wingtip and in the near field have been completed. Velocity fluctuation measurements show that the near-field core is not laminar. A large axial velocity excess was found to exist in the core of the vortex. A momentum balance in the near-field of the wingtip showed that the magnitude of the core Reynolds-stress gradient terms are the same order as the largest terms in the governing equations. Navier-Stokes computations of the identical configuration, including wind tunnel walls and using measured inflow and outflow boundary conditions, reproduced many of the features of the experiment. Inherent limitations of the Baldwin-Barth turbulence model combined with limited grid resolution caused the computed vortex core to be more diffuse than desired. The momentum balance also demonstrated that the level of numerically generated false diffusion in the vortex core is relatively high.

A93-48202*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
WAKE-VORTEX STRUCTURE FROM LIFT AND TORQUE INDUCED ON A FOLLOWING WING
VERNON J. ROSSOW (NASA, Ames Research Center, Moffett Field, CA) Jul. 1993 18 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-3013) Copyright

A procedure based on vortex lattice theory to interpret the lift and torque measured on a following model in a wind tunnel is developed to retrieve the velocity distribution in the vortex wake that caused the induced forces. It is concluded that the retrieval procedure has a potential for reliably determining the structure of vortex wakes that trail from the wings of subsonic transport aircraft. Tests using idealized theoretical models show that the procedure is highly reliable and accurate. However, certain difficulties are

found in the retrieval procedure when applied to actual data measured with following wings of various sizes in a wind tunnel. AIAA

A93-48205*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
DYNAMIC-OVERLAPPED-GRID SIMULATION OF AERODYNAMICALLY DETERMINED RELATIVE MOTION
GUAN-WEI YEN and OKTAY BAYSAL (Old Dominion Univ., Norfolk, VA) Jul. 1993 14 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(Contract NAG1-1150)
(AIAA PAPER 93-3018) Copyright

Currently, there is a need to develop a means of analyzing and studying unsteady flowfields which involve multiple component configurations with at least one of the components in relative motion with respect to the others. Two of the important phenomena that such analyses can help to understand are the unsteady aerodynamic interference and the boundary-induced component of the flowfield. With this motivation, a computational method is developed which couples the governing equations of the unsteady flowfield and the rigid-body dynamics in six degrees-of-freedom. These equations are solved on composite meshes of overlapped subdomain grids which can move with respect to each other. Initially, several measures that reduce the numerical error are studied and compared with the exact solution of a moving normal shock in a tube. It is concluded that a second-order accurate method, for spatial and temporal discretizations as well as for the moving subdomain interpolations, is needed as a minimum measure. Furthermore, the CFL numbers should be restricted to unity. Then, the method is used to simulate the flowfield history and predict the aerodynamically determined trajectory of a store dropped from its initial position under a wing.

A93-48206*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
A VISCOUS-INVISCID INTERACTION METHOD FOR 2-D UNSTEADY, COMPRESSIBLE FLOWS
ISMAIL H. TUNCER (U.S. Naval Postgraduate School, Monterey, CA), JOHN A. EKATERINARIS (U.S. Navy-NASA Joint Inst. of Aeronautics; Ames Research Center, Moffett Field, CA), and MAX F. PLATZER (U.S. Naval Postgraduate School, Monterey, CA) Jul. 1993 13 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 Research supported by National Research Council refs
(AIAA PAPER 93-3019)

A Navier-Stokes/potentia/flow interactive solution method suitable for the solution of steady-state and unsteady flowfields around airfoils has been developed. The Navier-Stokes equations are solved in the close proximity of an airfoil and in its wake. The inviscid flowfield surrounding the viscous flow regions is assumed to be irrotational and isentropic. In the inviscid flow region, the potential flow equations, which are based on distributed sources and vortices, are solved. The two solutions are strongly coupled through the application of their boundary conditions. The strongly coupled Navier-Stokes/potential flow interactive solution method confines computations to a small domain in the proximity of an airfoil. For steady flow solutions, the computational domain may be confined to a region which extends less than one-fifth of a chord length distance away from the airfoil surface. Computed solutions have the same accuracy as the full domain NavierStokes solutions. Yet, as a result of the significantly reduced computational domain and increased convergence rates, the Navier-Stokes/potential flow interactive solution method is about 40 percent more efficient computationally.

A93-48207#
COMPUTATIONS OF TRANSONIC WIND TUNNEL FLOWS ABOUT A FULLY CONFIGURED MODEL OF AIRCRAFT BY USING MULTI-DOMAIN TECHNIQUE
YOKO TAKAKURA (Fujitsu, Ltd., Supercomputer Systems Dept., Chiba, Japan), SATORU OGAWA, and YASUHIRO WADA (National Aerospace Lab., Tokyo, Japan) Jul. 1993 10 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-3022) Copyright

The transonic flows about a fully configured model of aircraft, ONERA-M5, within the transonic wind tunnel are numerically solved as a first step to investigate the reliability of numerical solutions synthetically. The multi-domain technique is used to solve the whole flow-field around the complicated configuration. In each domain the grid is generated by an algebraic method and the thin-layer Navier-Stokes equations are solved by the improved ChakravarthyOsher TVD scheme. Further a simple model is here presented to estimate the outflow or inflow effects at the perforated wall of wind tunnel and is taken as the boundary condition at the test-section wall. It is shown that the computational results obtained by the present methods agree well with NAL wind-tunnel experiments with regard to pressure coefficients on the main wing and total lift and drag coefficients.

A93-48208#
TRANSONIC MUTUAL INTERFERENCE OF WING-PYLON-MULTIPLE BODY CONFIGURATIONS USING AN OVERLAPPING GRID SCHEME
LAWRENCE E. LIJEWSKI (USAF, Wright Lab., Eglin AFB, FL) Jul. 1993 7 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-3023)

The accuracy of an overlapping grid/Euler flow solver technique to predict the pressure distribution on a wing-pylon configuration with multiple finned and unfinned bodies is demonstrated. The flow solutions compared well with wind tunnel data, and the forces and moments obtained from integrated surface pressure distributions resulted in physically realistic rigid body behavior in interference flowfields. The finned and unfinned configurations exhibited upward, inboard forces, and a nose-downward pitching moment for all three bodies. AIAA

A93-48209#
IMPROVEMENT OF TRANSONIC WING BUFFET BY GEOMETRIC MODIFICATIONS
SHEN-JWU SU (Aero Industry Development Center, Taichung, Taiwan) and CHUEN-YEN CHOW (Colorado Univ., Boulder) Jul. 1993 10 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-3024) Copyright

A computational procedure is established for studying the transonic buffet phenomenon of finite wings of arbitrary shape, with a special application to improve the buffet performance of a wing by modifying its geometry. Two types of wing modifications, respectively based the twisted wing and step wing concepts, have been investigated. The numerical results indicated that both of the two geometric modifications can effectively weaken the shock/boundary layer interaction, so that the buffet onset boundary is significantly raised in the transonic speed regime.

A93-48210#
CLEBSCH VARIABLE MODEL FOR UNSTEADY INVISCID TRANSONIC FLOW WITH STRONG SHOCK WAVES
J. WESTLAND and M. H. L. HOUNJET (National Aerospace Lab., Amsterdam, Netherlands) Jul. 1993 13 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 Research supported by Netherlands Agency for Aerospace Programs refs
(AIAA PAPER 93-3025) Copyright

An exact and easy to implement 3D unsteady flow Clebsch variable model describing both shock-generated entropy and vorticity is presented. The model is based on the Euler equations using variational principles. Results obtained for 3D steady and unsteady transonic flows show that shock positions are predicted less far aft on the airfoil as opposed to the full potential results. Results for 2D and 3D unsteady first harmonic transonic flow show that the Clebsch variable formulation has a strong impact on the peaks associated with the shock trajectories. AIAA

A93-48211#
A FAST ROBUST VISCOUS-INVISCID INTERACTION SOLVER FOR TRANSONIC FLOW ABOUT WING/BODY CONFIGURATIONS ON THE BASIS OF FULL POTENTIAL THEORY
A. J. VAN DER WEES, J. VAN MUIJDEN, and J. VAN DER VOOREN (National Aerospace Lab., Amsterdam, Netherlands) Jul. 1993 10 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 Research supported by Netherlands Agency for Aerospace Programs refs
(AIAA PAPER 93-3026) Copyright

A viscous-inviscid interaction method has been developed for the computation of transonic flow about wing/body configurations. The interaction method consists of a fast inviscid flow solver based on the full potential equation, formulated on curvilinear coordinates, a viscous flow solyer based on the unsteady boundary layer equations, formulated in integral form on curvilinear coordinates, and an interaction algorithm of quasisimultaneous type. The method is intented for (inverse) wing design purposes, and is shown to be fast and robust.

A93-48213*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
APPLICATION OF A TWO-EQUATION TURBULENCE MODEL FOR HIGH SPEED COMPRESSIBLE FLOWS USING UNSTRUCTURED GRIDS
GURURAJA R. VEMAGANTI and RAMADAS K. PRABHU (Lockheed Engineering & Sciences Co., Hampton, VA) Jul. 1993 16 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(Contract NAS1-19000; NAG1-1339)
(AIAA PAPER 93-3029)

Application of a two-equation compressible turbulence model for practical hypersonic flows 18 presented. The solution algorithm is based on solving all of the governing equations simultaneously. Application of the solution procedure to several test cases for compressible flows show good agreement with theoretical predictions and/or other computational results. The solution procedure is employed to investigate the effects of turbulence in Type III and Type IV shock-shock interactions in hypersonic flows in association with adaptive unstructured grids. Computational results for these cases are compared with available experimental data.

A93-48214#
BEHAVIOUR OF THE JOHNSON-KING TURBULENCE MODEL IN AXI-SYMMETRIC SUPERSONIC FLOWS
Y. NOGUCHI (Salford Univ., United Kingdom) and T. SHIRATORI (Tokyo Metropolitan Inst. of Technology, Hino, Japan) Jul. 1993 9 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 Research supported by British Council refs
(AIAA PAPER 93-3032) Copyright

A series of systematic tests are carried out on the Johnson-King (1985) turbulence model (JKM) for applied compressible aerodynamics. Two-dimensional flows with a moderate adverse pressure gradient and without separation at various Mach numbers are used for the tests. The results are compared with the Baldwin-Lomax (1978) model (BLM) as well as the measurements. The agreement of the results of both models and the measured data becomes poorer at higher Mach numbers. Overall, the performance of the JKM is slightly better than BLM except with respect to the prediction of the skin friction coefficient. The ordinary differential equation (ODE) in the JKM is effective in improving the prediction. However, the effects of the ODE are not as radical as in flows with separation. Use of the JKM even in nonseparated flows may improve accuracy of prediction which has not been clearly established before this work. Author (revised)

A93-48221#
STUDY OF THE NEAR-WAKE STRUCTURE OF A SUBSONIC BASE CAVITY FLOWFIELD USING PIV
M. J. MOLEZZI and J. C. DUTTON (Illinois Univ., Urbana) Jul. 1993 19 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(Contract DAAL03-90-G-0021)
(AIAA PAPER 93-3040) Copyright

A new particle image velocimetry (PIV) system has been used to study the near-wake structure of a twodimensional base in subsonic flow in order to determine the fluid dynamic mechanisms of observed base drag reduction in the presence of a base cavity. Experiments were done over a range of freestream Mach numbers up to 0.8, including local flowfield velocities over 300 m/s. Effects of the base cavity on the yon Karman vortex street wake were found to be related to the expansion and diffusion of vortices near the cavity, although the effects are of small magnitude and no significant change in the vortex formation location or path was observed. The base cavity effects are also less significant at higher freestream velocities due to the formation of vortices further downstream from the base. The base cavity drag reduction was found to be mainly due to the displacement of the base surface to a location upstream of the low-pressure wake vortices, with only a slight modification in the vortex street itself.

A93-48222*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
CFD CODE CALIBRATION AND INLET-FAIRING EFFECTS ON A 3D HYPERSONIC POWERED-SIMULATION MODEL
LAWRENCE D. HUEBNER (NASA, Langley Research Center, Hampton, VA) and KENNETH E. TATUM (Lockheed Engineering & Sciences Co., Hampton, VA) Jul. 1993 12 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-3041) Copyright

A three-dimensional (3D) computational study has been performed addressing issues related to the wind tunnel testing of a hypersonic powered-simulation model. The study consisted of three objectives. The first objective was to calibrate a state-of-the-art computational fluid dynamics (CFD) code in its ability to predict hypersonic powered-simulation flows by comparing CFD solutions with experimental surface pressure dam. Aftbody lower surface pressures were well predicted, but lower surface wing pressures were less accurately predicted. The second objective was to determine the 3D effects on the aftbody created by fairing over the inlet; this was accomplished by comparing the CFD solutions of two closed-inlet powered configurations with a flowing-inlet powered configuration. Although results at four freestream Mach numbers indicate that the exhaust plume tends to isolate the aftbody surface from most forebody flowfield differences, a smooth inlet fairing provides the least aftbody force and moment variation compared to a flowing inlet. The final objective was to predict and understand the 3D characteristics of exhaust plume development at selected points on a representative flight path. Results showed a dramatic effect of plume expansion onto the wings as the freestream Mach number and corresponding nozzle pressure ratio are increased.

A93-48223#
A FAMILY OF MULTIBLOCK CODES FOR COMPUTATIONAL AEROTHERMODYNAMICS - APPLICATION TO COMPLETE VEHICLE HYPERSONIC FLOWS
PENELOPE LEYLAND, FRANCOISE PERRELL, JAN B. VOS (Lausanne, Ecole Polytechnique Federale, Switzerland), and MAGNUS BERGMAN (Centre for Computational Mathematics and Mechanics, Stockholm, Sweden) Jul. 1993 13 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-3042) Copyright

Modular multiblock codes written on top of an object oriented data base manager are applied for calculating a wide range of flight conditions over several geometries, including the HERMES space shuttle. Both inviscid and viscous flows are calculated, and different thermo-chemical models for air are considered. The effect of these models on the aerodynamics of the HERMES space shuttle is discussed. The multiblock concept is adopted to facilitate the mesh generation for complex geometries and to use parallel computers efficiently. The flow equations are solved by the finite volume method using a space centered explicit time marching scheme stabilized by artificial dissipation terms. Both Euler and

Navier-Stokes calculations are made for 3D generic geometries such as the double ellipsoid, as well as real-life geometries as delta wings and the European Space Shuttle HERMES.

A93-48224#
DEVELOPING A DATA BASE FOR THE CALIBRATION AND VALIDATION OF HYPERSONIC CFD CODES - SHARP CONES
JOHN J. BERTIN (Sandia National Labs., Albuquerque, NM), ANTHONY MARTELLUCCI (Science Applications International Corp., Fort Washington, PA), RICHARD D. NEUMANN (Dayton Univ., OH), and KENNETH F. STETSON Jul. 1993 20 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-3044) Copyright

While supersonic flowfields about sharp cones are relatively simple, computations of these flowfields must include models of boundary layer transition, turbulence and ablation processes. Validation requires detailed data comparisons to verify the ability to compute the critical flow physics. These processes are difficult to model numerically and measure experimentally. The present paper reviews the types of data and the quality and limitations of the measurements and it provides guidance as to how the data can be used to obtain information relating to the flow mechanisms.

A93-48225#
THE EUROPEAN DATA BASE - A NEW CFD VALIDATION TOOL FOR THE DESIGN OF SPACE VEHICLES
REMI ABGRALL, JEAN-ANTOINE DESIDERI (INRIA, Valbonne, France), MICHEL MALLET, JACQUES PERIAUX, PIERRE PERRIER, and BRUNO STOUFFLET (Dassault Aviation, Saint-Cloud, France) Jul. 1993 17 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-3045) Copyright

International cooperative efforts to enhance code validation opportunities including three Europe/U.S. Short Courses on Hypersonics and two sessions of the scientific workshop organized by INRIA and GAMNI, which took place in Antibes, France are reviewed. Particular attention is given to the motivation for the choice of the test cases and an analysis and synthesis of obtained results. Result of the workshops were evaluated by intensive comparisons of different codes with experiments performing the same test cases which constitute the initial content of the European Hypersonic Data Base. AIAA

A93-48226#
CODE VALIDATION FOR HIGH SPEED FLOW SIMULATION OVER THE VLS LAUNCHER FAIRING
J. L. F. AZEVEDO, P. MORAES, JR. (Inst. de Aeronautica e Espaco, Sao Jose dos Campos, Brazil), C. R. MALISKA, C. H. MARCHI, and A. F. C. SILVA (Santa Catarina, Univ. Federal, Florianopolis, Brazil) Jul. 1993 10 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-3046) Copyright

An experimental wind tunnel investigation for pressure distribution and force measurements for Brazilian VLS is described. Particular attention is given to the physical validation of an all speed Euler and/or Navier-Stokes simulation code based on a segregated finite volume algorithm for 3D body conforming curvilinear coordinates with a colocated variable arrangement. Results obtained for subsonic and supersonic flow conditions are found to be in very good agreement with experimental data. AIAA

A93-48228#
SOME STABILITY CHARACTERISTICS OF THE BOUNDARY LAYER ON A YAWED CONE
A. HANIFI and A. A. DAHLKILD (Royal Inst. of Technology, Stockholm, Sweden) Jul. 1993 15 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 Research sponsored by Aeronautical Research Inst. of Sweden refs
(AIAA PAPER 93-3048) Copyright

The stability characteristics of the supersonic boundary layer on a yawed pointed cone are studied by means of linear stability theory. The basic flow at the windward and leeward rays are obtained using two different approaches. First a perturbation method for small angles of attack at the leeward meridian is used, and secondly the 'exact' boundary-layer equations are solved at the windward meridian. The transverse curvature and body divergence terms are included in the stability and boundary-layer equations. The e exp N method is used to predict the location of transition, and the results are compared to the experiments of Krogmann (1977). The calculations are carried out for both 2D and oblique instability waves. The N-factor criterion that recovers the transition onset Reynolds number of Krogmann's experiment is found to be N about 4.5, which is considerably lower than N about 10 found in other studies (e.g., Malik, 1989). However, the relative up- and downstream movement of the transition point on the lee- and windward meridians respectively is predicted fairly well for various yaw angles. Author (revised)

A93-48229#
TRANSITION FOR THREE-DIMENSIONAL BOUNDARY LAYERS ON WINGS IN THE TRANSONIC REGIME
ROBERT MARTINUZZI, MOHSEN MIRSHAMS, and ION PARASCHIVOIU (Ecole Polytechnique, Montreal, Canada) Jul. 1993 10 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 Research supported by Bombardier, Inc refs
(AIAA PAPER 93-3049) Copyright

Predictions of the point of laminar/turbulent transition for three-dimensional boundary layers in the transonic regime obtained with the code SCOLIC, which is based on temporal stability theory, are presented. Comparison is made with experimental data for seven different test cases. Results obtained using an extended version of the code implementing a simplified version of spatial stability theory offer support for the use of Gaster's relation. Validation tests are presented for seven different airfoils to assess the ability of SCOLIC to predict the location of boundary layer transition. These cases were selected from the available literature containing the measured surface pressure distributions and an observed estimate to the location of transition. Author (revised)

A93-48230#
BYPASS TRANSITION IN TWO- AND THREE-DIMENSIONAL BOUNDARY LAYERS
KENNETH S. BREUER and TAKEO KURAISHI (MIT, Cambridge, MA) Jul. 1993 13 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(Contract NSF CTS-92-10436)
(AIAA PAPER 93-3050) Copyright

The evolution of localized three-dimensional disturbance in two- and three-dimensional laminar boundary layers is examined. The linearized Navier-Stokes equations for three-dimensional disturbances in a three-dimensional parallel shear flow are solved numerically using Fourier transform Chebyshev collocation techniques. Modal analysis shows that substantial short-term energy growth can be obtained even when all instability waves are damped. This transient growth can increase the initial disturbance energy by two or three orders of magnitude, at which stage non-linear interactions might lead to a breakdown to turbulent flow, bypassing the traditional Tollmien-Schlichting instability mechanism. The dependence of the transient growth on wavenumber, Reynolds number, Sweep angle and Hartree parameter is determined and a method for predicting the maximum transient growth is proposed and found to be reasonably accurate over a wide parameter range. Localized disturbances are also examined and it is found that the bypass growth mechanism can enhance the formation of cross-flow vortices in a three-dimensional flow. Some implications are discussed, particularly with respect to the observed effects of roughness on transition location.

A93-48232*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
A DETAILED STUDY OF MEAN-FLOW SOLUTIONS FOR STABILITY ANALYSIS OF TRANSITIONAL FLOWS

R. RAMAKRISHNAN (Analytical Services and Materials, Inc., Hampton, VA), V. VATSA, J. OTTO, and A. KUMAR (NASA, Langley Research Center, Hampton, VA) Jul. 1993 13 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(Contract NAS1-19320)
(AIAA PAPER 93-3052)

A finite-volume upwind-difference parabolized Navier-Stokes code is utilized to obtain laminar mean-flow solutions at Mach 3.5 on a half-angle cone of 5 deg at an angle-of-attack of 2 deg. A detailed study is conducted on this configuration; the main focus is the velocity profiles in the leeward and windward symmetry planes at various axial locations. Comparisons of the solution profiles are made with both a central-difference code that incorporates scalar and matrix dissipation models and another state-of-the-art upwind-difference finitevolume code. The results obtained emphasize the importance of using matrix dissipation models for schemes that require explicit artificial dissipation. These results also illustrate the accuracy and efficiency of the planeby-plane marching procedure for computing mean-flow solutions for predicting the onset of transition with linear instability. Author (revised)

A93-48234*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
NAVIER-STOKES SIMULATION OF EXTERNAL/INTERNAL TRANSONIC FLOW ON THE FOREBODY/INLET OF THE AV-8B HARRIER II
STEPHEN J. MYSKO, WEI J. CHYU, MICHAEL W. STORTZ (NASA, Ames Research Center, Moffett Field, CA), and CHUEN-YEN CHOW (Colorado Univ., Boulder) Jul. 1993 12 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-3057)

In this work, the computation of combined external/internal transonic flow on the complex forebody/inlet configuration of the AV-8B Harrier II is performed. The actual aircraft has been measured and its surface and surrounding domain, in which the fuselage and inlet have a common wall, have been described using structured grids. The 'thin-layer' Navier-Stokes equations were used to model the flow along with the Chimera embedded multi-block technique. A fully conservative, alternating direction implicit (ADI), approximately factored, partially fluxsplit algorithm was employed to perform the computation. Comparisons to some experimental wind tunnel data yielded good agreement for flow at zero incidence and angle of attack. The aim of this paper is to provide a methodology or computational tool for the numerical solution of complex external/internal flows.

A93-48235*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
UNSTEADY NAVIER-STOKES SIMULATION OF THE CANARD-WING-BODY RAMP MOTION
EUGENE L. TU, SHIGERU OBAYASHI, and GURU P. GURUSWAMY (NASA, Ames Research Center, Moffett Field, CA) Jul. 1993 12 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-3058) Copyright

A time-accurate thin-layer Navier-Stokes simulation of the unsteady flowfield is performed for a typical canard-wing-body configuration undergoing ramp motions. The computations are made at a transonic Mach number of 0.90 and for ramp angles from 0 to 15 degrees. Accuracy is determined by comparisons with steady-state experimental data and with spatial and time-step refinement studies. During the ramp motion, the computational results show improved dynamic lift performance and a strong canard-wing interaction for the canard-on configuration. Formation of the canard leading-edge vortex is inhibited in the early stages of the ramp motion. An analysis performed on the transient flowfield after the ramp motion ends shows that the canard vortex rapidly gains strength and vortex breakdown eventually occurs. These characteristics of the canard vortex have significant influences on wing performance.

A93-48236*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
AN INITIAL COMPARISON OF CFD WITH EXPERIMENT FOR A GEOMETRICALLY SIMPLIFIED STOVL MODEL
KARLIN R. ROTH (NASA, Ames Research Center, Moffett Field, CA) Jul. 1993 9 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-3059) Copyright

The transition flight performance of a representative Short Take-Off or Vertical Landing (STOVL) model is investigated using side-by-side experimental and numerical simulations. The model consists of a 60 deg cropped delta wing planform; a simple fuselage shape blended to the wing; and tandem, circular, high-pressure-air lift jets that exit perpendicular to the flat lower surface. The configuration was chosen to minimize the geometric modeling complexity while retaining the important flow physics of the lift-jet/aerodynamic surface interaction. Three-dimensional, turbulent Navier-Stokes computations are made using a multiple, overset grid scheme. Results are presented and compared with the measured forces and pressures for the model at a freestream Mach number of 0.14 and a 10 deg angle-of-attack without lift jets operating. Computed surface flow patterns and particle traces show that the simulation predicts primary and secondary wing leading edge vortices for these conditions. Author (revised)

A93-48237#
INVESTIGATION OF THE FLOWFIELD OVER PARALLEL-ARRANGED LAUNCH VEHICLES
W. SCHROEDER and F. MERGLER (Deutsche Aerospace AG, Munich, Germany) Jul. 1993 16 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-3060) Copyright

A comprehensive study of viscous hypersonic flows over parallel-averaged launch vehicles at a gap width between upper and lower stage Delta z = 2.24 m has been made. We present a relaxation method to numerically integrate the 3D Navier-Stokes equations for laminar and turbulent flows. The application of several turbulence models to different hypersonic test problems showed the more versatile validity of the k-omega turbulence model compared to zero-equation models. The comparison of laminar and turbulent computed and measured results indicated that for the flow parameters considered the flow over the two-stage system can be assumed laminar. Contrasting experimental and numerical data at several relative angles of attack yielded good agreement with regard to lift, drag, and pitching moment coefficients and proves the numerical scheme to be a useful device for the meticulous analysis of flows over parallel-staged reusable launch vehicles. It showed that the impact of the upper stage on the flow over the lower stage decreases when the incidence angle to each other is increased and that the influence of the shock pattern within the gap between space vehicle and aircraft on the aerodynamic characteristics of the orbiter is less at higher relative angles of attack. Author (revised)

A93-48239*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
A THREE-DIMENSIONAL PRESSURE FLUX-SPLIT RNS APPLICATION TO SUB/SUPERSONIC FLOW IN INLETS AND DUCTS
P. K. KHOSLA, H. S. PORDAL, and S. G. RUBIN (Cincinnati Univ., OH) Jul. 1993 11 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(Contract NAG3-1178)
(AIAA PAPER 93-3063) Copyright

The reduced Navier-Stokes (RNS) formulation is combined with a pressure based flux split procedure for the computational analysis of three dimensional flow. Only lowest order diffusion, that is required to satisfy the no-slip boundary condition is retained in this approximation. The governing equations are appropriately differenced such that the physical boundary conditions are closely coupled and combined to form a closed discrete system. No numerical or characteristic type boundary conditions are required. A global pressure relaxation procedure, i.e. multi-sweep PNS, is

considered. A sparse matrix direct solver is applied to the crossplane solution. At the outflow boundary only the pressure or pressure gradient is prescribed. The resulting formulation has been applied to the solution of three-dimensional subsonic/supersonic internal flows in inlets and ducts.

A93-48240#
EXPERIMENTAL AND NUMERICAL STUDY OF TRANSONIC TURBINE CASCADE FLOW
TIBOR KISS, JOSEPH A. SCHETZ, and HAL L. MOSES (Virginia Polytechnic Inst. and State Univ., Blacksburg) Jul. 1993 10 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-3064) Copyright

A comprehensive study of the flowfield through a two-dimensional cascade of high pressure turbine blades of a jet engine is presented. The experimental studies were carried out on a cascade of eleven blades in a blow-down tunnel. The static pressure was measured on the cascade side-wall and on the blade surfaces and total pressure and total temperature measurements were taken upstream of the cascade. Shadowgraph pictures were taken for a study of the trailing edge shock structure and for the turbulent transition location. A single-plate interferometer technique was used for density field measurement. For the numerical studies the full Navier-Stokes equations were solved on a nonperiodic C-grid. In the attached boundary layer, the turbulence was modeled by a recently developed extended Clauser eddy viscosity model. In the trailing edge and wake region, the Baldwin-Lomax model was used. Good agreement between the measured and the calculated results was obtained for most aspects of the flowfield.

A93-48241*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
AVERAGING TECHNIQUES FOR STEADY AND UNSTEADY CALCULATIONS OF A TRANSONIC FAN STAGE
M. L. WYSS (Cincinnati Univ., OH), R. V. CHIMA, and D. L. TWEEDT (NASA, Lewis Research Center, Cleveland, OH) Jul. 1993 11 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-3065) Copyright

It is often desirable to characterize a turbomachinery flow field with a few lumped parameters such as total pressure ratio or stage efficiency. Various averaging schemes may be used to compute these parameters. Here three averaging schemes, the momentum, energy, and area averaging schemes, are described and compared for two computed solutions of the midspan section of a transonic fan stage: a steady averaging-plane solution in which average rotor outflow conditions were used as stator inflow conditions and an unsteady rotor-stator interaction solution. The unsteady solution is described, some unsteady flow phenomena are discussed and the steady pressure distributions are compared. Despite large unsteady pressure fluctuations on the stator surface, the steady pressure distribution matched the average unsteady distribution almost exactly. Stator wake profiles, stator loss coefficient, and stage efficiency were computed for the two solutions with the three averaging schemes and are compared. In general the energy averaging scheme gave good agreement between the averaging-plane solution and the time-averaged unsteady solution, even though certain phenomena due to unsteady wake migration were neglected. Author (revised)

A93-48245#
USE OF SHEAR-STRESS-SENSITIVE, TEMPERATURE-INSENSITIVE LIQUID CRYSTALS FOR BOUNDARY LAYER TRANSITION DETECTION IN HYPERSONIC FLOWS
D. P. AESCHLIMAN and R. H. CROLL (Sandia National Labs., Albuquerque, NM) Jul. 1993 17 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(Contract DE-AC04-76DP-00789)
(AIAA PAPER 93-3070) Copyright

A boundary layer transition liquid technique based on shear-stress-sensitive, temperature insensitive (SSS/TI) liquid crystals is evaluated for hypersonic flows at Mach 8 using a flat-plate wind tunnel model at near-zero angle of attack. Results show that the model provided reasonable heat transfer data with a minimum of plate distortion. The use of SSS/TI liquid crystals is considered to be an inexpensive, safe, easy to use boundary layer transition detection method for hypersonic flows. AIAA

A93-48250#
AUDIO POST-PROCESSING FOR SHEAR LAYER CALCULATIONS
SCOTT EBERHARDT (Washington Univ., Seattle) Jul. 1993 9 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(Contract NSF CTS-92-15487)
(AIAA PAPER 93-3075) Copyright

In this research the use of sound in post-processing of numerical simulations of confined, compressible shear layers is explored. An audio signal is produced from perturbation data extracted from unsteady flow calculations at various positions in the flow. This signal is used in conjunction with standard data postprocessing methods to obtain a more complete picture of flow instabilities. It is found that sound can be useful when interpreting the data but experience is required to appreciate all of the information contained in a single audio signal. In several cases an audio signal clarified the importance of instability modes excited by non-linear interactions of other flow instabilities.

A93-48253*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
FREE-WAKE COMPUTATION OF HELICOPTER ROTOR FLOWFIELDS IN FORWARD FLIGHT
K. RAMACHANDRAN (Flow Analysis, Inc., Moffett Field, CA), S. SCHLECHTRIEM (Aachen, Rheinisch-Westfaelische Technische Hochschule, Germany), F. X. CARADONNA (U.S. Army; NASA, Ames Research Center, Moffett Field, CA), and JOHN STEINHOFF (Tennessee Univ.; Flow Analysis, Inc., Tullahoma) Jul. 1993 14 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(Contract DAAL03-89-C-0027)
(AIAA PAPER 93-3079) Copyright

A new method has been developed for computing advancing rotor flows. This method uses the Vorticity Embedding technique, which has been developed and validated over the last several years for hovering rotor problems. In this work, the unsteady full potential equation is solved on an Eulerian grid with an embedded vortical velocity field. This vortical velocity accounts for the influence of the wake. Dynamic grid changes that are required to accommodate prescribed blade motion and deformation are included using a novel grid blending method. Free wake computations have been performed on a two-bladed AH-1G rotor at low advance ratios including blade motion. Computed results are compared with experimental data. The sudden variations in airloads due to blade-vortex interactions on the advancing and retreating sides are well captured. The sensitivity of the computed solution to various factors like core size, time step and grids has been investigated. Computed wake geometries and their influence on the aerodynamic loads at these advance ratios are also discussed.

A93-48254#
SCV MEASUREMENTS IN THE WAKE OF A ROTOR IN HOVER AND FORWARD FLIGHT
R. B. FUNK, P. A. FAWCETT, and N. M. KOMERATH (Georgia Inst. of Technology, Atlanta) Jul. 1993 11 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 Research supported by NSF refs
(Contract DAAL03-88-C-0003-AD2; DAAH04-93-G-0002-AD3)
(AIAA PAPER 93-3080) Copyright

Progress in the capability to measure instantaneous velocity fields in complex flows and over large areas is discussed. The rotor wake is a complex flowfield containing a wide range of velocity scales that exhibit a periodic variation with rotor azimuth. The

measurement of instantaneous planar velocity fields over large areas in such flows is demonstrated using spatial correlation velocimetry. A dual video camera system is used to obtain images over short intervals, with velocities computed using a fully numerical procedure. Results are presented for 12 azimuth positions in the wake of a 2-bladed teetering rotor of 0.457-m radius, at 1050 rpm in low-speed forward flight, with smoke in the flow illuminated using a pulsed laser sheet. Detection of a roll-up under the rotor hub is discussed. A second area of application is shown in the measurement of turbulence statistics in recirculating flows over large areas. Ensemble-averaging of local mean and rms velocity components is presented, with incoherent light sheets created from quartz lamps. Problems encountered and possible solutions are discussed. Author (revised)

A93-48255#
THE THREE-DIMENSIONAL BOUNDARY LAYER FLOW DUE TO A ROTOR-TIP VORTEX
H. AFFES, Z. XIAO, A. T. CONLISK (Ohio State Univ., Columbus), J. M. KIM, and N. M. KOMERATH (Georgia Inst. of Technology, Atlanta) Jul. 1993 13 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(Contract DAAL03-90-K-0095)
(AIAA PAPER 93-3081) Copyright

The behavior of vortex systems in the vicinity of solid surfaces is a matter of intense interest in rotorcraft aerodynamics, as well as in many other areas of fluid dynamics. In the present paper, we consider the viscous flow on a simplified model of a helicopter airframe due to a helicopter rotor tip vortex both experimentally and computationally. As the tip vortex approaches the airframe, the computational results predict the genesis of a region of high vorticity just upstream of the main vortex, characterized by reversed flow and rapid growth in size. The experiments clearly show evidence of such a high-vorticity region in the region under the tip vortex in the region predicted by the computations. The secondary vorticity field in the computations is of a sign opposite to the vorticity associated with the tip vortex. Results for the streamline patterns and vorticity field during the genesis of the secondary eddy are presented. The nature of the mature reversed-flow eddy is elucidated through flow visualization and the results for the pressure during this interaction show a second suction peak which is believed to be due to boundary layer flow itself.

A93-48256#
CORRELATION OF UNSTEADY PRESSURE AND INFLOW VELOCITY FIELDS OF A PITCHING ROTOR BLADE
MIHIR K. LAL, S. G. LIOU, G. A. PIERCE, and N. M. KOMERATH (Georgia Inst. of Technology, Atlanta) Jul. 1993 12 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 Research supported by U.S. Army refs
(AIAA PAPER 93-3082) Copyright

Measurements of unsteady inflow velocity and surface pressure distributions on rotor blades in hover are correlated with predictions from four different analytical methods. A stiff two-bladed teetering rotor is subjected to n-per-rev simple harmonic pitch oscillations. The chordwise distribution of unsteady pressure is correlated with Theodorsen's and Loewy's 2-D incompressible unsteady aerodynamic theories and with Kaladi's pulsating doublet distribution method at three radial locations. Inflow velocity is correlated with Peters' theory. The effect of dynamic inflow on rotor unsteady surface pressure is studied. Excellent agreement is obtained at inboard locations where the 2-D theories are valid. The inflow velocity agrees very well with Peters' theory under steady as well as dynamic pitch. Tip effects and mean pitch angle effects have been demonstrated.

A93-48257#
FLOW FIELD CHARACTERISTICS OF A COMPLEX BLADE TIP AT HIGH ANGLES OF ATTACK
S. G. LIOU, N. M. KOMERATH, and M. PETROSKI (Georgia Inst. of Technology, Atlanta) Jul. 1993 12 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 Research supported by U.S. Army refs
(AIAA PAPER 93-3083) Copyright

Flow separation phenomena on rotating blades are of interest in increasing the forward speed and agility of rotorcraft. The flow around a swept-tipped blade was visualized and measured with the blade operated first as a rotor in hover and then as a fixed wing in forward flight. Rotor pitch angles of 15 and 30 degrees were used. The fixed-wing velocity measurements were made at wind speeds corresponding to the rotor section speeds and at incidence angles of 11 and 22 degrees which matched the measured effective incidence angles from the hover case. Previous work was extended to study surface flow patterns on the rotating blade using image processing of wax condensation. The inboard notch vortex was captured using laser sheet imaging in the fixed wing case, but was not visible in the rotor tests. The tightly-wound tip vortices at the lower incidence angles contrasted with the expanded burst vortex patterns at the higher incidence. Flow separation was very strong on the inboard portion of the blade at the higher incidence in both rotor and fixed wing tests. At the lower incidence, separation on the tip was confined to the leading-edge vortices at the notch and the outer edge. At the higher incidence, the tip region between the vortices maintained attached flow. The attached flow region was smaller in the rotor case, where centrifugal effects weaken the notch vortex. Separation is more severe inboard, and the tip vortex lifts off the surface and bursts upstream of the trailing edge.

A93-48258#
SUMMARY OF THE INTERACTION OF A ROTOR WAKE WITH A CIRCULAR CYLINDER
J. M. KIM and N. M. KOMERATH (Georgia Inst. of Technology, Atlanta) Jul. 1993 15 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(Contract DAAL03-88-C-0003-AD2)
(AIAA PAPER 93-3084) Copyright

To compute the aerodynamics of a rotorcraft in low-speed flight, the interaction of the strong vortices in the rotor wake with the airframe must be modeled. Using a hemisphere-cylinder airframe and a 2-bladed rotor for reference, the various phenomena encountered during such interactions are summarized, combining previous results on various configurations with recent experimental results. Effects of compressibility are excluded. Differences between the interaction at the front and aft portions of the wake are discussed. The pre-collision phase conforms to expectations from potential flow, and includes distortion of the vortex trajectory determined by the sense of rotation of the vortex. The collision phase involves complex boundary-layer interactions. The axial velocity in the vortex core causes substantial asymmetry, and influences the surface pressure distribution on the airframe side under the advancing rotor blade, where the axial flow stagnates. The post-interaction vortex is much weaker, but still contains some swirl energy. Where flow separation occurs due to airframe shapes, the interaction is not modified significantly, because the vortex dominates the interaction with separated shear layers for parameter values of practical interest. Issues for detailed studies of vortex/airframe interaction are discussed.

A93-48266#
ON NUMERICAL SOLUTIONS OF BURNETT EQUATIONS FOR HYPERSONIC FLOW PAST 2-D CIRCULAR BLUNT LEADING EDGES IN CONTINUUM TRANSITION REGIME
XIAOLIN ZHONG (California Univ., Los Angeles) Jul. 1993 17 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(Contract F49620-92-J-0090)
(AIAA PAPER 93-3092) Copyright

Using the Burnett equations is one way to advance the continuum approach based on the Navier-Stokes equations into the continuum transition flow regime for rarefied hypersonic flow. Though two-dimensional flow-field numerical solutions of the Burnett equations have been obtained in our previous studies, it is still uncertain how to formulate boundary conditions for the higher-order Burnett equations. Furthermore, few comparative

studies have been performed to validate the Burnett equations in multidimensional applications. This paper presents a new method to formulate the additional boundary conditions for the Burnett equations. The new method for the Burnett equations requires the same number of physical surface slip conditions as for the Navier-Stokes equations. We subsequently have obtained numerical solutions of the two-dimensional Burnett equations with the new boundary condition treatment for hypersonic flow past a cylinder where Knudsen numbers range from 0.02 to 0.4. The results show that the Burnett solutions with the first order slip conditions agree better with DSMC results than the Navier-Stokes solutions do, but the Burnett solutions with the Schamberg second order slip conditions seem to be inaccurate for Knudsen numbers above 0.2.

A93-48269*# National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.
DSMC SIMULATION OF IONIZED RAREFIED FLOWS
TIMOTHY J. BARTEL (Sandia National Labs., Albuquerque, NM) and CHARLES R. JUSTIZ (NASA, Johnson Space Center, Houston, TX) Jul. 1993 10 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(Contract DE-AC04-76DP-00789)
(AIAA PAPER 93-3095) Copyright

Recently a renewed interest has been exhibited in understanding contamination and space environmental effect in the LEO range of 200 to 600 km as well as in low density microelectronics manufacturing technologies. Realistic simulations must model the physics of the highly coupled effects of neutral and charged particle flows, thermodynamic nonequilibrium, surface charging, and electromagnetic field effects. The computational requirements are enormous for this level of modeling and are almost impossible on current single processor supercomputers. An effort was initiated to develop this capability on a massively parallel MIMD supercomputers. The Wake Shield Facility experiment will be used for test case calculations. Preliminary results indicate that parallel supercomputers may be the only computers capable of simulating the required level of physics and spatial resolution. Calculations which contain from 1 to 8 million simulation particles are presented. Author (revised)

A93-48270#
DSMC NUMERICAL INVESTIGATION OF RAREFIED COMPRESSION CORNER FLOW
A. CHPOUN, J. C. LENGRAND, L. COHEN, and K. S. HEFFNER (CNRS, Lab. d'Aerothermique, Meudon, France) Jul. 1993 22 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-3096) Copyright

A numerical study using DSMC is carried out to investigate rarefied hypersonic flows on a compression corner. In the first part of the work, the incipient separation angle is determined for three sets of incoming flow conditions. The rarefaction level of the free stream was varied from near continuum to moderately rarefied flows. As expected, a relatively large angle is required to induce separation at these conditions. The results of incipient separation angle are compared with the existing correlation established for continuum laminar regimes. In the second part of the work, the effects of increasing leading edge bluntness on flowfield and wall quantities are analyzed. For each case of incoming flows, the leading edge bluntness is varied from zero to an order of magnitude of the incoming flow mean free path. Author (revised)

A93-48271#
A STUDY OF TURBULENCE IN RAREFIED GASES
PATRICK H. REISENTHEL, STANLEY C. PERKINS, JR. (Nielsen Engineering & Research, Inc., Mountain View, CA), and DAVID NIXON (Queen's Univ., Belfast, United Kingdom) Jul. 1993 18 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(Contract F49620-91-C-0010)
(AIAA PAPER 93-3097) Copyright

Theoretical analyses and numerical simulations are used to assess the effects of slight rarefaction on flow turbulence. Subsonic rarefied gas flow in a channel is modeled by integrating Grad's Thirteen Moment Equations. The results are compared to integrations of the Navier-Stokes equations. Unlike the Burnett equations, Grad's equations are shown to be stable to small disturbances. Slip at the wall is found to be the dominant feature associated with slight rarefaction, with further rarefaction effects occurring at frequencies on the order of the inverse stress-relaxation time scale. Preliminary results of the numerical simulations are presented. These indicate that the effects of rarefaction on turbulence production and, particularly, turbulence dissipation can be significant.

A93-48273#
THE EFFECT OF LARGE SCALE UNSTEADY MOTION ON TURBULENT REATTACHING SHEAR LAYER - APPLICATION TO THE SUPERSONIC COMPRESSION RAMP
MARTIN J. GUILLOT (Inst. for Advanced Technology, Austin, TX) and DENNIS E. WILSON (Texas Univ., Austin) Jul. 1993 10 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-3100) Copyright

A phenomenological model is developed to simulate the effect of large-scale unsteadiness developed in a supersonic reattaching shear layer. A triple decomposition in terms of Favre averaged variables is performed on the Navier-Stokes equations. The averaging procedure produces equations containing the usual Reynolds stresses plus additional terms due to the large-scale unsteadiness. Time-dependent equations are also obtained which describe the large-scale fluctuations. The model is then tested on the 2-D compression ramp using the simpler boundary layer equations. The phenomenological model appears as a velocity boundary condition to the time-dependent momentum equation. A simplified form of this equation is solved analytically and this solution is used to calculate the additional terms in the time-averaged equations.

A93-48280#
HIGH LIFT AIRFOIL FLOW SIMULATION USING A WALL-CORRECTED ALGEBRAIC STRESS MODEL
G. FRESKOS, S. UNDREINER, and H. H. MINH (CERFACS, Toulouse, France) Jul. 1993 10 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 Research supported by SNECMA refs
(AIAA PAPER 93-3109) Copyright

This paper presents the results of turbulent flow simulations on the AS239 profile of AEROSPATIALE (A-profile) and a flat rate. The aim is to improve the Algebraic stress model in the viscous region, in order to obtain a better prediction of the recirculating region or the A-profile and latter the stall. The ASM low-Reynolds number of H. Iacovides doesn't give better results than the ASM combined with the 1ow-Reynolds number k-epsilon of Jones-Launder, and than the ASM combined with the Wolfshtein's one equation model. Some improvements of the ASM low-Reynolds model are obtained on the flat plate by using the general form of the redistribution term. Author (revised)

A93-48281#
A TWO LAYER K-EPSILON COMPUTATION OF TRANSONIC VISCOUS FLOW INCLUDING SEPARATION OVER THE DLR-F5 WING
L. TOURRETTE (Aerospatiale; CERFACS, Toulouse, France) Jul. 1993 12 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-3110) Copyright

Two-layer k-epsilon and Baldwin-Lomax computations of transonic viscous flow past the DRL-F5 wing performed on a 387737 nodes O-O type mesh are presented. A numerical treatment of the source terms in the k- and epsilon equations is presented which provides a robust scheme which can serve as a reliable basis for future improvements. The k-epsilon and Baldwin-Lomax solutions are compared and the influence of the location of the

frontier between the two layers is studied. The great influence of the mesh size on the solution clearly indicates that, for such a complex flow the medium mesh is too coarse. The flow appears to be very sensitive to the turbulence model. The k-epsilon model appears to behave best in the separated region but definitive results cannot be given here. AIAA

A93-48282*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
DESIGN EFFICIENCY EVALUATION FOR TRANSONIC AIRFOIL OPTIMIZATION - A CASE FOR NAVIER-STOKES DESIGN
J. O. HAGER, S. EYI, and K. D. LEE (Illinois Univ., Urbana) Jul. 1993 13 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(Contract NCA2-742)
(AIAA PAPER 93-3112) Copyright

A constrained-optimization design method which improves the aerodynamic performance of transonic airfoils is evaluated from a design-quality and design-efficiency viewpoint. Design efficiency is a measure of the performance improvement and the design time (CPU time). Total-airfoil design and upper-surface design are performed using the Euler and Navier-Stokes equations with several grids, and are evaluated using the Navier-Stokes equations to determine the anticipated physical design response. Even though the cost of the Euler design is lower than Navier-Stokes design, the Navier-Stokes evaluation indicates that the Euler design does not necessarily improve the aerodynamic performance. Therefore, the design optimization should be based on an accurate flow simulation to achieve an actual performance improvement, and the design time is a secondary concern.

A93-48283#
ENGINEERING METHOD FOR CALCULATING INLET FACE PROPERTY PROFILES ON HIGH SPEED VEHICLE FOREBODIES
D. B. LANDRUM, K. T. CHOJNACKI, and J. A. BLEVINS (Alabama Univ., Huntsville) Jul. 1993 12 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 Research supported by Univ. of Alabama refs
(AIAA PAPER 93-3113) Copyright

Results of a preliminary study to investigate the performance of a previously developed engineering technique in predicting shock-layer pitot pressures are presented in this paper. The engineering method uses a modification of Maslen's approximate technique to calculate shock-layer properties. The method has previously been shown to approximately reproduce experimental surface pressure and heat transfer data obtained on a generic hypersonic vehicle design. Comparisons were made between experimental pitot pressure distributions obtained by Cleary in the flow fields surrounding simple sharp and blunted cones and the approximate technique. The inviscid engineering method adequately reproduced the conical pressure distribution about sharp cones except near the surface where viscous dissipation dominates. Predictions for two blunted cone cases did not exhibit the pressure peak produced by an inflection in the bow shock. For stations ahead of the inflection and in leeward flow fields at aft stations, the method appears to have underpredicted the conical shock angle and thus overpredicted the pitot pressure. The pitot pressure profiles through windward shock-layers were adequately reproduced, except for the pressure peak due to shock inflection.

A93-48284*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
DEMONSTRATION OF MULTIPOINT DESIGN PROCEDURES FOR TRANSONIC AIRFOILS
RAYMOND E. MINECK and RICHARD L. CAMPBELL (NASA, Langley Research Center, Hampton, VA) Jul. 1993 13 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-3114) Copyright

Two multipoint design procedures were applied to reduce the wave drag of a baseline airfoil at two design points. The first procedure iteratively averages two intermediate airfoil shapes, each one redesigned at one of the two design points, to develop an improved airfoil. The second procedure iteratively averages two pressure distributions, each one obtained from an intermediate airfoil redesigned at one of the two design points, to develop an improved airfoil. Successful application of each procedure to design an improved airfoil for design points with similar chordwise pressure distributions, shock locations, and shock strengths is demonstrated. Application of a combination of both procedures to design an improved airfoil at design points with dissimilar chordwise pressure distributions, shock locations, and shock strengths is also presented. Results from wind tunnel tests of the baseline airfoil and of the improved airfoil for the dissimilar design points verified the predicted drag improvements.

A93-48285*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
SHAPE OPTIMIZATION FOR AERODYNAMIC EFFICIENCY AND LOW OBSERVABILITY
HOANG VINH, C. P. VAN DAM, and HARRY A. DWYER (California Univ., Davis) Jul. 1993 10 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(Contract NCA2-568; NCA2-581)
(AIAA PAPER 93-3115) Copyright

Field methods based on the finite-difference approximations of the time-domain Maxwell's equations and the potential-flow equation have been developed to solve the multidisciplinary problem of airfoil shaping for aerodynamic efficiency and low radar cross section (RCS). A parametric study and an optimization study employing the two analysis methods are presented to illustrate their combined capabilities. The parametric study shows that for frontal radar illumination, the RCS of an airfoil is independent of the chordwise location of maximum thickness but depends strongly on the maximum thickness, leading-edge radius, and leadingedge shape. In addition, this study shows that the RCS of an airfoil can be reduced without significant effects on its transonic aerodynamic efficiency by reducing the leading-edge radius and/or modifying the shape of the leading edge. The optimization study involves the minimization of wave drag for a non-lifting, symmetrical airfoil with constraints on the airfoil maximum thickness and monostatic RCS. This optimization study shows that the two analysis methods can be used effectively to design aerodynamically efficient airfoils with certain desired RCS characteristics.

A93-48286#
HYPERSONIC CONFIGURATION OPTIMIZATION WITH AN EULER/BOUNDARY LAYER COUPLING TECHNIQUE
F. MONNOYER (Deutsche Aerospace AG, Munich, Germany) Jul. 1993 13 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-3116) Copyright

This paper presents the application of an Euler/boundary layer coupling method to the analysis of the flow properties on the forebody of the German air-breathing hypersonic demonstrator HYTEX. In order to define guidelines for the optimization of the configuration with emphasis on the heat loads and the flow characteristics at the inlet of the propulsion system, a parametric study was carried out where the effects of various flow characteristics were assessed: the gas model (perfect gas and equilibrium real gas), the wall radiation, the transition location and extent, and the nose radius. Author (revised)

A93-48287#
DESIGN OF AXISYMMETRIC CHANNELS WITH ROTATIONAL FLOW
M. KOUMANDAKIS, V. DEDOUSSIS, P. CHAVIAROPOULOS, and K. D. PAPAILIOU (Athens National Technical Univ., Greece) Jul. 1993 10 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-3117) Copyright

This paper presents an inverse subsonic inviscid method for the design of axisymmetric channels, with rotational flow. The rotational character of the flow is due to prescribed total enthalpy,

entropy and/or swirl gradients along the inlet of the channel. The method is based on a potential function/stream function formulation. The Clebsch transformation is employed to decompose the (meridional) velocity vector into a potential and a rotational part. The rotational part is shown to be proportional to the total enthalpy gradient, the coefficient of proportionality being the drift function. A body-fitted coordinate transformation is employed to map the sought boundaries on the (phi,psi) space. The governing equation for the magnitude of the meridional velocity component is derived by treating the inverse problem on the (phi,psi) space as a purely geometric one, employing dfferential geometry principles. The integration of the governing equations is performed on an auxiliary computational grid using a simple iterative scheme. The geometry, in particular, is determined by integrating Frenet equations along the grid lines. The present design method has been applied successfully to the 'reproduction' of two 'real-life' geometries concerning the annular duct of a two-stage axial compressor as well as a radial one. Author (revised)

A93-48291*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
EXPERIMENTAL AND NUMERICAL INVESTIGATION OF SUPERSONIC TURBULENT FLOW IN AN ANNULAR DUCT
K. E. WILLIAMS, F. B. GESSNER (Washington Univ., Seattle), and G. J. HARLOFF (Sverdrup Technology, Inc., Brook Park, OH) Jul. 1993 8 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(Contract NAG3-376; NAS3-25266)
(AIAA PAPER 93-3123) Copyright

Experimental and numerical results are presented for developing supersonic turbulent flow in an annular duct formed by a circular centerbody and outer shroud. The experimental results are based on data taken in a new flow facility that was designed to generate a shock-free, supersonic annular flow. Numerical computations were performed using the Baldwin-Lomax turbulence model for comparison with experimentally measured profiles. The results demonstrate that computed and measured profiles are in excellent agreement, so that studies can now be conducted of shock wave/boundary layer interaction phenomena within the duct, such as those induced by changes in downstream duct geometry or by the placement of struts between the duct walls.

A93-48293*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
NUMERICAL SIMULATION OF A SHOCK WAVE/TURBULENT BOUNDARY LAYER INTERACTION IN A DUCT
WEI-LI YANG and ISAAC GREBER (Case Western Reserve Univ., Cleveland, OH) Jul. 1993 11 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(Contract NAG3-725)
(AIAA PAPER 93-3127) Copyright

A numerical investigation of the interaction of an incident oblique shock wave with a turbulent duct flow is presented. The investigation consists of solving the three-dimensional, unsteady, compressible, mass averaged Navier-Stokes equations, using an implicit finite volume, lower-upper time marching code and incorporates the three-dimensional Baldwin-Lomax turbulence model. Computed results are obtained Mach number 2.9 for a turning angle of 13 degrees and Reynolds number based on duct width of 1.36 x 10 exp 7. Under various inlet conditions, the results clearly depict the flow characteristics, including the shock geometry, the separated flow region, the wall pressure distribution, and the skin friction distribution. The findings provide a physical understanding of the three-dimensional vortex structure of the flow in a duct in which a shock wave interacts with a turbulent boundary layer. The results show that the ratio of the boundary layer thickness to the duct width is the critical parameter in determining the separation structure. Author (revised)

A93-48294#
ABNORMAL PEAKS OF INCREASED HEAT-TRANSFER ON THE BLUNTED DELTA WING IN THE HYPERSONIC FLOW
VLADIMIR V. LUNEV (Central Research Inst. of Machine Building, Kaliningrad, Russia) Jul. 1993 9 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-3129) Copyright

A thin long delta wing with small nose bluntness was placed in hypersonic flow under moderate values of the angles of attack alpha and beta. Under these conditions, two narrow longitudinal strips appeared on the windward surface of the wing over which the heat transfer rate increased by a few times. These strips reached the trailing edge of the model and spread nearly parallel to the axis. AIAA

A93-48296#
EXPERIMENTAL STUDY OF TRANSITIONAL AXISYMMETRIC SHOCK-BOUNDARY LAYER INTERACTIONS AT MACH 5
K. S. HEFFNER, A. CHPOUN, and J. C. LENGRAND (CNRS, Lab. d'Aerothermique, Meudon, France) Jul. 1993 16 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-3131) Copyright

An experimental study has been conducted in the SH2 Hypersonic Wind Tunnel facility at the Laboratoire d'Aerothermique on an axisymmetric compression corner in a Mach 5 flow for compression angles of 10, 20, and 30 deg over a range of Reynolds numbers, Re(L) between 0.65 x 10 exp 6 and 1.8 x 10 exp 6, where Re(L) is based on the leading edge-corner distance. The models consisted essentially of sharp hollow cylinders fitted with skirts. Chpoun (1988) performed a similar study for a rectangular geometry, flat plate with ramp, in the same experimental facility. In the present study, surface pressure and heat transfer measurements were made in order to determine the influence of the well-known end effects in the laminar-turbulent transitional regime as well as to investigate the combined effects of compression angle and Reynolds number on maximum heat transfer rates and the extent of the separated region. Author (revised)

A93-48297*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
EXPLORATORY STUDY OF SHOCK REFLECTION NEAR AN EXPANSION CORNER
FRANK K. LU and KUNG-MING CHUNG (Texas Univ., Arlington) Jul. 1993 10 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(Contract NAG1-891)
(AIAA PAPER 93-3132) Copyright

Experiments were performed at Mach 8 in which a shock was reflected off a low Reynolds number, turbulent boundary layer past an expansion corner. The shock was generated by 2- and 4-deg sharp wedges, and the corner was either 2.5 or 4.25 deg. The inviscid shock reflection was one boundary layer thickness ahead or behind the corner or at the corner itself. All interactions were unseparated. The dynamic surface pressure distributions were examined together with the case of shock reflection on a flat plate. With shock reflection ahead of the corner, the mean surface pressure downstream was attenuated due to the proximity of the corner. With shock reflection downstream of the corner, the surface pressure distribution showed a reduced upstream influence. The highly swept expansion fan produced a surface pressure which rose gently downstream with no minima, unlike in supersonic flows with the same shock-corner separation distance. In many of the interactions, an anomalous pressure peak was found downstream. The surface pressure through the interaction exhibited unsteadiness. Author (revised)

A93-48298*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
FLOWFIELD DYNAMICS IN BLUNT FIN-INDUCED SHOCK WAVE/TURBULENT BOUNDARY LAYER INTERACTIONS
L. BRUSNIAK and D. S. DOLLING (Texas Univ., Austin) Jul. 1993 30 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(Contract NAG3-1023)
(AIAA PAPER 93-3133) Copyright

Fluctuating wall pressure measurements were made on centerline upstream of a blunt fin in a Much 5 turbulent boundary layer. By examining the ensemble average wall pressure distributions for different fixed shock foot positions, it was shown that local fluctuating wall pressure measurements are due to a distinct pressure distribution, P(i), which undergoes a stretching and flattening effect as its upstream boundary translates aperiodically between the upstream influence and separation lines. The locations of the maxima and minima in the centerline wall standard deviation distribution can be accurately predicted using this distribution, providing quantitative confirmation of the model. This model also explains the observed cross-correlations and ensemble average measurements within the interaction. Using the P(i) model, wall pressure signals from under the separated flow region were able to reproduce the position-time history of the separation shock foot. The negative time delay peak in the cross-correlation between the predicted and actual shock foot histories shows that the separated region fluctuations precede shock foot motion. Author (revised)

A93-48299# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
AEROTHERMODYNAMIC HEATING DUE TO SHOCK WAVE/LAMINAR BOUNDARY-LAYER INTERACTIONS IN HIGH-ENTHALPY HYPERSONIC FLOW
CHARLES M. HACKETT (NASA, Langley Research Center, Hampton, VA) Jul. 1993 12 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 Research supported by NASA and USAF refs
(AIAA PAPER 93-3135) Copyright

The interaction between a swept shock wave and a laminar boundary layer was investigated experimentally in high-enthalpy hypersonic flow. The effect of high-temperature, real gas physics on the interaction was examined by conducting tests in air and helium. Heat transfer measurements were made on the surface of a flat plate and a shock-generating fin using thin-film resistance sensors for fin incidence angles of 0, 5, and 10 deg at Mach numbers of 6.9 in air and 7.2 in helium. The experiments were conducted in the NASA HYPULSE expansion tube, an impulse-type facility capable of generating high-enthalpy, high-velocity flow with freestream levels of dissociated species that are particularly low. The measurements indicate that the swept shock wave creates high local heat transfer levels in the interaction region, with the highest heating found in the strongest interaction. The maximum measured heating rates in the interaction are order of magnitude greater than laminar flat plate boundary layer heating levels at the same location. Author (revised)

A93-48300*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
FLOWFIELD MEASUREMENTS ABOUT A MULTI-ELEMENT AIRFOIL AT HIGH REYNOLDS NUMBERS
VINCENT D. CHIN, DAVID W. PETERS (McDonnell Douglas Aerospace, Long Beach, CA), FRANK W. SPAID (McDonnell Douglas Aerospace, Saint Louis, MO), and ROBERT J. MCGHEE (NASA, Langley Research Center, Hampton, VA) Jul. 1993 16 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-3137) Copyright

This paper describes experimental data obtained with a multi-element airfoil at flight Reynolds numbers and lift coefficients including Clmax. The wind tunnel test was conducted in the NASA Langley Low Turbulence Pressure Tunnel as part of a cooperative effort between McDonnell Douglas Aerospace and NASA Langley. The airfoil model is a supercritical design configured with a leading-edge slat and a single-segment trailing-edge flap. Data include surface static-pressure distributions (integrated to obtain lift), drag data obtained with wake-rake surveys, and flowfield surveys obtained with a flat-tube and five-hole probe at nine stations on the configuration's upper surface. Effects of variations in Reynolds number and flap gap on airfoil performance and flowfield survey data are presented.

A93-48313#
ON COMPUTING VORTEX ASYMMETRIES ABOUT CONES AT ANGLE OF ATTACK USING THE CONICAL NAVIER-STOKES EQUATIONS
DOUGLAS W. DUSING and PAUL D. ORKWIS (Cincinnati Univ., OH) *In* AIAA Atmospheric Flight Mechanics Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers Washington American Institute of Aeronautics and Astronautics 1993 p. 122-130. refs
(Contract DAAL03-92-G-0240)
(AIAA PAPER 93-3628) Copyright

An implicit upwind symmetric factorization finite volume solver for the conical Navier-Stokes equations was used to compute asymmetric vortices about a 5 deg cone at a 20 deg angle of attack. Asymmetric vortices were computed without asymmetric disturbances, providing independent verification of the conical Navier-Stokes equation results obtained by Siclari and Marconi (1989), and Kandil et al. (1991). The results also suggest that computation of the asymmetric vortices is grid dependent, establishing a possible explanation for the failure of three dimensional studies to produce the asymmetries without boundary condition perturbations. Grid refinement studies further indicate that a low level of unsteadiness might exist in the flowfield, whereas previous researchers had reported convergence to a steady state for this test case. Author (revised)

A93-48314*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
BASE DRAG PREDICTION ON MISSILE CONFIGURATIONS
F. G. MOORE, T. HYMER (U.S. Navy, Naval Surface Warfare Center, Dahlgren, VA), and F. WILCOX (NASA, Langley Research Center, Hampton, VA) *In* AIAA Atmospheric Flight Mechanics Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers Washington American Institute of Aeronautics and Astronautics 1993 p. 131-143. refs
(AIAA PAPER 93-3629)

New wind tunnel data have been taken, and a new empirical model has been developed for predicting base drag on missile configurations. The new wind tunnel data were taken at NASA-Langley in the Unitary Wind Tunnel at Mach numbers from 2.0 to 4.5, angles of attack to 16 deg, fin control deflections up to 20 deg, fin thickness/chord of 0.05 to 0.15, and fin locations from 'flush with the base' to two chord-lengths upstream of the base. The empirical model uses these data along with previous wind tunnel data, estimating base drag as a function of all these variables as well as boat-tail and power-on/power-off effects. The new model yields improved accuracy, compared to wind tunnel data. The new model also is more robust due to inclusion of additional variables. On the other hand, additional wind tunnel data are needed to validate or modify the current empirical model in areas where data are not available. Author (revised)

A93-48316#
ANALYSIS OF MISSILE CONFIGURATIONS WITH WRAP-AROUND FINS USING COMPUTATIONAL FLUID DYNAMICS
GREGG L. ABATE and THERESA COOK (USAF, Wright Lab., Wright-Patterson AFB, OH) *In* AIAA Atmospheric Flight Mechanics Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers Washington American Institute of Aeronautics and Astronautics 1993 p. 157-166. refs
(AIAA PAPER 93-3631)

The aerodynamics associated with wrap around fin (WAF) missile configurations at subsonic and supersonic Mach numbers were investigated using CFD techniques and qualitatively comparing the results to experimental data. The results obtained indicate that WAF thickness is a critical parameter. Therefore, CFD models need to pay close attention to this detail. The results also indicate that a 0 deg angle-of-attack roll moment is obtained using an inviscid Euler code, and this roll moment reverses direction at Mach 1. This result is consistent with experimental observations. Further, results show that fin attachment geometry as well as fin curvature contribute to roll moment. Author (revised)

A93-48318#
DEVELOPMENT OF AN ACCURACY CRITERIA FOR BODY-ON-FIN CARRYOVER INTERFERENCE
KEITH A. BURNS (McDonnell Douglas Aerospace, Saint Louis, MO) *In* AIAA Atmospheric Flight Mechanics Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers Washington American Institute of Aeronautics and Astronautics 1993 p. 177-186. refs
(AIAA PAPER 93-3633) Copyright

A study of missile performance sensitivity to interference between a fin and a body was performed, and an accuracy criterion was developed for the carryover interference factor K sub W(B). Carryover interference parameters such as K sub W(B) provide the core for component build-up aerodynamic prediction methods. An analytic accuracy criterion for fin-body carryover is here investigated that may be used to assess current and future carryover interference methods. The study also used trajectory simulations to assess the sensitivity of performance parameters to variations in carryover interference. For the analysis, representative air-to-air missile and cruise missile configurations were selected; their aerodynamic characteristics were perturbed via the carryover interference factor K sub W(B), and their performance sensitivity was assessed. This study concludes that K sub W(B) should be predicted within 10 percent for preliminary design. Author (revised)

A93-48319#
IDENTIFICATION OF A FULL SUBSONIC ENVELOPE NONLINEAR AERODYNAMIC MODEL OF THE F-14 AIRCRAFT
THOMAS L. TRANKLE (Lockheed Research Labs., Palo Alto, CA) and STEPHEN D. BACHNER (U.S. Navy, Naval Air Warfare Center, Patuxent River, MD) *In* AIAA Atmospheric Flight Mechanics Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers Washington American Institute of Aeronautics and Astronautics 1993 p. 187-197. Research supported by Systems Control Technology, Inc. refs
(Contract N00421-88-D-0227)
(AIAA PAPER 93-3634) Copyright

We identified a full subsonic flight envelope model of the aerodynamics of the F-14 aircraft. The data set consisted of 8.9 hours of flight data stored as 983 separate maneuver files. We used a unified system identification computer code implementing kinematic consistency, model structure determination, and parameter estimation functions. The code implements generalized filter error, encompassing both equation error and output error types of performance measures. Our program can operate in a nearly automated manner, completely processing about one hour of flight data in about 40 hours of UNIX workstation time. The resulting aerodynamic model represents nonlinear angle of attack, Mach number, and static flexibility effects. This model has 521 independent aerodynamic terms and 97 independent instrumentation terms. The identified model is an incremental model that adds to an existing nonlinear simulation. One and two dimensional spline functions represent the aerodynamic coefficients.

A93-48321*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
NONLINEAR AERODYNAMIC MODELING USING MULTIVARIATE ORTHOGONAL FUNCTIONS
EUGENE A. MORELLI (Lockheed Engineering & Sciences Co.; NASA, Langley Research Center, Hampton, VA) *In* AIAA Atmospheric Flight Mechanics Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers Washington American Institute of Aeronautics and Astronautics 1993 p. 212-222. refs
(Contract NAS1-19000)
(AIAA PAPER 93-3636) Copyright

A technique was developed for global modeling of nonlinear aerodynamic coefficients using multivariate orthogonal functions based on the data. Each orthogonal function retained in the model was decomposed into an expansion of ordinary polynomials in the independent variables, so that the final model could be interpreted as selectively retained terms from a multivariable power series expansion. A predicted squared-error metric was used to determine the orthogonal functions to be retained in the model; analytical derivatives were easily computed. The approach was demonstrated on the Z-body axis aerodynamic force coefficient (Cz) wind tunnel data for an F-18 research vehicle which came from a tabular wind tunnel and covered the entire subsonic flight envelope. For a realistic case, the analytical model predicted experimental values of Cz very well. The modeling technique is shown to be capable of generating a compact, global analytical representation of nonlinear aerodynamics. The polynomial model has good predictive capability, global validity, and analytical differentiability. Author (revised)

A93-48356*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
NAVIER-STOKES COMPUTATIONS ON FULL-SPAN WING-BODY CONFIGURATION WITH OSCILLATING CONTROL SURFACES
SHIGERU OBAYASHI, ING-TSAU CHIU, and GURU P. GURUSWAMY (NASA, Ames Research Center, Moffett Field, CA) *In* AIAA Atmospheric Flight Mechanics Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers Washington American Institute of Aeronautics and Astronautics 1993 p. 555-565. refs
(AIAA PAPER 93-3687) Copyright

Unsteady Navier-Stokes simulations have been performed for vortical flows over an 'arrow-wing' configuration of a supersonic transport in the transonic regime. Computed steady pressures and integrated force coefficients with and without control surface deflection at a moderate angle of attack are compared with experiment. For unsteady cases, oscillating trailing-edge control surfaces are modeled by using moving grids. Response characteristics between symmetric and anti-symmetric oscillatory motions of the control surfaces on the left and right wings are studied. The anti-symmetric case produces higher lift than the steady case with no deflection, and the unsteady symmetric case produces higher lift than the anti-symmetric case. The detailed analysis of the wake structure revealed a strong interaction between the primary vortex and the wake vortex sheet from the flap region when the flap is deflected up.

A93-48357*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
SIMULATION OF TAIL BUFFET USING DELTA WING-VERTICAL TAIL CONFIGURATION
OSAMA A. KANDIL, HAMDY A. KANDIL, and STEVEN J. MASSEY (Old Dominion Univ., Norfolk, VA) *In* AIAA Atmospheric Flight Mechanics Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers Washington American Institute of Aeronautics and Astronautics 1993 p. 566-577. Research supported by USAF refs
(Contract NAG1-648)
(AIAA PAPER 93-3688) Copyright

Computational simulation of the vertical tail buffet problem is accomplished using a delta wing-vertical tail configuration. Flow conditions are selected such that the wing primary-vortex cores experience vortex breakdown and the resulting flow interacts with the vertical tail. This multidisciplinary problem is solved successively using three sets of equations for the fluid flow, aeroelastic deflections and grid displacements. For the fluid dynamics part, the unsteady, compressible, full Navier-Stokes equations are solved accurately in time using an implicit, upwind, flux-difference splitting, finite-volume scheme. For the aeroelastic part, the aeroelastic equation for bending vibrations is solved accurately in time using the Galerkin method and the four-stage Runge-Kutta scheme. The grid for the fluid dynamics computations is updated every few time steps using a third set of interpolation equations. The computational application includes a delta wing of aspect ratio 1 and a rectangular vertical tail of aspect ratio 2, which is placed at 0.5 root-chord length downstream of the wing trailing edge. The wing angle of attack is 35 deg and the flow Mach number and Reynolds number are 0.4 and 10,000, respectively.

A93-48501
2-D THEORETICAL ANALYSIS OF CIRCUMFERENTIAL GROOVED CASING TREATMENT
ZHAOHUI DU, QIANZHI LIU, and ZHIWEI LIU (Northwestern Polytechnical Univ., Xian, China) Journal of Aerospace Power (ISSN 1000-8055) vol. 8, no. 2 April 1993 p. 97-100. In CHINESE refs

On the basis of analyzing the 2D simplified extended stability model of circumferential grooved casing treatment, a new rapid practical method for engineering design and analysis, is developed. An exact and time-saving program without repeat process is written for calculating the cascade flow field on an arbitrary rotary surface. In the program the boundary element method is used to determine the initial flow field for analyzing the model. The effects of structural and performance parameters of circumferential grooved casing treatment on the stability of the compressor are discussed. This method features definiteness of physical meaning and ease in practical application. The new method and technique are provided to design and analyze the circumferential grooved casing treatment equipment. Author (revised)

A93-48502
NUMERICAL SIMULATION OF UNSTEADY FLOW IN A TRANSONIC CASCADE
YANGJUN ZHANG and DEPING TAO (Beijing Univ. of Aeronautics and Astronautics, China) Journal of Aerospace Power (ISSN 1000-8055) vol. 8, no. 2 April 1993 p. 101-104. In CHINESE refs

The effects of unsteady separation, shock, and viscosity on the stall flutter have now become a primary obstacle to aeroelastic study. The 2D unsteady flow in an oscillating cascade is taken as composed of two parts: the steady mean flow and the small disturbance flow. The stall flutter is predicted by solving the steady Navier-Stokes equations and linearized Navier-Stokes equations separately, and can be simulated numerically for different kinds of flow separation, and then the unsteady separation can be treated effectively. The calculation results show that unsteady separation, shock, and viscosity have significant effects on the stall flutter. Therefore, the unsteady pressure response in the separated zone cannot be taken as zero. Author (revised)

A93-48504
CONTROL OF SEPARATION BY DYNAMIC AIR JETS
GUOPIN REN and SHIYING ZHANG (Nanjing Aeronautical Inst., China) Journal of Aerospace Power (ISSN 1000-8055) vol. 8, no. 2 April 1993 p. 109-111. In CHINESE refs

Results on the effects on separation of an aerofoil at high angle of attack by air jets producing a streamwise vortex of alternating circulation and spanwise vortex fluctuating up and down above the surface are given. Combined effects of the above two kinds of jets are also investigated. The actions of these jets cause both the retardation of separation and earlier reattachment. The suitable design and arrangement of the jets gain a reduction of 76-percent separation bubble length. Author (revised)

A93-48509
A CALCULATION OF SECONDARY FLOWS AND DEVIATION ANGLES IN MULTISTAGE AXIAL-FLOW COMPRESSORS
SHIMING LI (Tsinghua Univ., Beijing, China) and MAOZHANG CHEN (Beijing Inst. of Aeronautics and Astronautics, China) Journal of Aerospace Power (ISSN 1000-8055) vol. 8, no. 2 April 1993 p. 129-132. In CHINESE refs

A secondary flow model and a method for calculating the blade deviation angle have been developed for multistage axial-flow compressors. This model is a modification of Adkins-Smith model. The secondary flow vorticities are modeled based on the calculated meridional flow including different kinds of spanwise mixing effects. The secondary flows are obtained on the fanlike surface downstream the blade rows with a standard separation-of-variables approach which yields a complex series. The secondary flow model includes effects of blade passage vortex, blade trailing edge vortex, blade end clearances, blade end shrouding, blade boundary layer, and wake centrifugation. The deviation angles are related to the calculated cross-passage secondary velocities and a modified Carter's rule. Good agreement has been obtained between experimental data and the calculated results in the cases of design-point-type applications for which significant regions of separated flow are not present. Author (revised)

A93-48512
AN EXPERIMENTAL INVESTIGATION OF ENDWALL FLOW CONTROL IN A COMPRESSOR PLANE CASCADE WIND TUNNEL
XIHONG LI, GUOHUA WU, and ZEYAN PENG (Beijing Univ. of Aeronautics and Astronautics, China) Journal of Aerospace Power (ISSN 1000-8055) vol. 8, no. 2 April 1993 p. 143-147. In CHINESE refs

A comparative experimental investigation on three kinds of end-treatment cascade in relation to an original cascade is presented. Three end-treatment techniques are end-bend, end-forward-sweep, and end-sweep-bend. The last one is a new kind of endwall flow control technique. Experimental results show that the end-forward-sweep cascade can be used to delay flow separation and improve the distribution of flow parameters at the cascade exit. For a shrouded stator, the end-bend cascade with increasing turning angle at the end of the blade would increase the loss around the endwall region and induce flow separation in the mid-span region. For the case when it is required to increase the turning angle in the endwall region, the end-sweep-bend cascade has better performance than the end-bend blade. Author (revised)

A93-48513
EXPERIMENTAL INVESTIGATION ON EFFECT OF SOLID PARTICLES ON BLADE PRESSURE DISTRIBUTION IN COMPRESSOR CASCADE FLOW
JINGHAI YI, CAIFEN MA, JINGSHI GAO, and ZHONG XU (Xian Jiaotong Univ., China) Journal of Aerospace Power (ISSN 1000-8055) vol. 8, no. 2 April 1993 p. 148-150. In CHINESE

The blade pressure distribution of gas-particle two-phase flow in a compressor cascade has been investigated experimentally. Detailed measurements were made for three mass concentrations of 1.1, 2.0, and 4.5 percent, for two inlet velocities of 10 and 22 m/s, and for two inlet angles of attack of 7 and 27.5 deg. The results for two inlet angles of attack of 7 deg and 27.5 deg indicate that the solid phase has a certain effect on the blade pressure distribution of the gas phase. With increasing inlet velocity and mass concentration, the effects of solid particles on the blade pressure distribution are enhanced and the wake deviation is obvious. Also, the variation of the effects depends on the inlet angle of attack. Author (revised)

A93-48515
EXPERIMENTAL INVESTIGATION ON PATTERNED BLADES OF COMPRESSOR
RUNTIAN MIAO, LIANGUI WANG, LUHONG QIAN (Shenyang Liming Engine Manufacturing Co., China), ZHIMING TANG, and GE GAO (Beijing Univ. of Aeronautics and Astronautics, China) Journal of Aerospace Power (ISSN 1000-8055) vol. 8, no. 2 April 1993 p. 155-157. In CHINESE

Results of an experimental investigation of the patterned blades of a compressor showing a novel way to improve compressor performance are presented. The experiments were performed with the HP compressor of a twin-spool turbojet engine in a multistage compressor rig. The HP compressor consists of three stages (the fourth, fifth, and sixth stages). Two kinds of patterns are engraved on the surfaces of the fourth-and fifth-stage stator blades. Pattern I is 45-deg cross grooves, and pattern II is streamwards grooves. It is shown that the efficiencies and surge margins of the compressor with appropriately patterned stator blades can increase sigificantly. AIAA

A93-48517
NUMERICAL ANALYSIS OF AERODYNAMIC LOSSES IN FILM-COOLED VANE CASCADE

TAO JIANG, WEIHONG FAN, and SONGLING LIU (Northwestern Polytechnical Univ., Xian, China) Journal of Aerospace Power (ISSN 1000-8055) vol. 8, no. 2 April 1993 p. 161-164. In CHINESE refs

The integral boundary-layer parameter method based on a 2D film-cooling flow and heat-transfer prediction program, STANCOOL, is provided to predict the aerodynamic losses in the film-cooled vane cascade. The comparison of the numerical analysis with the corresponding experimental data demonstrates that the present method is more suitable to the case when blowing rates are low or the film cooling is located at thick local boundary layer. Finally this method is compared with another loss predicting method, TOTLOS, and it is concluded that both methods have their own advantages and extent of application. In practice it is reasonable to use the two methods in combination. Author (revised)

A93-48521
AN AERODYNAMIC DESIGN PROGRAM FOR CONTRA-ROTATING TURBINE CASCADES

RUIXIAN CAI, YONGMEI HE (Chinese Academy of Sciences, Inst. of Engineering Thermophysics, Beijing, China), and XINGLU WEI (Beijing Univ. of Aeronautics and Astronautics, China) Journal of Aerospace Power (ISSN 1000-8055) vol. 8, no. 2 April 1993 p. 177, 178. In CHINESE refs

An extremely simple, rapid, and universal turbine cascade design program is developed for contrarotating turbine cascades. With its simplest operating condition, only four parameters are necessary to be input for obtaining the geometry of a good enough cascade. They are the input data for designing a cascade, the inlet Mach number and flow angle, the outlet Mach number, and the specific heat ratio of the working substance. Therefore, the design can be accomplished without any additional human decision. The program is based on the mean-stream-line method. It is shown in detail how to select the independent design functions of this method in programming. This program enables to be operated with a very small computer, even a pocket computer such as the Sharp PC-1500. Author (revised)

A93-48544
A WAKE SINGULARITY POTENTIAL FLOW MODEL FOR AIRFOILS EXPERIENCING TRAILING-EDGE STALL

W. W. H. YEUNG (Nanyang Technological Univ., Singapore) and G. V. PARKINSON (British Columbia Univ., Vancouver, Canada) Journal of Fluid Mechanics (ISSN 0022-1120) vol. 251 June 1993 p. 203-218. Research supported by NSERC refs
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An incompressible inviscid flow theory for single and two-element airfoils experiencing trailing-edge stall is presented. For the single airfoil the model requires a simple sequence of conformal transformations to map a Joukowsky airfoil, partially truncated on the upper surface, onto a circle over which the flow problem is solved. Source and doublet singularities are used to create free streamlines simulating shear layers bounding the near wake. The model's simplicity permits extension of the method to airfoil-flap configurations in which trailing-edge stall is assumed on the flap. Williams' analytical method to calculate the potential flow about two lifting bodies is incorporated in the Joukowsky-arc wake-singularity model to allow for flow separation. The theoretical pressure distributions from these models show good agreement with wind-tunnel measurements.

A93-48826
CALCULATION OF THE PARAMETERS OF INSTABILITY WAVES IN THE PRESEPARATION REGION [RASCHET PARAMETROV VOLN NEUSTOJCHIVOSTI V PREDOTRYVNOJ OBLASTI]

V. M. GALKIN, B. YU. ZANIN, and V. A. KUPAREV (RAN, Inst. Teoreticheskoj i Prikladnoj Mekhaniki, Novosibirsk, Russia) Sibirskij Fiziko-Tekhnicheskij Zhurnal (ISSN 0869-1339) no. 2 Mar.-Apr. 1993 p. 25-28. In RUSSIAN refs
Copyright

The evolution of unstable perturbations in the boundary layer on a wing profile is calculated analytically, and the results are compared with the experimentally determined parameters of actual instability waves. The equations of the boundary layer are solved numerically using a second-order finite difference scheme. The perturbations on the wing are calculated by using a simplified version of the envelope method proposed by Strokowski and Orszag (1977). The calculated frequency and propagation velocity of instability waves are found to be in generally good agreement with the experimental data. AIAA

A93-48827
A STUDY OF THE EFFECT OF SURFACE RIBLETS ON THE EVOLUTION OF A SOLITARY WAVE PACKET (LAMBDA VORTEX) IN A LAMINAR BOUNDARY LAYER [ISSLEDOVANIE VLIYANIYA OREBRENIYA POVERKHNOSTI NA PROTSESS RAZVITIYA UEDINENNOGO VOLNOVOGO PAKETA /LAMBDA-VIKHRYA/ V LAMINARNOM POGRANICHNOM SLOE]

G. R. GREK, V. V. KOZLOV, and S. V. TITARENKO (RAN, Inst. Teoreticheskoj i Prikladnoj Mekhaniki, Novosibirsk, Russia) Sibirskij Fiziko-Tekhnicheskij Zhurnal (ISSN 0869-1339) no. 2 Mar.-Apr. 1993 p. 29-36. In RUSSIAN refs
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Results of an experimental study of the effect of surface riblets on the formation and evolution of lambda vortices are reported. It is found that surface riblets in the flow direction significantly reduce perturbation velocity fluctuations in the region of a nonlinear wave packet in comparison with a smooth surface. Riblets normal to the flow direction increase the intensity of perturbation velocity fluctuations. Thus, local surface riblets in the region of lambda vortex formation and evolution can control the process of perturbation transformation to turbulent spots, accelerating or delaying it, depending on the riblet orientation relative to the flow direction. AIAA

A93-48844
DETERMINATION OF THE SHAPE OF A WING PROFILE IN BOUNDARY LAYER FLOW WITH A GIVEN VELOCITY DIAGRAM [OPREDELENIE FORMY KRYLOVOGO PROFILYA, OBTEKAEMOGO VBLIZI GRANITSY RAZDELA SRED, PO ZADANNOJ EPYURE SKOROSTEJ]

N. B. IL'INSKIJ, M. V. LOTFULLIN, D. V. MAKLAKOV, and A. V. POTASHEV Rossijskaya Akademiya Nauk, Izvestiya, Mekhanika Zhidkosti i Gaza (ISSN 0568-5281) no. 6 Nov.-Dec. 1992 p. 15-21. In RUSSIAN refs
Copyright

Solutions for particular cases of the general inverse problem of boundary layer flow past a wing airfoil are obtained by using a modified version of the iteration method developed by Maklakov (1984, 1985) for the direct problem. The formalism of quasi-solutions is used at each iteration step. The calculations presented here demonstrate the efficiency of the approach. The effect of a solid boundary on the geometrical and aerodynamic characteristics of a profile is examined. AIAA

A93-48848
AERODYNAMIC CHARACTERISTICS AND STATIC STABILITY MARGIN OF CONICAL STAR-SHAPED BODIES AT SUPERSONIC VELOCITIES [AEHRODINAMICHESKIE KHARAKTERISTIKI I ZAPAS STATICHESKOJ USTOJCHIVOSTI KONICHESKIKH ZVEZDOOBRAZNYKH TEL PRI SVERKHZVUKOVYKH SKOROSTYAKH]

M. A. ZUBIN and N. A. OSTAPENKO Rossijskaya Akademiya Nauk, Izvestiya, Mekhanika Zhidkosti i Gaza (ISSN 0568-5281) no. 6 Nov.-Dec. 1992 p. 142-150. In RUSSIAN refs
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Results of an experimental study of the aerodynamic characteristics of conical bodies with a star-shaped cross section are reported for a wide range of geometrical parameters for a freestream Mach of 6. The position of the center of pressure of star-shaped bodies with an optimal shape of the trailing edge is investigated as a function of theoretically determined similarity parameters. A correlation is established between the derivatives

of the normal force with respect to the angle of attack of star-shaped pyramidal bodies and bodies with an optimal trailing edge. AIAA

A93-48849
EFFECT OF THE SIZE OF A PLANE OBSTACLE ON SELF-OSCILLATIONS GENERATED IN AN UNDEREXPANDED SUPERSONIC JET [VLIYANIE RAZMERA PLOSKOJ PREGRADY NA AVTOKOLEBANIYA, VOZNIKAYUSHCHIE PRI EE OBTEKANII SVERKHZVUKOVOJ NEDORASSHIRENNOJ STRUEJ]
V. N. GLAZNEV and V. YU. POPOV Rossijskaya Akademiya Nauk, Izvestiya, Mekhanika Zhidkosti i Gaza (ISSN 0568-5281) no. 6 Nov.-Dec. 1992 p. 164-168. In RUSSIAN refs
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Results of an experimental study of self-oscillations generated in an underexpanded supersonic jet flowing around a cylinder end are reported. An analysis of the results obtained indicates that the intensity of the generated oscillations depends in a noticeable and nonmonotonic manner on the obstacle size. The results are presented in graphic form. AIAA

A93-48901
PROBLEMS IN THE AERODYNAMICS OF FLIGHT VEHICLES AND THEIR PARTS [VOPROSY AEHRODINAMIKI LETATEL'NYKH APPARATOV I IKH CHASTEJ]
YU. A. RYZHOV, ED. Moscow Moskovskij Aviatsionnyj Institut 1991 88 p. In RUSSIAN For individual items see A93-48902 to A93-49915
Copyright
The book presents results of recent studies of certain aspects of the aerodynamics of flight vehicles and their components. In particular, attention is given to the aerodynamic characteristics of a sweptforward-wing aircraft model in unsteady motion at large angles of attack in subsonic flow, the use of triangular elements in panel methods for calculating flow past aircraft, and calculation of the turbulent viscosity coefficient. Papers are also presented on subsonic flow of a gas past an airfoil, effect of the wing planform on the optimal deformation of the middle surface, and pressure pulsation on a delta wing in incompressible flow. AIAA

A93-48902
AERODYNAMIC CHARACTERISTICS OF A SWEPTFORWARD-WING AIRCRAFT MODEL IN UNSTEADY MOTION AT LARGE ANGLES OF ATTACK IN SUBSONIC FLOW [AEHRODINAMICHESKIE KHARAKTERISTIKI MODELI SAMOLETA S KRYLOM OBRATNOJ STRELOVIDNOSTI PRI NEUSTANOVIVSHEMSYA DVIZHENII NA BOL'SHIKH UGLAKH ATAKI V DOZVUKOVOM POTOKE]
A. L. KIR'YANOV, G. S. SADEKOVA, and A. N. ZHUK *In* Problems in the aerodynamics of flight vehicles and their parts Moscow Moskovskij Aviatsionnyj Institut 1991 p. 4-11. In RUSSIAN refs
Copyright
Results of experimental parametric studies of the aerodynamic characteristics of an aircraft configuration with a sweptforward wing in unsteady motion are reported. The tests were carried out using an improved version of the natural vibration method at angles of attack up to 43 deg and low subsonic velocities (30 m/s). Results of the tests are presented in the form of dependences of the normal force coefficients and pitching moment on angle of attack and dependences characterizing changes in the normal force coefficient in unsteady motion in comparison with steady motion. AIAA

A93-48904
THE USE OF TRIANGULAR ELEMENTS IN PANEL METHODS FOR CALCULATING FLOW PAST FLIGHT VEHICLES [ISPOL'ZOVANIE TREUGOL'NYKH EHLEMENTOV V PANEL'NYKH METODAKH RASCHETA OBTEKANIYA LA]
YU. S. SOROKIN *In* Problems in the aerodynamics of flight vehicles and their parts Moscow Moskovskij Aviatsionnyj Institut 1991 p. 18-24. In RUSSIAN refs
Copyright
The use of triangular, rather than rectangular, panels has made it possible to improve the accuracy of calculations of flow past flight vehicles at supersonic velocities without a significant increase in the required computer resources. Here, an attempt is made to apply the concept of triangular elements in the panel method to the calculation of flow past a wing at subsonic velocities. Calculations for a NACA0012 airfoil are presented as an example. The convergence of the method is found to be reasonably good. AIAA

A93-48905
NUMERICAL CALCULATION OF POLARS AND HEAT TRANSFER FOR SUPERSONIC THREE-DIMENSIONAL FLOW PAST WINGS WITH ALLOWANCE FOR RADIATION [CHISLENNYJ RASCHET POLYAR I TEPLOOBMENA PRI SVERKHZVUKOVOM PROSTRANSTVENNOM OBTEKANII KRYL'EV S UCHETOM IZLUCHENIYA]
A. P. KOSYKH and G. A. SHCHEKIN *In* Problems in the aerodynamics of flight vehicles and their parts Moscow Moskovskij Aviatsionnyj Institut 1991 p. 24-30. In RUSSIAN refs
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The paper focuses on the lifting properties and heat transfer of plane delta wings with a sharp leading edge and an attached shock wave in supersonic three-dimensional flow. The equilibrium surface temperature is determined with allowance for thermal radiation in accordance with the Stefan-Boltzmann law. Three-dimensional supersonic flow past the wing is calculated in the context of weak interaction theory. In general, the effect of thermal radiation in aerodynamic heating calculations is found to be substantial: the radiation reduces the surface temperature by several hundred degrees and leads to a redistribution of surface temperature within several tens of degrees. AIAA

A93-48908
CALCULATION OF SUBSONIC FLOW OF A GAS PAST AN AIRFOIL [RASCHET OBTEKANIYA PROFILYA DOZVUKOVYM POTOKOM GAZA]
V. D. SOFRONOV and R. V. KLIMENKO *In* Problems in the aerodynamics of flight vehicles and their parts Moscow Moskovskij Aviatsionnyj Institut 1991 p. 42-47. In RUSSIAN refs
Copyright
An iteration procedure for solving the problem of subsonic flow of a compressible barotropic gas past an airfoil is described. Calculation results demonstrate the efficiency of methods for calculating gas flows based on the solution of the Prandtl-Glauert equation using programs for calculating incompressible flow. With proper selection of computational schemes for velocity component derivatives, the approach described here can also be used for calculating supersonic flows. AIAA

A93-48910
MINIMIZATION OF THE INDUCED DRAG OF NONPLANAR LIFTING SYSTEMS [MINIMIZATSIYA INDUKTIVNOGO SOPROTIVLENIYA NEPLOSKIKH NESUSHCHIKH SISTEM]
A. N. KOLOBKOV and M. I. NIKOLAEV *In* Problems in the aerodynamics of flight vehicles and their parts Moscow Moskovskij Aviatsionnyj Institut 1991 p. 52-57. In RUSSIAN refs
Copyright
The problem of minimizing the induced drag of lifting systems based on vorticity distribution in the wake can be solved analytically only for the simplest configurations (e.g., an isolated wing, a biplane, a wing with end plates, etc.). Here, a numerical algorithm is proposed which makes it possible to determine the optimal (from the standpoint of minimum induced drag) vorticity distribution in the wake of an arbitrary lifting system. Calculation results are presented for a joined wing system. AIAA

A93-48912
PRESSURE PULSATIONS ON A DELTA WING IN INCOMPRESSIBLE FLOW [O PUL'SATSIYAKH DAVLENIYA NA TREUGOL'NOM KRYLE V NESZHIMAEMOM POTOKE]
A. V. BAUMAN, A. L. LATYSHEV, and A. N. RADTSIG *In* Problems in the aerodynamics of flight vehicles and their parts Moscow Moskovskij Aviatsionnyj Institut 1991 p. 63-68. In RUSSIAN refs
Copyright
Results of an experimental study of pressure pulsations at the trailing edge of a thin plane delta wing with a leading-edge sweep angle of 70 deg are reported. It is shown, in particular, that the spectrum of pressure pulsations at the trailing edge of a delta wing is largely determined by the angle of attack and the x coordinate. The measurements described here can be used for the analysis of flow near a configuration with closely spaced lifting surfaces. AIAA

A93-48913
A STUDY OF THE EFFECT OF THE SHAPE OF A PARASAIL ON ITS LIFT-DRAG RATIO [ISSLEDOVANIE VLIYANIYA FORMY PARASHYUTA-KRYLA NA EGO AEHRODINAMICHESKOE KACHESTVO]
A. G. VIKTORCHIK, A. A. MIKHAJLYUK, and A. S. PAVLOV *In* Problems in the aerodynamics of flight vehicles and their parts Moscow Moskovskij Aviatsionnyj Institut 1991 p. 68-73. In RUSSIAN refs
Copyright
The lift-drag ratio of parasails is investigated experimentally as a function of their principal geometrical parameters, such as the relative coordinate of the cord attachment, relative leading edge radius, and canopy aspect ratio. Experimental results are presented for three canopy models with aspect ratios of 1.6, 2.4, and 3.2 for an incoming flow velocity of 20 m/s. The ranges of geometrical parameter values corresponding to a maximum lift-drag ratio are determined. AIAA

A93-48914
AN EXPERIMENTAL STUDY OF A COMPOUND SUPERSONIC JET [EHKSPERIMENTAL'NOE ISSLEDOVANIE SOSTAVNOJ SVERKHZVUKOVOJ STRUI]
E. N. BONDAREV, S. S. VTULKIN, E. I. MOSPANOV, and A. V. PECHERITSA *In* Problems in the aerodynamics of flight vehicles and their parts Moscow Moskovskij Aviatsionnyj Institut 1991 p. 73-80. In RUSSIAN refs
Copyright
An experimental study is made of a free supersonic jet issuing from a two-nozzle block at various angles of attack (0-6 deg) and external flow Mach numbers (0-1.5). The existence of different propagation regimes of a compound underexpanded jet in transverse flow is demonstrated. Conditions under which boundary layer separation occurs are determined. AIAA

A93-48924
EFFECT OF ANOMALOUS AERODYNAMIC HEATING DURING THE DESCENT OF A PARACHUTE ALONG A TRAJECTORY [EHFFEKT ANOMAL'NOGO AEHRODINAMICHESKOGO NAGREVA PRI SPUSKE PARASHYUTA PO TRAEKTORII]
YU. M. DAVYDOV and V. A. MOZGOVOJ (NII Parashyutostroeniya, Moscow, Russia) Rossijskaya Akademiya Nauk, Doklady (ISSN 0869-5652) vol. 330, no. 1 May 1993 p. 48-51. In RUSSIAN refs
Copyright
Numerical calculations and experimental studies of descent in the atmosphere indicate that temperatures under the parachute canopy often exceed breaking temperatures calculated for given trajectory points, when calculations are performed using equations of motions for streamlined aerodynamic bodies, such as aircraft or rockets. This paper presents a numerical experiment in which the air temperature under the parachute canopy is calculated for a supersonic conical parachute descending through the earth atmosphere, taking into consideration the fact that the density of the air flow under the canopy increases continuously during the descent. It is shown that consideration of this additional continuously increasing pressure makes it possible to identify certain new effects that are not detectable in steady motion analysis. AIAA

A93-48966
APPROXIMATE METHOD FOR THE AERODYNAMIC DESIGN OF FLIGHT VEHICLES FOR HIGH SUPERSONIC FLIGHT SPEEDS [PRIBLIZHENNYI METOD AEHRODINAMICHESKOGO RASCHETA LETATEL'NYKH APPARATOV PRI BOL'SHIKH SVERKHZVUKOVYKH SKOROSTYAKH POLETA]
V. YU. ALEKSANDROV, V. S. GALKIN, G. G. NERSESOV, and V. S. NIKOLAEV Moscow Izdatel'skij Otdel TsAGI (TsAGI, Trudy, No. 2492) 1990 17 p. In RUSSIAN refs
Copyright
An approximate method for the aerodynamic design of hypersonic flight vehicles is described which employs known analysis methods applicable to limited parameter ranges and approximation expressions for the matching of results produced by different methods (e.g., Newton methods, methods of tangent wedges and cones, the Prandtl-Meyer expansion flow method, strong explosion theory, and theory of laminar boundary layer interaction with nonviscous flow). Results of the refinement of some of the existing calculation methods and validation of the approximation formulas are presented. A computational algorithm based on the approach proposed here is described. AIAA

A93-48971
THREE-DIMENSIONAL HYPERSONIC FLOW OF A GAS PAST WINGS [PROSTRANSTVENNOE OBTEKANIE KRYL'EV GIPERZVUKOVYM POTOKOM GAZA]
V. N. GOLUBKIN Rossijskaya Akademiya Nauk, Izvestiya, Mekhanika Zhidkosti i Gaza (ISSN 0568-5281) no. 5 Sept.-Oct. 1992 p. 148-161. In RUSSIAN refs
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Results of a theory for three-dimensional hypersonic flow past a wing based on the method of a thin shock layer are reviewed. The approach presented here employs approximate formulations to obtain similarity laws and analytical and numerical-analytical solutions yielding explicit, although sometimes complex, relations between the aerodynamic characteristics and determining parameters of a problem. The results can be used for preliminary estimates and calculations. They can also be used as the basis for formulating and solving variational problems concerned with the selection of optimal shapes of lifting surfaces for hypersonic velocities. AIAA

A93-48973
SUPERSONIC FLOW PAST ENERGY RELEASE REGIONS [SVERKHZVUKOVOE OBTEKANIE OBLASTEJ EHNERGOVYDELENIYA]
L. V. TERENT'EVA Rossijskaya Akademiya Nauk, Izvestiya, Mekhanika Zhidkosti i Gaza (ISSN 0568-5281) no. 5 Sept.-Oct. 1992 p. 179-182. In RUSSIAN refs
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The problem of supersonic flow past three-dimensional axisymmetric regions of heat release is solved in the context of linear theory. The distribution of parameters over the flow is investigated as a function of the shape of the heat release region. It is shown that, in all cases of supersonic flow past cylindrical heat release regions, an extended low-pressure zone is formed behind these regions. AIAA

A93-48974
HYPERSONIC FLOW PAST A LOW-ASPECT-RATIO TRIANGULAR PLATE AT LARGE ANGLES OF ATTACK [GIPERZVUKOVOE OBTEKANIE TREUGOL'NOJ PLASTINKI MALOGO UDLINENIYA PRI BOL'SHIKH UGLAKH ATAKI]
N. S. BACHMANOVA, V. I. LAPYGIN, and YU. M. LIPNITSKIJ Rossijskaya Akademiya Nauk, Izvestiya, Mekhanika Zhidkosti i Gaza (ISSN 0568-5281) no. 5 Sept.-Oct. 1992 p. 183-185. In RUSSIAN refs
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The problem of hypersonic flow past a low-aspect-ratio triangular plate at angles of attack close to pi/2 is solved numerically using the method proposed by Lipnitskii et al. (1972). The existence of a conical flow at angles of attack approximately equal to pi/2, with the velocity vector directed toward the vertex of the plate, is demonstrated. The calculated flow parameters are in good agreement with experimental data. AIAA

A93-48975
EFFECT OF THE FORMATION OF EXCITED OXYGEN MOLECULES ON THE KINETICS OF EXCHANGE REACTIONS AND THE HEAT FLUX DURING BRAKING IN THE UPPER LAYERS OF THE ATMOSPHERE [VLIYANIE OBRAZOVANIYA VOZBUZHDENNYKH MOLEKUL KISLORODA NA KINETIKU OBMENNYKH REAKTSIJ I VELICHINU TEPLOVOGO POTOKA PRI TORMOZHENII V VERKHNIKH SLOYAKH ATMOSFERY]
V. D. BERKUT Rossijskaya Akademiya Nauk, Izvestiya, Mekhanika Zhidkosti i Gaza (ISSN 0568-5281) no. 5 Sept.-Oct. 1992 p. 186-188. In RUSSIAN refs
Copyright

The effect of the formation of excited oxygen atoms on heat flow during the entry of a blunt body into the upper layers of the atmosphere is investigated for gliding entry trajectories corresponding to maximum heat loads. It is shown that, in the case of formation of electron-excited oxygen molecules during heterogeneous recombination, consideration of the dependence of the chemical reaction rate constants on the quantum state of the reagents leads to a significant (up to 20 percent) reduction in heat fluxes during braking in the upper layers of the atmosphere. This effect should be taken into account in calculating heat fluxes toward spacecraft during the reentry and in determining the rate constants of catalytic atomic recombination reactions in gasdynamic experiments involving flow of dissociated air. AIAA

A93-49002
PERIODIC VORTEX SHEDDING OVER DELTA WINGS
O. K. REDINIOTIS, H. STAPOUNTZIS, and D. P. TELIONIS (Virginia Polytechnic Inst. and State Univ., Blacksburg) AIAA Journal (ISSN 0001-1452) vol. 31, no. 9 Sept. 1993 p. 1555-1562. refs
(Contract AF-AFOSR-89-0283; NATO-0441/87)
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An experimental investigation was conducted on delta wings at high angles of attack. It was found that for angles of attack larger than 35 deg, periodic vortices are shed. Two modes of shedding were discovered: an alternate and a simultaneous. The first involves alternate shedding of vortices, much like shedding over two-dimensional bluff bodies. The second is dominated by simultaneous shedding of vortices, but its spatial characteristics are not yet well understood.

A93-49003
THOUGHTS ON CONICAL FLOW ASYMMETRY
L. E. ERICSSON (Lockheed Missiles & Space Co., Inc., Sunnyvale, CA) AIAA Journal (ISSN 0001-1452) vol. 31, no. 9 Sept. 1993 p. 1563-1568. AIAA, Aerospace Sciences Meeting and Exhibit, 30th, Reno, NV, Jan. 6-9, 1992, AIAA Paper 92-0427. Previously cited in issue 09, p. 1353, Accession no. A92-26275 refs
(Contract F33615-87-C-3607)
Copyright

A93-49008* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
SKIN FRICTION AND VELOCITY PROFILE FAMILY FOR COMPRESSIBLE TURBULENT BOUNDARY LAYERS
P. G. HUANG (Eloret Inst.; NASA, Ames Research Center, Moffett Field, CA), P. BRADSHAW (Stanford Univ., CA), and T. J. COAKLEY (NASA, Ames Research Center, Moffett Field, CA) AIAA Journal (ISSN 0001-1452) vol. 31, no. 9 Sept. 1993 p. 1600-1604. refs

The paper presents a general approach to constructing mean velocity profiles for compressible turbulent boundary layers with isothermal or adiabatic walls. The theory is based on a density-weighted transformation that allows the extension of the incompressible similarity laws of the wall to the compressible regions. The velocity profile family is compared to a range of experimental data, and excellent agreement is obtained. A self-consistent skin friction law, which satisfies the proposed velocity profile family, is derived and compared with the well-known Van Driest II theory for boundary layers in zero pressure gradient. The results are found to be at least as good as those obtained by using the Van Driest II transformation.

A93-49009* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
SECONDARY INSTABILITY MECHANISMS IN COMPRESSIBLE AXISYMMETRIC BOUNDARY LAYERS
LIAN L. NG (Analytical Services and Materials, Inc., Hampton, VA) and THOMAS A. ZANG (NASA, Langley Research Center, Hampton, VA) AIAA Journal (ISSN 0001-1452) vol. 31, no. 9 Sept. 1993 p. 1605-1610. AIAA, Aerospace Sciences Meeting and Exhibit, 30th, Reno, NV, Jan. 6-9, 1992, AIAA Paper 92-0743. Previously cited in issue 10, p. 1555. Accession no. A92-28224 refs
(Contract NAS1-18599)
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A93-49010* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
EFFECT OF CURVATURE ON STATIONARY CROSSFLOW INSTABILITY OF A THREE-DIMENSIONAL BOUNDARY LAYER
RAY-SING LIN and HELEN L. REED (Arizona State Univ., Tempe) AIAA Journal (ISSN 0001-1452) vol. 31, no. 9 Sept. 1993 p. 1611-1617. Research supported by NASA and Tohoku Univ refs
Copyright

An incompressible three-dimensional laminar boundary-layer flow over a swept wing is used as a model to study both the wall-curvature and streamline-curvature effects on the stationary crossflow instability. The basic state is obtained by solving the full Navier-Stokes (N-S) equations numerically. The linear disturbance equations are cast on a fixed, body-intrinsic, curvilinear coordinate system. Those nonparallel terms which contribute mainly to the streamline-curvature effect are retained in the formulation of the disturbance equations and approximated by their local finite difference values. The resulting eigenvalue problem is solved by a Chebyshev collocation method. The present results indicate that the convex wall curvature has a stabilizing effect, whereas the streamline curvature has a destabilizing effect. A validation of these effects with an N-S solution for the linear disturbance flow is provided.

A93-49011
UPWIND FINITE-VOLUME NAVIER-STOKES COMPUTATIONS ON UNSTRUCTURED TRIANGULAR MESHES
DARTZI PAN and JEN-CHIEH CHENG (National Cheng Kung Univ., Tainan, Taiwan) AIAA Journal (ISSN 0001-1452) vol. 31, no. 9 Sept. 1993 p. 1618-1625. refs
(Contract NSC-82-0210-D006-008)
Copyright

A Navier-Stokes solver using upwind finite-volume method on unstructured triangular meshes is developed and tested. A Godunov-type upwind method is used for inviscid flux computations. An accurate linear reconstruction is used to compute the Two Riemann states at the cell face, and Roe's approximate Riemann solver is solved for inviscid fluxes. A finite-volume formulation for the viscous terms, which can be second-order accurate for a large class of triangular cells, is developed and tested. The algebraic Baldwin-Lomax turbulence model is implemented via the use of a turbulence reference grid, the only purpose of which is to provide necessary length scales to the model. All of the turbulence computations are done on the unstructured main mesh without interpolation to and from the reference grid. An approximate lower-upper factorization scheme is used for implicit time integration. Various low and high Reynolds number flows are

computed to verify the proposed scheme, including a high Reynolds number flow over a two-element airfoil.

A93-49014
MODEL FOR ENTROPY PRODUCTION AND PRESSURE VARIATION IN CONFINED TURBULENT MIXING
DIMITRI PAPAMOSCHOU (California Univ., Irvine) AIAA Journal (ISSN 0001-1452) vol. 31, no. 9 Sept. 1993 p. 1643-1650. refs
Copyright

A quasi-one-dimensional model for the planar, confined shear layer is constructed with the purpose of obtaining estimates of entropy production and pressure variation due to turbulent mixing. The turbulent Prandtl and Lewis numbers are assumed to be unity. It is found that entropy production is strongly coupled to the intrinsic compressibility, with total pressure losses becoming significant as the convective Mach number increases. For the isothermal case, the entropy flux is roughly proportional to the third power of the velocity difference, and the equivalent total pressure ratio decays exponentially with the square of the convective Mach number. Pressure gradients in a parallel channel are strong and adverse at high compressibility levels. The model predictions of equivalent total pressure ratio and shear-layer displacement thickness compare well with existing experimental data.

A93-49015
VORTICAL SOLUTIONS IN SUPERSONIC CORNER FLOWS
R. MARSILIO (Torino, Politecnico, Turin, Italy) AIAA Journal (ISSN 0001-1452) vol. 31, no. 9 Sept. 1993 p. 1651-1658. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993, AIAA Paper 93-0760. Previously cited in issue 08, p. 1312, Accession no. A93-24845 Research supported by BRITE EURAM Project refs
Copyright

A93-49016* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
EULER CALCULATIONS OF UNSTEADY INTERACTION OF ADVANCING ROTOR WITH A LINE VORTEX
G. R. SRINIVASAN and W. J. MCCROSKEY (NASA, Ames Research Center, Moffett Field, CA) AIAA Journal (ISSN 0001-1452) vol. 31, no. 9 Sept. 1993 p. 1659-1666. AIAA, Fluid Dynamics, Plasma Dynamics and Lasers Conference, 20th, Buffalo, NY, June 12-14, 1989, AIAA Paper 89-1848. Previously cited in issue 18, p. 2756, Accession no. A89-42076 refs
(Contract DAAL03-88-C-0006; DAAL03-90-C-0013)

A93-49027
MULTIGRID TECHNIQUES FOR HYPERSONIC VISCOUS FLOWS
F. GRASSO and M. MARINI (Roma I, Univ., Rome, Italy) AIAA Journal (ISSN 0001-1452) vol. 31, no. 9 Sept. 1993 p. 1729-1731. Abridged. AIAA, Aerospace Sciences Meeting and Exhibit, 31st, Reno, NV, Jan. 11-14, 1993, AIAA Paper 93-0771. Previously cited in issue 08, p. 1313, Accession no. A93-24855 Research supported by Dassault Aviation and ASI refs
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A93-49185
AN EXPERIMENTAL STUDY ON BLADE NEGATIVE CURVING IN A TURBINE CASCADE WITH A LARGE TURNING ANGLE
ZHONGQI WANG, CHUNQING TAN, WANJIN HAN, and MOCHUN ZHOU (Harbin Inst. of Technology, China) Journal of Aerospace Power (ISSN 1000-8055) vol. 8, no. 3 Oct. 1992 p. 209-212. In CHINESE refs

Turbine rectangular cascades with conventional straight blades and negative curved ones at obtuse angles between their pressure surfaces and both end walls were investigated in a low speed plane cascade wind-tunnel. The measuring planes with five-hole microspherical probes were arranged as 3 before, 6 in, and 1 after the cascades. The experimental results show that the origination and development of horseshoe vortices and passage vortices as well as the meeting of the passage vortices in the midspan region almost dominate the whole flow field of conventional straight cascade. In comparison with those of conventional straight cascade, blade negative curving improves the flows around blade leading edges near both the end walls, and reduces the intensities and viscous dissipation losses of leading edge vortices and passage vortices. As a result, the flux capability of the cascade increases by 3.2 percent, the mass flux averaged overall loss coefficient is cut down by 19.1 percent; at the same time the good inlet condition is provided for the rotor cascade.
Author (revised)

A93-49188
INVESTIGATION OF FLOWS IN A CONTROLLED DIFFUSION AIRFOIL CASCADE PASSAGE
RONGHUI CHENG, YONGXING ZHONG (Gas Turbine Establishment, China), and RUQUN YUN (Northwestern Polytechnical Univ., Xian, China) Journal of Aerospace Power (ISSN 1000-8055) vol. 8, no. 3 Oct. 1992 p. 221-224. In CHINESE

This paper presents flow measurements in a blade passage and downstream of a high-turning controlled diffusion airfoil (CDA) cascade and flow visualization on the end wall and blade surfaces. This helps understand flow in the blade passage, especially in the end wall area, the vortex structure, and the effect of end wall boundary layer and secondary flow on the performance of the cascade. It can be used for improving the flow conditions in the end wall area of a compressor and developing the second generation of controlled diffusion airfoils. Author (revised)

A93-49198
EFFECTS OF EXTERNAL EXCITATION ON THE LEADING-EDGE SEPARATION FLOWFIELD
CHENG XU (East China Inst. of Technology, Nanjing, China), SHIYING ZHANG, and MINGDE ZHOU (Nanjing Aeronautical Inst., China) Journal of Aerospace Power (ISSN 1000-8055) vol. 8, no. 3 Oct. 1992 p. 271-274. In CHINESE refs

This paper presents a comparison of leading-edge separation flows without and with the excitation of select frequency. A variety of excitation effects on the separation flowfield are revealed, such as (1) delaying separation flow or decreasing separation flow area, (2) modifying turbulence structure, intensifying turbulent activity, and enhancing growth rate of separated shear layer, (3) enhancing backflow activity of local region, (4) promoting reattachment and changing separation patterns and vortex distribution, (5) weakening turbulence fluctuation of wake flow, and (6) increasing inclination of the wake flow. Author (revised)

A93-49323
A METHOD FOR CALCULATING THE AERODYNAMIC AND MASS CHARACTERISTICS OF COAXIAL ROTORS WITH RIGID BLADE FASTENING (THE ABC SYSTEM) [METODIKA RASCHETA AEHRODINAMICHESKIKH I MASSOVYKH KHARAKTERISTIK SOOSNYKH NESUSHCHIKH VINTOV S ZHESTKIM KREPLENIEM LOPASTEJ /SISTEMA ABC/]
L. S. VIL'DGRUBE TsAGI, Trudy no. 2474 1990 p. 3-53. In RUSSIAN refs
Copyright

Approximate formulas are presented for calculating the aerodynamic and mass characteristics of coaxial rotors with rigid blade fastening (the Advanced Blade Conception system) in the general case of unsteady helicopter flight along a curvilinear trajectory. The formulas are based on the disk vortex theory and allow for the effect of counterrotating rotors. Calculation results are presented in graphic form. AIAA

A93-49324
FORMULAS FOR DETERMINING THE INDUCED VELOCITY IN THE DIRECT AND INVERSE ROTOR PROBLEMS [FORMULY DLYA OPREDELENIYA INDUKTIVNOJ SKOROSTI V PRYAMOJ I OBRATNOJ ZADACHAKH TEORII NESUSHCHEGO VINTA]
EH. D. SAFRONOV TsAGI, Trudy no. 2474 1990 p. 54-62. In RUSSIAN refs
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Formulas are obtained for determining the mean induced flow velocity of a rotor in the classical direct and inverse rotor problems. Allowance is made for the following geometrical characteristics of the blades: total pitch angle, static and dynamic twist, and radial position of the beginning of the aerodynamically efficient part of the blade. Approximate formulas for calculating the local induced velocity at selected points of a rotor are presented which reduce the computational effort in comparison with vortex theory calculations. The results of the study are applicable to different types of rotors and propellers. AIAA

A93-49507
INVESTIGATION OF NACELLE UPPER COWL FLOW SEPARATION USING ON- AND OFF-BODY FLOW VISUALIZATION TECHNIQUES
SAID DINI (Western New England College, Springfield, MA), NADER SANIEI (Southern Illinois Univ., Edwardsville, IL), and PETER C. CONWAY (Western New England College, Springfield, MA) *In* Heat Transfer and Fluid Mechanics Institute, 33rd, California State Univ., Sacramento, June 3, 4, 1993, Proceedings Sacramento, CA California State University 1993 p. 23-39. refs
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An investigation of the flow field and the pressure distribution over a simulated inoperable jet engine nacelle is described. Photographs are presented for flow patterns over upper surface of the nacelle for a limited range of Reynolds number (75,000-175,000). Blackened and iridescent oils were used to study the onbody flow characteristics. Based on the experimental results a mapping of the flow separation was determined. A variation of the separation pattern over the range of angle of attack and limited range of Reynolds number was noted.

A93-49515# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
AN EXPERIMENTAL STUDY OF THE EFFECTS OF BODYSIDE COMPRESSION ON FORWARD SWEPT SIDEWALL COMPRESSION INLETS INGESTING A TURBULENT BOUNDARY LAYER
PATRICK E. RODI (NASA, Langley Research Center, Hampton, VA) Jul. 1993 16 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 Research supported by National Research Council and NASA refs
(AIAA PAPER 93-3125)

Forward swept sidewall compression inlets have been tested in the Mach 4 Blowdown Facility at the NASA Langley Research Center to study the effects of bodyside compression surfaces on inlet performance in the presence of an incoming turbulent boundary layer. The measurements include mass flow capture and mean surface pressure distributions obtained during simulated combustion pressure increases downstream of the inlet. The kerosene-lampblack surface tracer technique has been used to obtain patterns of the local wall shear stress direction. Inlet performance is evaluated using starting and unstarting characteristics, mass capture, mean surface pressure distributions and permissible back pressure limits. The results indicate that inlet performance can be improved with selected bodyside compression surfaces placed between the inlet sidewalls.

A93-49516*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
HYPERSONIC AERODYNAMIC CHARACTERISTICS FOR LANGLEY TEST TECHNIQUE DEMONSTRATOR
W. P. PHILLIPS and C. I. CRUZ (NASA, Langley Research Center, Hampton, VA) Aug. 1993 12 p. AIAA, Applied Aerodynamics Conference, Monterey, CA, Aug. 9-11, 1993 refs
(AIAA PAPER 93-3443) Copyright

Experimental longitudinal and lateral-directional aerodynamic characteristics were obtained for a generic transatmospheric vehicle concept referred to as the Langley Test Technique Demonstrator. The baseline configuration, without engine modules, was longitudinally and directionally unstable over the hypersonic Mach number range of the investigation and exhibited untrimmed (L/D)max levels between 2.6 and 2.8. Adding various engine modules to the baseline configuration produced mainly, degradations in lift-to-drag ratio. In general, longitudinal aerodynamic coefficients predicted with an engineering code referred to as Aerodynamic Preliminary Analysis System (APAS) were in qualitative, and often quantitative agreement with measurement.

A93-49517*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
TWO-DIMENSIONAL COMPUTATIONAL ANALYSIS OF A TRANSPORT HIGH-LIFT SYSTEM AND A COMPARISON WITH FLIGHT-TEST RESULTS
JAY D. HARDIN (Lockheed Engineering & Sciences Co.; NASA, Langley Research Center, Hampton, VA), R. C. POTTER, C. P. VAN DAM (California Univ., Davis), and LONG P. YIP (NASA, Langley Research Center, Hampton, VA) Aug. 1993 14 p. AIAA, Applied Aerodynamics Conference, Monterey, CA, Aug. 9-11, 1993 refs
(AIAA PAPER 93-3533) Copyright

Two currently available coupled inviscid/viscous multielement computational codes, including a relatively simple panel method and an Euler method, are used to analyze a high-lift system. The results are compared with two-dimensional wind-tunnel test results and then with the three-dimensional flight-test results obtained from the NASA Langley Transport Systems Research Vehicle five-element high-lift wing section. Comparisons were also made between the panel method, the Euler method, and flight data for two high-lift configurations, one representing a take-off configuration and the other an approach configuration. For the take-off configuration, both codes agreed reasonably well with experimental data, but both codes were found to overpredict the flap upper-surface pressures for the approach configuration. AIAA

A93-49521
COMPUTATIONAL METHODS IN HYPERSONIC AERODYNAMICS
T. K. S. MURTHY, ED. (Wessex Inst. of Technology, Southampton, United Kingdom) Southampton, United Kingdom/Dordrecht, Netherlands Computational Mechanics Publications/Kluwer Academic Publishers (Fluid Mechanics and Its Applications. Vol. 9) 1992 507 p. For individual items see A93-49522 to A93-49533
(ISBN 0-7923-1673-8) Copyright

The present volume on computational methods in hypersonic aerodynamics discusses the physical aspects of hypersonic aerodynamics, computational methods for viscous hypersonic flow, a numerical simulation of hypersonic flows, and point-implicit relaxation strategies for viscous hypersonic flows. Attention is given to flux-split algorithms for hypersonic flow, efficient multigrid computation of steady hypersonic flows, laminar-turbulent transition, and second-order effects in hypersonic laminar boundary layers. Topics addressed include real gas effects in 2D and 3D hypersonic, laminar boundary layers, flow analysis and design optimization methods for nozzle-afterbody of a hypersonic vehicle, the computation over unstructured grids of inviscid hypersonic reactive flow by upwind finite-volume schemes, and computational aerothermodynamics for 2D and 3D space vehicles. AIAA

A93-49522
INTRODUCTION TO THE PHYSICAL ASPECTS OF HYPERSONIC AERODYNAMICS
R. GRUNDMANN (Von Karman Inst. for Fluid Dynamics, Rhode-St.-Genese, Belgium) *In* Computational methods in hypersonic aerodynamics Southampton, United Kingdom/ Dordrecht, Netherlands Computational Mechanics Publications/Kluwer Academic Publishers 1992 p. 1-28. refs
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The physical phenomena of thermochemical nonequilibrium flows in the high-temperature environment of hypersonic aerodynamics are described. The glide path of an orbital vehicle leading through this environment of various energy excitation zones is discussed. Some basic considerations on fluxes and transport

properties in hypersonic flows are given. Simple computations of chemical nonequilibrium boundary layers along a flat plate show the general behavior of high-temperature effects. A set of definitions for reacting gas mixtures in high-temperature flows is provided. The atmospheric temperature and speed of sound distribution vs the altitude, energy excitation zones for the stagnation point, and the reentry corridor in the altitude vs velocity plot are illustrated.
AIAA

A93-49529
SECOND-ORDER EFFECTS IN HYPERSONIC LAMINAR BOUNDARY LAYERS
J. PH. BRAZIER, B. AUPOIX, and J. COUSTEIX (ONERA, Centre d'Etudes et de Recherches de Toulouse, France) *In* Computational methods in hypersonic aerodynamics Southampton, United Kingdom/Dordrecht, Netherlands Computational Mechanics Publications/Kluwer Academic Publishers 1992 p. 265-291. refs
Copyright

In hypersonic flows, the bow shock wave in front of the body is the cause of a vortical inviscid flow in the shock layer. The conventional boundary layer theory of Prandtl can not deal with it. Van Dyke has derived an extended boundary layer theory using matched asymptotic expansions where several second order effects as outer flow vorticity, displacement, or wall curvature are accounted for. However, the matching between the boundary-layer flow and the external inviscid flow is not perfect with second order expansions when the Reynolds number is low and thus the boundary layer thick. To improve this and ensure a smooth merging of the viscous flow into the inviscid one, a defect approach coupled with asymptotic expansions has been proposed. Calculations on simple two-dimensional hypersonic bodies are performed using the two methods and compared to full Navier-Stokes solutions.

A93-49530
REAL GAS EFFECTS IN TWO- AND THREE-DIMENSIONAL HYPERSONIC, LAMINAR BOUNDARY LAYERS
B. AUPOIX and J. COUSTEIX (ONERA, Centre d'Etudes et de Recherches de Toulouse, France) *In* Computational methods in hypersonic aerodynamics Southampton, United Kingdom/Dordrecht, Netherlands Computational Mechanics Publications/Kluwer Academic Publishers 1992 p. 293-339. refs
Copyright

This paper is devoted to hypersonic laminar boundary layers as the maximum heat loads during the re-entry of a space shuttle occur in the laminar regime. The emphasis is placed upon the real gas effects which deeply affect the evolution of the flow. As boundary layers are addressed, thermal non-equilibrium effects are neglected and the attention is focused upon chemical non-equilibrium effects. A simplified atom/molecule model is justified and more complex models are detailed. The influences of the wall catalysis, of the scatter in chemical reaction rate data and of the wall temperature are brought into evidence. Self similar solutions, to determine the flow and the wall heat flux at two- and three-dimensional stagnation points or along attachment lines are presented.

A93-49531* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
FLOW ANALYSIS AND DESIGN OPTIMIZATION METHODS FOR NOZZLE-AFTERBODY OF A HYPERSONIC VEHICLE
O. BAYSAL (Old Dominion Univ., Norfolk, VA) *In* Computational methods in hypersonic aerodynamics Southampton, United Kingdom/Dordrecht, Netherlands Computational Mechanics Publications/Kluwer Academic Publishers 1992 p. 341-386. Previously announced in STAR as N92-21456 refs
(Contract NAS1-811; NAG1-1188)
Copyright

This report summarizes the methods developed for the aerodynamic analysis and the shape optimization of the nozzle-afterbody section of a hypersonic vehicle. Initially, exhaust gases were assumed to be air. Internal-external flows around a single scramjet module were analyzed by solving the 3D Navier-Stokes equations. Then, exhaust gases were simulated by a cold mixture of Freon and Ar. Two different models were used to compute these multispecies flows as they mixed with the hypersonic airflow. Surface and off-surface properties were successfully compared with the experimental data. The Aerodynamic Design Optimization with Sensitivity analysis was then developed. Pre- and postoptimization sensitivity coefficients were derived and used in this quasi-analytical method. These coefficients were also used to predict inexpensively the flow field around a changed shape when the flow field of an unchanged shape was given. Starting with totally arbitrary initial afterbody shapes, independent computations were converged to the same optimum shape, which rendered the maximum axial thrust.
Author (revised)

A93-49532
THE COMPUTATION OVER UNSTRUCTURED GRIDS OF INVISCID HYPERSONIC REACTIVE FLOW BY UPWIND FINITE-VOLUME SCHEMES
J.-A. DESIDERI (INRIA, Valbonne, France) *In* Computational methods in hypersonic aerodynamics Southampton, United Kingdom/Dordrecht, Netherlands Computational Mechanics Publications/Kluwer Academic Publishers 1992 p. 387-446. refs
Copyright

The study presents finite-volume and finite-element solutions to the Euler equations for the computation of inviscid hypersonic reactive flows around blunt bodies. Robust spatial approximations are constructed from either first-order or MUSCL-type quasi-second-order upwind schemes in which the flux-vector splitting accounts for a mixture of five perfect gases (N2, O2, NO, N, and O) in the equation of state and for a local value of the parameter gamma (the ratio of enthalpy to internal energy). The basic method is combined with a classic algebraic model, solved by Newton's method, to obtain equilibrium flow solutions. It is verified that as R(b) approaches infinity, M(infinity) being fixed, the nonequilibrium flow solution slowly approaches the equilibrium solution. The inviscid nonequilibrium blunt-body flow is found to be singular at the stagnation point.
AIAA

A93-49533
COMPUTATIONAL AEROTHERMODYNAMICS FOR 2D AND 3D SPACE VEHICLES
J. HAEUSER, J. MUYLAERT, H. WONG, and W. BERRY (ESTEC, Noordwijk, Netherlands) *In* Computational methods in hypersonic aerodynamics Southampton, United Kingdom/Dordrecht, Netherlands Computational Mechanics Publications/Kluwer Academic Publishers 1992 p. 447-490. refs
Copyright

An overview of current hypersonic activities in Europe (the Hermes spaceplane, the Titan probe Huygens, the Mars lander, and studies on airbreathing propelled future launchers) is presented. The special physical effects of high-speed flows are discussed qualitatively, and scaling laws as well as relevant parameters characterizing perfect gas, equilibrium, and nonequilibrium flow are derived. The mathematical formulation of the governing physical equations, including the physical submodels, is given. The numerical solution technique is presented for multispecies Navier-Stokes equations, with emphasis on the role of flux linearization, to retain positivity. Grid adaptation and interactive grid generation are also discussed.
AIAA

A93-49661#
SWIRLING FLOWS IN A CONTOURED-WALL COMBUSTION CHAMBER
D. LEE, C. L. YEH (National Cheng Kung Univ., Tainan, Taiwan), C. W. LIAO, and D. C. TIEN (Chung Shan Inst. of Science and Technology, Taichung, Taiwan) Jun. 1993 11 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(Contract NSC-82-0401-D006-001)
(AIAA PAPER 93-1765) Copyright

In this study, the flowfields of a combustor with contoured-wall are studied numerically. A computer code is developed for the simulation of the three-dimensional gas-turbine combustor flows. The predictions are supported by the measurements obtained in the laboratory. The measurements are made in a combustor model which contains five swirlers. Both of the swirling and non-swirling flow fields are measured using the LDV. The predictions are agreeable with the measurements in velocity profiles and the distribution of the turbulence kinetic energy. It is demonstrated that the effect of the side walls of the model combustor on the flowfield can be significant. The effect of the swirl number on the flowfields is also studied in both reacting and nonreacting cases.

A93-49686#
A LAMINAR FLOW ROTOR FOR A RADIAL INFLOW TURBINE
I. HUNTSMAN and H. P. HODSON (Cambridge Univ., United Kingdom) Jun. 1993 10 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Research supported by Rolls-Royce, PLC refs
(AIAA PAPER 93-1796) Copyright

The state of the boundary layers on the blade surfaces of the rotor of a radial inflow turbine has been investigated. The boundary layers are shown to be laminar or intermittently turbulent at the design flow condition. This is despite the fact that the Reynolds number is relatively high. Surface pressure distributions and an inviscid prediction method are used to assist in the explanation for the state of the boundary layers.

A93-49687#
VISCOUS ANALYSIS OF HIGH PRESSURE TURBINE INLET GUIDE VANE FLOW INCLUDING COOLING INJECTIONS
PHILIPPE CHANEZ, BERTRAND PETOT (SNECMA, Moissy-Cramayel, France), and CHRISTINE JOURDREN (ONERA, Chatillon, France) Jun. 1993 11 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Research supported by DRET and Service Technique des Programmes Aeronautiques refs
(AIAA PAPER 93-1798; ONERA, TP NO. 1993-88) Copyright

This paper presents the aerodynamic and thermal analysis of a highly loaded high pressure turbine inlet guide vane with cooling slots at the trailing edge. A quasi-three-dimensional Navier-Stokes code with mixing length turbulence model is used to compute the flow in the transonic range of exit Mach numbers and at high temperatures. The mixing-length turbulence model has been modified to include cooling slots by addition of two different jet models. The code has been extensively validated on sub- and transonic turbine blades without cooling slots. The analysis includes computations of two different cooling slots geometries. The aerodynamic and thermal results are compared with those obtained on the no-injection version of the blade, computed with both the Navier-Stokes code and a boundary layer code.

A93-49688#
A NONPERIODIC BOUNDARY APPROACH FOR COMPUTATION OF COMPRESSIBLE VISCOUS FLOWS IN ADVANCED TURBINE CASCADES
GERALD J. MICKLOW, KARTHIKEYAN SHIVARAMAN, and HONGJUN LI (Florida Univ., Gainesville) Jun. 1993 11 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-1799) Copyright

A two-dimensional flow solver is presented for advanced turbine cascades, with high turning, with or without embedded shocks. Options allow for solution of the steady or unsteady Euler, thin layer or the full Reynolds averaged Navier-Stokes equations. A cell-centered finite volume formulation with variable artificial viscosity is used for viscous flows. The time stepping is achieved by a hybrid multi-stage Runge-Kutta scheme, and the solution is accelerated using local time stepping, enthalpy damping and implicit residual averaging. For turbine cascades with high stagger, conventional periodic C-type grids are highly skewed, leading to considerable solution degradation. A nonperiodic boundary grid has been used to overcome this problem. In this work, grid generation and the treatment of the nonperiodic boundary is discussed. Results are presented for two-dimensional flow in two transonic turbine cascades. Good agreement with the data is found.

A93-49695*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
INSTALLED F/A-18 INLET FLOW CALCULATIONS AT 60 DEG ANGLE-OF-ATTACK AND 10 DEG SIDE SLIP
S. D. PODLESKI (Sverdrup Technology, Inc., Brook Park, OH) Jun. 1993 21 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(Contract NAS3-25266)
(AIAA PAPER 93-1806)

This paper presents the results of PARC3D numerical calculations on a 19.78 percent scale forebody/inlet model of the F/A-18 at a Mach number of 0.20, an angle-of-attack of 60 deg, and a side-slip angle of 10 deg. The main purpose of these calculations is to support an upcoming wind-tunnel test program in the prediction of engine inlet compressor face total pressure recovery and flow distortion. The GRIDGEN system was used to generate a grid which includes the inlet and lip, and other aircraft components which are considered to be important to inlet performance, such as the ramp/splitter plate, the diverter and slot, and the deflected leading edge flap. PARC3D shows complex flow patterns on the fuselage surfaces below the leading edge extensions, on the ramp/splitter plate, inlet lip, and inside the inlet. PARC3D tends to underpredict total pressure recovery and overpredict the flow distortion at the inlet compressor face.
Author (revised)

A93-49720*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
CALCULATION OF SCRAMJET INLET WITH THICK BOUNDARY-LAYER INGESTION
H. T. LAI, S. C. KIM (Sverdrup Technology, Inc., Brook Park, OH), and H. T. NAGAMATSU (Rensselaer Polytechnic Inst., Troy, NY) Jun. 1993 15 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(Contract NAS3-24105; NAS3-25266)
(AIAA PAPER 93-1836)

Numerical flowfields around a scramjet inlet model are simulated and analyzed. The present inlet flowfield is characterized by thick boundary-layer ingestion and strong viscous/inviscid interaction because of a combined effect of high hypersonic freestream Mach and low Reynolds numbers. Shock-induced separation further enlarges regions of viscous flows which occupy most of the inlet flowfield. Results obtained from the computations with the PARC code developed for ideal gas are presented for several 2D cases at various hypersonic Mach numbers ranging from 10 to 25, and two 3D simulations at Mach numbers of 12 and 19 are also discussed. Comparison between computation and experiment is made in terms of pressure distributions at the wall center line. Large discrepancy is observed and may be partially attributed to the lack of real gas and/or 3D effects in the simulation as well as to the uncertainty of the experiment.

A93-49721*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
NUMERICAL STUDY OF THE PERFORMANCE OF SWEPT, CURVED COMPRESSION SURFACE SCRAMJET INLETS
JOHN J. KORTE (NASA, Langley Research Center, Hampton, VA), D. J. SINGH (Analytical Services and Materials, Inc., Hampton, VA), AJAY KUMAR (NASA, Langley Research Center, Hampton, VA), and AARON H. AUSLENDER (Lockheed Engineering and Sciences Co., Hampton, VA) Jun. 1993 14 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-1837) Copyright

The paper describes a computational performance-enhancement study in which systematic modifications

were applied to a planar-sidewall compression scramjet inlet operating at an entrance Mach number of 4 and at a dynamic pressure of 2040 lbs/sq ft, and the performance of the modified inlet was compared to that of the original geometry by evaluating numerical flowfield solutions. The planar-sidewall compression angle was modified as a function of height using sidewall curvature and simultaneously employing both forward-swept and reverse-swept compression surfaces. The results of calculations illustrate the feasibility of obtaining enhanced performance via contour modifications of a baseline swept-sidewall compression scramjet inlet operating at an entrance Mach number of 4. AIAA

A93-49723#
CFD ANALYSIS AND TESTING ON A TWIN INLET RAMJET
LARS-ERIK ERIKSSON, ULF JOHANSSON, and RONALD BORG (Volvo Flygmotor, AB, Trollhattan, Sweden) Jun. 1993 13 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Research supported by Swedish Defence Materiel Administration refs
(AIAA PAPER 93-1839) Copyright

Testing and CFD activities within an ongoing ramjet technology program at Volvo Flygmotor are presented. Measurements and calculations on an isolated supersonic inlet, installed inlets and a twin inlet side dump combustor (non-reacting flow) have been performed using windtunnel and watertank facilities as well as several inhouse developed flow simulation computer codes. CFD analysis has also been used in the design of an inlet simulation rig for future tests of the combustor with reacting flow. The overall objectives of these activities have been to maintain and further develop experience and knowledge in the ramjet technology area and to apply modern CFD techniques, both for code validation purposes and as a tool in the design and development of inlets and combustors.

A93-49728*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
3-D VISCOUS FLOW CFD ANALYSIS OF THE PROPELLER EFFECT ON AN ADVANCED DUCTED PROPELLER SUBSONIC INLET
CHANTHY IEK, DONALD R. BOLDMAN (NASA, Lewis Research Center, Cleveland, OH), and MOUNIR IBRAHIM (Cleveland State Univ., OH) Jun. 1993 40 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Previously announced in STAR as N93-29162 refs
(AIAA PAPER 93-1847) Copyright

The time-marching Navier-Stokes code PARC3D was used to study the 3D viscous flow associated with an advanced ducted propeller subsonic inlet at take-off operating conditions. At a free stream Mach number of 0.2, experimental data for the inlet-with-propeller test model indicated that the airflow was attached on the cowl windward lip at an angle of attack of 25 deg became unstable at 29 deg, and separated at 30 deg. An experimental study with a similar inlet and without propeller (through-flow) indicated that flow separation occurred at an angle of attack a few degrees below the value observed when the inlet was tested with the propeller, indicating the propeller's favorable effect on inlet performance. In the present numerical study, flow blockage analogous to the propeller was modeled via a PARC3D computational boundary condition (BC), the 'screen BC', based on 1-1/2 dimension actuator disk theory. The application of the screen BC in this numerical study provided results similar to those of past experimental efforts in which either the blockage device or the propeller was used. Author (revised)

A93-49729#
ROTOR-ROTOR INTERACTION FOR COUNTER-ROTATING FANS. I - THREE DIMENSIONAL FLOWFIELD MEASUREMENTS
HYOUN-WOO SHIN, CHARLOTTE E. WHITFIELD, and DAVID C. WISLER (GE Aircraft Engines, Cincinnati, OH) Jun. 1993 15 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-1848) Copyright

The rotor wake/vortex flowfield generated in a scale model simulator of GE's counter-rotating Unducted Fan (UDF) engine was investigated using three-dimensional hot-wire anemometry. The purpose was to obtain a set of benchmark experimental aerodynamic data defining the rotor wake and vortex structure, particularly in the tip region, and to relate this observed flow structure to its acoustic signature. The tests were conducted in a large, free-jet anechoic chamber. Measurements of the three components of velocity were made at axial stations upstream and downstream of each rotor for conditions that simulate takeoff, cutback and approach power. Two different forward blade designs were evaluated. The tip vortices, the axial velocity defect in the vortex core and differences in the interaction of the wakes and vortices generated by the forward and aft rotor are used to explain differences in noise generated by the two different rotor designs. Part 1 presents the three dimensional flowfield measurements. Part 2, which will be presented later, will give an acoustic prediction using the measured data.

A93-49743*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
UNSTEADY AERODYNAMIC FLOW PHENOMENA IN A TRANSONIC COMPRESSOR STAGE
C. HAH (NASA, Lewis Research Center, Cleveland, OH), S. L. PUTERBAUGH, and W. W. COPENHAVER (USAF, Wright Lab., Wright-Patterson AFB, OH) Jun. 1993 12 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-1868)

A three-dimensional unsteady, viscous aerodynamic analysis has been developed for the flow inside a transonic, high-through-flow, single stage compressor. The compressor stage is comprised of a low-aspect-ratio rotor and a closely coupled stator. The analysis is based on a numerical method for solving the three-dimensional Navier-Stokes equation for unsteady viscous flow through multiple turbomachinery blade rows. The method solves the fully three-dimensional Navier-Stokes equation with an implicit scheme. A two-equation turbulence model with a low-Reynolds-number modification is applied for the turbulence closure. A third-order accurate upwinding scheme is used to approximate convection terms while a second-order accurate central difference scheme is used for the discretization of the viscous terms. A second-order accurate scheme is employed for the temporal discretization. The numerical method is applied to study the unsteady flow field inside a transonic, high-through-flow, axial compressor stage. The numerical results are compared with available experimental data.

A93-49744#
TIP SHOCK STRUCTURES IN TRANSONIC COMPRESSOR ROTORS
M. D. SELLIN, STEVEN L. PUTERBAUGH, and WILLIAM W. COPENHAVER (USAF, Wright Lab., Wright-Patterson AFB, OH) Jun. 1993 13 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-1869)

An experimental investigation of rotor-tip shock structures was performed for a series of three parametrically related transonic compressor rotors. Each is a high-speed, low-aspect-ratio, high-through-flow fan rotor, differing in levels of leading-edge sweep, throat margin, and suction-surface contouring. The data presented herein take the form of contour plots of rotor-tip pressures, as measured by steady and unsteady probes mounted in the rotor casing. These plots trace the evolution of the macroscopic tip flow structure as the rotors were throttled from choked flow, past peak efficiency, to a near-stall operating point. The flow structure progressed from a dual-shock system at open throttle, through a single leading-edge shock at peak efficiency, to a detached shock near stall. Evidence of a tip-leakage vortex is present in every contour. A comparison of flowfields between

rotors reveals negligible visible differences, regardless of design, yet the tip flow field is shown to have the greatest impact on overall rotor performance. Hence the differences in tip performance are attributable to phenomena not present in the ensemble-averaged unsteady casing pressures.

A93-49745#
STALL INCEPTION IN SINGLE STAGE, HIGH-SPEED COMPRESSORS WITH STRAIGHT AND SWEPT LEADING EDGES
K. M. BOYER, P. I. KING, and WILLIAM W. COPENHAVER (USAF, Wright Lab., Wright-Patterson AFB, OH) Jun. 1993 11 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-1870)

Two single-stage, transonic (relative flow) compressor designs (one rotor with straight leading edges, the second with swept leading edges) were tested under various undistorted inlet operating conditions to characterize the process leading up to aerodynamic stall. Extensive instrumentation measured the compressor steady performance, and eight high-response pressure transducers equally spaced around the annulus detected stall development. The latter measurements were spatially and temporally analyzed using discrete Fourier techniques. During transient closing of the compressor throttle and at all speeds tested for both designs, stall was preceded by the growth of small amplitude rotating waves. The amplitudes increased slowly until just prior to stall then grew rapidly into fully-developed rotating stall within 6-10 rotor revolutions. Pre-stall detection time for the rotating waves varied considerably with compressor operating condition, with times ranging from less than one-tenth of a second to more than two seconds depending on the shaft rotation speed. In general, pre-stall warning times were greater for the swept rotor.

A93-49779#
A STAGGERED FINITE VOLUME SCHEME FOR SOLVING CASCADE FLOW WITH A TWO-EQUATION MODEL OF TURBULENCE
FENG LIU and XIAOQING ZHENG (California Univ., Irvine) Jun. 1993 13 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Research supported by California Space Inst., Univ. of California, and NNSFC refs
(AIAA PAPER 93-1912) Copyright

A k-omega turbulence model by Wilcox (1988) is applied to cascade flow calculations. A staggered finite volume scheme is proposed to solve the compressible Reynolds-averaged Navier-Stokes equations and the k-omega model equations. The Navier-Stokes equations are solved with a cell-centered scheme while the k-omega equations are solved on staggered control volumes with k and omega defined at the cell-vertices of the original grid. By use of this combination of the cell-centered and cell-vertex schemes, the method maintains a small stencil for all diffusion terms and closely couples the Navier-Stokes and k-omega equations. This enhances the stability of the numerical computation. The method was first tested for a flat-plate flow, and the results compare well with empirical correlations. Application to cascade flow was conducted at design and off-design conditions. Good agreement with experimental data was achieved. The proposed discretization is applicable to other one- or two-equation turbulence models. Author (revised)

A93-49780#
AN UNSTRUCTURED GRID FLOW SOLVER FOR TURBOMACHINERY FLOWS
RICHARD J. MATUS and RICHARD J. LOUNSBURY (Fluent, Inc., Lebanon, NH) Jun. 1993 9 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-1913) Copyright

Rampant an unstructured flow solver developed at Fluent Inc., is used to compute three-dimensional, viscous, turbulent, compressible turbomachinery flow-fields. Rampant is a commercially available, finite-volume, explicit, m-stage Runga-Kutta time-stepping, multigrid flow solver capable of computing complex flowfields using either triangular (2D) or tetrahedral (3D) unstructured grids. The paper gives an overview of technical aspects of the Rampant flow solver and grid generation and presents flowfield solutions compared to experimental data for a cascade of turbine vanes, a transonic, axial-flow fan, and a sweptback, centrifugal compressor.

A93-49784#
ANALYSIS OF THE STABILITY CHARACTERISTICS OF HYPERSONIC FLOW OF A DETONABLE GAS MIXTURE IN THE STAGNATION REGION OF A BLUNT BODY
GENADI TIVANOV and JOSEF ROM (Technion - Israel Inst. of Technology, Haifa) Jun. 1993 11 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Research supported by Wolfson Family Charitable Trust, Ministry of Absorption, and Technion - Israel Inst. of Technology refs
(AIAA PAPER 93-1918) Copyright

An investigation is conducted of the stability characteristics of the hypersonic flow of a fuel/oxidizer mixture within the stagnation region of a blunt-nosed body, giving attention to the flow behind the detached shock wave and the detonation wave that may be generated behind the shock wave, but ahead of the blunt nose. It is shown that, using time-dependent flow equations that include chemical reactions, it is possible to obtain a second-order differential equation for the pressure. The calculated eigenvalues of the solutions are used to define oscillation stability boundaries, amplitudes, and frequencies. AIAA

A93-49788*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
AN ADAPTIVE GRID/NAVIER-STOKES METHODOLOGY FOR THE CALCULATION OF NOZZLE AFTERBODY BASE FLOWS WITH A SUPERSONIC FREESTREAM
MORGAN WILLIAMS, DENNIS LIM, and RONALD UNGEWITTER (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA) Jun. 1993 9 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Research sponsored by NASA refs
(AIAA PAPER 93-1922) Copyright

This paper describes an adaptive grid method for base flows in a supersonic freestream. The method is based on the direct finite-difference statement of the equidistribution principle. The weighting factor is a combination of the Mach number, density, and velocity first-derivative gradients in the radial direction. Two key ideas of the method are to smooth the weighting factor by using a type of implicit smoothing and to allow boundary points to move in the grid adaptation process. An AGARD nozzle afterbody base flow configuration is used to demonstrate the performance of the adaptive grid methodology. Computed base pressures are compared to experimental data. The adapted grid solutions offer a dramatic improvement in base pressure prediction compared to solutions computed on a nonadapted grid. A total-variation-diminishing (TVD) Navier-Stokes scheme is used to solve the governing flow equations.

A93-49791# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
INVESTIGATION OF A STRUT/ENDWALL INTERACTION IN SUPERSONIC ANNULAR FLOW
K. E. WILLIAMS (Washington Univ., Seattle), G. J. HARLOFF (Sverdrup Technology, Inc., NASA Lewis Research Center Group, Brook Park, OH), and F. B. GESSNER (Washington Univ., Seattle) Jun. 1993 15 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Research supported by NASA refs
(Contract NAG3-376; NAS3-25266)
(AIAA PAPER 93-1925) Copyright

A combined experimental and numerical investigation of strut/endwall interactions within an annular duct having a supersonic core flow has been conducted. Four diamond-shaped

struts with a 7 deg half angle were positioned circumferentially equidistant within an annular duct having a gap height of 0.7 strut chords, and an inner-to-outer wall radius ratio of 0.7. Turbulent boundary layers exist on both inner and outer walls of the duct, but have not merged. The core flow upstream of the struts is uniform at a nominal Mach number of 3.0 and a Reynolds number of 3 x 10 exp 5 based on the strut chord length. Experimental results, which include Pitot pressure distributions within the flow field, static pressure distributions on the inner and outer walls of the duct, and oil flow visualization on the centerbody and strut, are presented and compared with CFD predictions. Secondary flows associated with the interactions are examined including the trajectories of the horseshoe vortices formed at the leading and trailing edges of the strut and the trajectories of the vortices formed in the corner of the strut/endwall intersection. Author (revised)

A93-49794#
SHOCK TUNNEL EXPERIMENTS AND APPROXIMATIVE METHODS ON HYPERVELOCITY SIDE-JET CONTROL EFFECTIVENESS
K. W. NAUMANN, H. ENDE, G. MATHIEU, and A. GEORGE (St.-Louis French-German Research Inst., France) Jun. 1993 14 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-1929) Copyright

This paper presents experimental and theoretical investigations on the force, which is produced by the interaction of a laterally blowing jet with a hypervelocity cross-flow, i.e., the surface integral of the surface pressure increment. The experiments are carried out in the ISL shock tubes, which reproduce velocity, temperature, Mach- and Reynolds-number of tropospheric hypervelocity flow conditions. The experiments comprise millisecond aerodynamic force measurements and visualization by differential interferometry. The theoretical considerations make use of the blast wave analogy, which is coupled with a solution of the equivalent blunt body to improve the accuracy near the jet orifice. In a case, where the viscous effects are not dominant, the inviscid interaction force calculated by this improved blast wave analogy method agrees well with the experimental results.

A93-49795#
THE NUMERICAL CALCULATION ON THE FLOWFIELDS OF TRANSVERSE JET INTERACTION IN THE BASE OF VEHICLE AT SUPERSONIC SPEEDS
Z. H. WANG and C. Y. WANG (Changsha Inst. of Technology, China) Jun. 1993 7 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-1931) Copyright

A numerical calculation of 2D and axisymmetric jet interaction flow is here conducted by a novel flux-splitting implicit finite-volume method under an arbitrary nonorthogonal grid system. The results thus obtained indicate this method's superiority to the MacCormack explicit finite difference method in both stability and accuracy. In particular, the explicit scheme's convergence rate is greatly accelerated upon vectorization and macrotasking by the MIMD supercomputer employed. AIAA

A93-49819#
BOUNDARY CONDITION PROCEDURES FOR CFD ANALYSES OF PROPULSION SYSTEMS - THE MULTI-ZONE PROBLEM
W. W. ROMER and R. H. BUSH (McDonnell Douglas Corp., Saint Louis, MO) Jun. 1993 17 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-1971) Copyright

A genetic, multi-zone boundary condition procedure has been developed for computational fluid dynamics (CFD) analyses of propulsion flow fields. The zonal interface scheme employed requires neither overlap of adjacent grids nor a priori knowledge of the grid topology at the zone interface, thereby reducing the user interaction and computational overhead of this scheme when compared with others. This paper discusses the implementation of this boundary condition procedure in a three-dimensional CFD code and the development of a zonal interface boundary condition for multi-zone, non-overlapping grids with grid discontinuities at the zonal interfaces. Two formulations of the zonal interface scheme are presented: the first utilizes one-dimensional characteristic theory at the zone boundary, and the second treats the zone boundary as a flux cell interface in a Roe-type flux difference splitting scheme. The two formulations are compared using a simple oblique shock test case. Several advanced CFD applications are presented which utilize the subject boundary condition procedure, including the zonal interface scheme.

A93-49820*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
SUMMARY OF THE GASP CODE APPLICATION AND EVALUATION EFFORT FOR SCRAMJET COMBUSTOR FLOWFIELDS
SHIVAKUMAR SRINIVASAN, ROBERT D. BITTNER, and GLENN J. BOBSKILL (Analytical Services and Materials, Inc., Hampton, VA) Jun. 1993 16 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(Contract NAS1-19864)
(AIAA PAPER 93-1973) Copyright

Numerical simulations of 3D turbulent mixing and reacting flows have been systematically evaluated by comparison with experimental data and other numerical solutions to provide confidence in the General Aerodynamic Simulation Program (GASP) code version 1.3. Specifically, the GASP flow solver has been used to model high speed flow through scram jet combustors. Unit injector problems evaluated include (1) UVA staged sonic normal injection of air into Mach 2 air stream, (2) the VPI Mach 1.7 low angled (15 deg) flush wall helium injection into an unconfined Mach 6 'cold air' stream, and (3) the HYPULSE angled (30 deg) flush wall hydrogen injection into a Mach 6, high enthalpy (flight Mach 17 simulation) nitrogen and air test gases. Results of the numerical simulation for the first two test cases have been compared with detailed in-stream measurements and with SPARK CFD solutions. The results for the last two cases have been compared with measured wall pressure and heat flux data and with SPARK CFD solutions. The present GASP solutions compare favorably with both the experimental data and the SPARK solutions. Author (revised)

A93-49821#
SECONDARY FLOW COMPUTATION BY MEANS OF AN INVISCID MULTIGRID FINITE VOLUME LAMBDA FORMULATION
FRANCESCO CASALINI and ANDREA DADONE (Bari, Politecnico, Italy) Jun. 1993 12 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Research supported by MURST refs
(AIAA PAPER 93-1974) Copyright

An accurate inviscid flow computational technique, the Finite Volume Lambda Formulation, is presented together with a new multigrid strategy. In order to numerically prove the remarkable improvement of the convergence rate due to the new multigrid strategy, a two-dimensional flow is computed by employing different mesh sizes and a different number of grid levels. Secondary flows in a contracting, 90 degree, rectangular variable area channel and inside a turbine cascade are then computed and the advantages of the new multigrid strategy are proven again. Finally the merits of the Finite Volume Lambda Formulation are demonstrated by comparison of the computed results with other published numerical results as well as with experimental data.

A93-49822#
AN UNSTRUCTURED ADAPTIVE QUADRILATERAL MESH-BASED SCHEME FOR VISCOUS TURBOMACHINERY FLOW CALCULATIONS
SCOTT M. RICHARDSON (USAF, Wright Lab., Wright-Patterson AFB, OH) Jun. 1993 13 p. AIAA, SAE, ASME, and ASEE,

Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-1975)

A method is presented for solving the quasi-3D Navier-Stokes equations on solution-adaptive unstructured meshes. The flow equations are written in a cell-vertex finite volume formulation and are solved using a five-step Runge-Kutta algorithm. The effect of turbulence is modeled using a k-epsilon model with low-Reynolds number effects included to allow a homogeneous wall boundary treatment. The scheme is implemented in a fully unstructured way to allow solution dependent adaption of the quadrilateral mesh in one or two directions. Simple cases are presented to validate the viscous terms and the turbulence model. Quasi-3D computations of flow through a transonic compressor cascade are compared with experimental data. Author (revised)

A93-49823#
THE EFFECTS OF TURBULENCE MODELING ON THE NUMERICAL SIMULATION OF CONFINED SWIRLING FLOWS
GERALD J. MICKLOW, MICHAEL R. HARPER (Florida Univ., Gainesville), and JOHN M. DEUR (Sverdrup Technology, Inc., Brook Park, OH) Jun. 1993 21 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-1976) Copyright

Modifications to a k-epsilon turbulence model for confined swirling flows in advanced gas turbine combustors are examined. Results obtained show that the turbulence model modifications have very little effect on the NO emission calculations for the Anderson LPP flame tube. As the swirl velocity for this case was zero, the modifications had little or no effect at all. For the axisymmetric can combustor the two test cases made better predictions of the axial velocity profiles than the base case. But none of the cases matched the experimental swirling velocity profiles which is attributed to inlet velocity. AIAA

A93-49825*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
TURBOFAN FLOWFIELD SIMULATION USING EULER EQUATIONS WITH BODY FORCES
RAMESH PANKAJAKSHAN, ABDOLLAH ARABSHAHI, and DAVID L. WHITFIELD (NSF, Computational Fluid Dynamics Lab.; Mississippi State Univ., Mississippi State) Jun. 1993 11 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(Contract NAG1-226)
(AIAA PAPER 93-1978) Copyright

A method for flow computations around ducted propfans is presented. The approach is to use the body force terms in the three-dimensional Euler equations to model the propeller. Numerical solutions are compared with experimental data for three ducted propfan configurations for different flow conditions.

A93-49827#
SIMULATION OF SHOCK-BOUNDARY LAYER INTERACTION IN A FAN BLADE PASSAGE
R. P. SHREEVE, D. D. MYRE, W. L. GOLDEN, JR., and C. C. COLLINS (U.S. Naval Postgraduate School, Monterey, CA) Jun. 1993 16 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Research supported by U.S. Navy refs
(AIAA PAPER 93-1980)

A cascade modeling of the flow through a transonic fan blade passage is attempted experimentally using a small blow down wind tunnel at M = 1.4. The model is scaled to allow investigation of separation alleviation techniques, resulting in the selection of two passages and one center-blade. Based on measurements of surface pressure, impact pressure surveys behind the model and flow visualization observations, it is concluded that the incorporation of boundary layer diversion from all four nozzle walls led to good two-dimensionality through a narrow model and that periodicity was affected by incidence changes. A viscous CFD solution and loss calculations following the method of Koch and Smith are compared with the experimental results.

A93-49855#
AN INVESTIGATION ON THE USE OF A HEAVY GAS TO IMPROVE THE PERFORMANCE OF THE EQUILIBRIUM INTERFACE TECHNIQUE IN SHOCK TUBE FLOWS
MARCO A. S. MINUCCI, MARCO A. C. NASCIMENTO (Centro Tecnico Aeroespacial, Inst. de Estudos Avancados, Sao Jose dos Campos, Brazil), and HENRY T. NAGAMATSU (Rensselaer Polytechnic Inst., Troy, NY) Jun. 1993 12 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2017) Copyright

A 0.3 m diameter Hypersonic Shock Tunnel has been designed and constructed to investigate the effect of a thin layer of a separating gas on the performance of the tunnel when operating in the equilibrium interface (EI) condition. The separating gas is placed between the driver gas, He, and the test gas, air. Preliminary experiments employing He, Ar and SF6 as the separating gases indicate a strong dependence of the final EI pressure on the gas used. The highest equilibrium pressure is attained when SF6 is used; the time required to reach this pressure is the shortest when compared to the other two gases tested. The separating gas acts as a gaseous piston enhancing the compression provided by the moving He/air interface. Tests involving the CO2 laser radiation absorption in SF6 were also conducted. These tests revealed not only the arrival of the gaseous piston at a given shock tunnel station but also the existence of SF6 leakage through the boundary layer. Author (revised)

A93-49856*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
NUMERICAL STUDY OF THE TRANSIENT FLOW IN THE DRIVEN TUBE AND THE NOZZLE SECTION OF A SHOCK TUNNEL
SUSAN TOKARCIK-POLSKY and JEAN-LUC CAMBIER (Eloret Inst., Palo Alto, CA) Jun. 1993 11 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(Contract NCC2-420; NCC2-487)
(AIAA PAPER 93-2018)

The initial flow in a shock tunnel was examined numerically using computational fluid dynamics (CFD). A finite-volume total variation diminishing (TVD) scheme was used to calculate the transient flow in a shock tunnel. Both viscous and inviscid, chemically nonreacting flows were studied. The study consisted of two parts, the first dealt with the transient flow in the driven-tube/nozzle interface region (inviscid calculations). The effects of varying the geometry in this region was examined. The second part of the study examined the transient flow in the nozzle (viscous calculations). The results were compared to experimental data.

A93-49858#
MOLECULAR MIXING OF JETS IN SUPERSONIC FLOW
CORIN SEGAL, JOHN D. ABBITT, and BRUCE F. CARROLL (Florida Univ., Gainesville) Jun. 1993 6 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2021) Copyright

An account is given of experimental methods and results obtained to date for the molecular-level mixing, mixing-combustion coupling effects, and performance-enhancing mixing and combustion control of supersonic mixing. The facility employed in these studies can operate over a wide range of initial conditions: 0.33-1.0 atm pressure Mach numbers 1.6-3.6, and temperatures to 1000 K. Attention is given to the experimental apparatus test section. AIAA

A93-49909#
COMPUTATIONAL ANALYSIS OF NONLINEAR AEROELASTIC PHENOMENA DURING STALL FLUTTER OF CASCADED AIRFOILS
F. SISTO, S. THANGAM, and T. CHEN (Stevens Inst. of Technology, Hoboken, NJ) Jun. 1993 9 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2082) Copyright

The nonlinear aeroelastic behavior of spanwise finite airfoil cascades during stall flutter is analyzed from a computational point of view. The structural characteristics of the airfoils are modeled using discretized beam theory and coupled with the unsteady aerodynamic analysis and solved simultaneously. The results indicate a multitude of interesting features of fundamental importance to turbomachinery. The frequency entrainment - wherein over an interval the fundamental stall frequency is entrained by the blade frequency - is observed for both pure and coupled mode vibration. The chaotic behavior that is common to nonlinear systems is observed in airfoil cascades when a coherent vibration is not present. In contrast when either of these modes dominate the other a well defined limit cycle behavior which is characteristic of stall flutter is shown to be present.

A93-49913*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
UNSTEADY AERODYNAMICS AND FLUTTER BASED ON THE POTENTIAL EQUATION
MILIND A. BAKHLE, THEO G. KEITH, JR. (Toledo Univ., OH), and MARC H. WILLIAMS (Purdue Univ., West Lafayette, IN) Jun. 1993 13 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(Contract NAG3-1234)
(AIAA PAPER 93-2086) Copyright

A time-domain three-dimensional full-potential solver is coupled with a linear structural dynamics model to investigate the unsteady aerodynamics and aeroelasticity of propfans. The solver allows calculations in multiple blade passages with independent blade motions. Aeroelastic calculations are performed in both frequency and time domains. Results are presented for two propfan configurations. Good agreement is seen between the full-potential results and results from linear theory since the flow is subsonic and the thickness of the propfan blades is small; the agreement is not as good for the cases in which the angle of attack is high. Some difficulty is encountered due to wave reflections from outer computational boundaries; however, this does not affect the results in the range of frequencies of interest.

A93-49914#
COMPRESSOR UNSTEADY AERODYNAMIC RESPONSE TO ROTATING STALL AND SURGE EXCITATIONS
KUK H. KIM and SANFORD FLEETER (Purdue Univ., West Lafayette, IN) Jun. 1993 15 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(Contract AF-AFOSR-91-0251)
(AIAA PAPER 93-2087) Copyright

An experimental investigation is presently conducted with a highly instrumented three-stage axial flow compressor to ascertain the fundamental aeromechanics of pure rotating stall, surge, and the unstable modified surge flow regimes that lie between these two modes. Forcing function data are analyzed in terms of the streamwise and transverse gust components of the mean rotor relative velocity. Rotating stall is found to excite a relatively constant rotor blade response; surge excites an unsteady response proportional to the level of surge that is present in the instability mode, thereby increasing as the instability mode parameter increases. AIAA

A93-49970*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
A COMPARATIVE STUDY OF FULL NAVIER-STOKES AND REDUCED NAVIER-STOKES ANALYSES FOR SEPARATING FLOWS WITHIN A DIFFUSING INLET S-DUCT
B. H. ANDERSON, D. R. REDDY, and K. KAPOOR (NASA, Lewis Research Center, Cleveland, OH) Jun. 1993 8 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2154) Copyright

A three-dimensional implicit Full Navier-Stokes (FNS) analysis and a 3D Reduced Navier Stokes (RNS) initial value space marching solution technique has been applied to a class of separated flow problems within a diffusing S-duct configuration characterized by vortex-liftoff. Both the FNS and the RNS solution technique were able to capture the overall flow physics of vortex lift-off, and gave remarkably similar results which agreed reasonably well with the experimental measured averaged performance parameters of engine face total pressure recovery and distortion. However, the Full Navier-Stokes and Reduced Navier-Stokes also consistently predicted separation further downstream in the M2129 inlet S-duct than was indicated by experimental data, thus compensating errors were present in the two Navier-Stokes analyses. The difficulties encountered in the Navier-Stokes separations analyses of the M2129 inlet S-duct center primarily on turbulence model issues, and these focused on two distinct but different phenomena, namely, (1) characterization of low skin friction adverse pressure gradient flows, and (2) description of the near wall behavior of flows characterized by vortex lift-off.

A93-49971#
AN INVESTIGATION OF SHOCK WAVE TURBULENT BOUNDARY LAYER INTERACTION WITH BLEED THROUGH NORMAL AND SLANTED SLOTS
A. HAMED, J. J. YEUAN, and S. H. SHIH (Cincinnati Univ., OH) Jun. 1993 8 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(Contract AF-AFOSR-91-0101)
(AIAA PAPER 93-2155) Copyright

The effect of bleed configuration in the interaction region of an oblique shock wave and a turbulent boundary layer was investigated using numerical simulations. The numerical solution to the compressible Navier Stokes equations reveals the flow details throughout the interaction zone and inside the slanted and normal bleed slots. Results are presented for an incident oblique shock of sufficient strength to cause boundary layer separation in the absence of bleed. Bleed is applied across the shock impingement point and different bleed mass flow rates are obtained by changing the plenum pressure. The results show the expansion/compression waves across the slot opening, and a recirculation zone inside the slot. The performance characteristics of the different bleed configurations are compared in terms of the discharge coefficient and the boundary layer characteristics downstream of the interaction, at bleed mass flow rates of up to 16 percent of the incoming boundary layer. Author (revised)

A93-49973*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
APPLYING AND VALIDATING THE RANS-3D FLOW-SOLVER FOR EVALUATING A SUBSONIC SERPENTINE DIFFUSER GEOMETRY
MICHAEL J. FLETCHER, MARK J. WON, GARY B. COSENTINO (NASA, Ames Research Center, Moffett Field, CA), and ALEXANDER TE (Sterling Federal Systems, Inc., Palo Alto, CA) Jun. 1993 17 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2157) Copyright

Subsonic inlet ducts for advanced, high-performance aircraft are evolving towards complex three-dimensional shapes for reasons of overall integration and weight. These factors lead to diffuser geometries that may sacrifice inlet performance, unless

careful attention to design details and boundary layer management techniques are employed. The ability of viscous computational fluid dynamic (CFD) analysis of such geometries to aid the aircraft configurator in this complex design problem is herein examined. The RANS-3D Reynolds-Averaged Navier-Stokes solver is applied to model the complex flowfield occurring in a representative diffuser geometry and the solutions are compared to experimental results from a static test of the inlet duct. The computational results are shown to compare very favorably with experimental results over a range of mass flow rates, including those involving large amounts of separation in the diffuser. In addition, a novel grid topology is presented, and two turbulence models are evaluated in this study as part of the RANS-3D code.

A93-50035#
A SIMPLIFIED APPROACH FOR CONTROL OF ROTATING STALL. I - THEORETICAL DEVELOPMENT
O. O. BADMUS, S. CHOWDHURY, K. M. EVEKER, C. N. NETT, and C. J. RIVERA (Georgia Inst. of Technology, Atlanta) Jun. 1993 30 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Research supported by U.S. Navy, NSF, and USAF refs
(AIAA PAPER 93-2229) Copyright

The theoretical foundations of a simplified approach for control of rotating stall are developed. This approach requires 2D sensing but only a single 1D axisymmetric effector with relatively low bandwidth requirements. The reduced actuation requirements of this approach are a consequence of the fact that in this approach one does not require or act upon rotating stall phase information. This is due to the fact that in this approach one does not seek to extend the theoretical stable axisymmetric flow range of the compressor. Rather, one seeks to directly address persistent disturbances which would otherwise throttle the equilibrium into the unstable axisymmetric flow range of the compressor. In addition, one seeks to enlarge the domains of attraction of linearly stable axisymmetric equilibria, thereby addressing impulsive disturbances which would otherwise perturb the system state beyond the domain of attraction of the stable axisymmetric equilibrium.
Author (revised)

A93-50036#
LOCAL NONLINEAR CONTROL OF STALL INCEPTION IN AXIAL FLOW COMPRESSORS
RAYMOND A. ADOMAITIS and EYAD H. ABED (Maryland Univ., College Park) Jun. 1993 9 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(Contract F49620-93-J-0186; NSF CDR-88-03012)
(AIAA PAPER 93-2230) Copyright

A combination of theoretical and computational nonlinear analysis techniques are used to study the scenario of bifurcations responsible for the initiation of rotating stall in an axial flow compressor model. It is found that viscosity tends to damp higher-frequency modes and so results in a sequence of bifurcations along the uniform-flow solution branch to stall cells of different mode number. Lower-mode stalled flow solutions are born in subcritical bifurcations, meaning that these equilibria will be unstable for small amplitudes. Secondary bifurcations, however, can render them stable, leading to hysteresis. Using throttle position as a control, we find that while the stall bifurcations are not linearly stabilizable, nonlinear state feedback of the first mode amplitude will reduce the hysteresis. This improves the nonlinear stability of the compression system near the stall margin.

A93-50037#
APPLICATION OF ANALOG COMPUTING TO REAL-TIME SIMULATION OF STALL AND SURGE DYNAMICS
J. MAGILL, J. BOND, J. DORSEY, and M. BROOKE (Georgia Inst. of Technology, Atlanta) Jun. 1993 12 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2231) Copyright

A method for real-time simulation of fast nonlinear dynamics, with particular application to stall and surge, is presented. The simulation takes advantage of advanced precision analog computing techniques. Though the simulator is not as easily reconfigured as a digital simulator, high execution speeds can be achieved with small circuits. A set of 'building blocks' for constructing analog computers is described. The essential element is an analog precision multiplier used to model nonlinearities, such as compressor characteristics, using polynomial approximations. A simulator for a simple compression system is used as a design example. Experimental results are presented for simulations conducted at up to ten times faster than real-time, with comparison to digital simulations to demonstrate accuracy of the analog circuits. Simulations for a single-spool turbojet are also presented.

A93-50038#
A SIMPLIFIED APPROACH FOR CONTROL OF ROTATING STALL. II - EXPERIMENTAL RESULTS
O. O. BADMUS, S. CHOWDHURY, K. M. EVEKER, C. N. NETT, and C. J. RIVERA (Georgia Inst. of Technology, Atlanta) Jun. 1993 32 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Research supported by U.S. Navy, NSF, and USAF refs
(AIAA PAPER 93-2234) Copyright

The objective of this paper is to provide experimental validation of the simplified approach to control of rotating stall developed by Badmus et al. (1993). The experimental rig utilized is a low-speed single-stage axial compressor rig. It is shown that the controller based on this approach has significant ability to reject persistent disturbances which cause the uncontrolled system to enter rotating stall. In addition, it is shown that the effective stable axisymmetric flow range of the compressor has been extended by this controller. This is a consequence of the fact that the controller enlarges the domains of attraction of linearly stable axisymmetric equilibria. The paper study also investigates the presence of rotating stall precursors in this rig, in order to determine the most appropriate signal processing to apply to sensor data prior to using it in the controller. In this rig, two first mode rotating stall precursors traveling at different speeds are found when appropriate spectral separation of measured data is performed. Author (revised)

A93-50039*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
A MODEL FOR THE SELECTIVE AMPLIFICATION OF SPATIALLY COHERENT WAVES IN A CENTRIFUGAL COMPRESSOR ON THE VERGE OF ROTATING STALL
PATRICK B. LAWLESS and SANFORD FLEETER (Purdue Univ., West Lafayette, IN) Jun. 1993 14 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Research supported by U.S. Army and NASA refs
(AIAA PAPER 93-2236) Copyright

A simple model for the stability zones of a low speed centrifugal compressor is developed, with the goal of understanding the driving mechanism for the changes in stalling behavior predicted for, and observed in, the Purdue Low Speed Centrifugal Research Compressor Facility. To this end, earlier analyses of rotating stall suppression in centrifugal compressors are presented in a reduced form that preserves the essential parameters of the model that affect the stalling behavior of the compressor. The model is then used to illuminate the relationship between compressor geometry, expected mode shape, and regions of amplification for weak waves which are indicative of the susceptibility of the system to rotating stall. The results demonstrate that increasing the stagger angle of the diffuser vanes, and consequently the diffusion path length, results in the compressor moving towards a condition where higher-order spatial modes are excited during stall initiation. Similarly, flow acceleration in the diffuser section caused by an increase in the number of diffuser vanes also results in the excitation of higher modes. Author (revised)

A93-50040#
SPATIAL DOMAIN CHARACTERIZATION OF ABRUPT ROTATING STALL INITIATION IN AN AXIAL FLOW COMPRESSOR
PATRICK B. LAWLESS, KUK K. KIM, and SANFORD FLEETER (Purdue Univ., West Lafayette, IN) Jun. 1993 15 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Research supported by U.S. Army refs
(AIAA PAPER 93-2238) Copyright

The detection of rotating stall precursors has become a focus of current research because of the desirability of implementing a control scheme well before a compressor enters a stall condition. To identify spatially coherent pressure waves which would serve as precursors to the development of an instability in the Purdue Axial Flow Research Compressor, sensitive electret microphones were uniformly distributed around the circumference of the compressor. Fourier analysis of simultaneously sampled data from these microphone arrays was employed to identify the development of dominant spatial modes in the pressure field in the compressor. The transition to stall was observed to be an abrupt process, with the eruption of a stall cell on rotor blades corresponding to a strong rise in the spatial mode magnitude. However, a weak, circumferentially distorted pressure wave was detected which began adjusting to the ultimate phase propagation velocity of the finite stall pattern from within 5 to 25 revolutions prior to a significant rise in the mode magnitude and the indication of a stall cell on the rotor blade. Comparison of the first and second harmonics of this signal indicate that this disturbance is represented in the spatial domain by an impulsive-type waveform, and thus likely represents a small, propagating flow separation. Author (revised)

A93-50041#
NUMERICAL SIMULATIONS OF THE UNSTART PHENOMENON IN A SUPERSONIC INLET/DIFFUSER
RUSTY A. BENSON and D. S. MCRAE (North Carolina State Univ., Raleigh) Jun. 1993 13 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(Contract F49620-92-J-0189)
(AIAA PAPER 93-2239) Copyright

The numerical investigation of the unsteady phenomenon of inlet unstart is continued. The Full Navier-Stokes equations are integrated in time using an explicit, multi-stage Runge-Kutta algorithm. The dynamic solution-adaptive grid algorithm developed by the authors has been coupled with the integration scheme in order to resolve the features of the flow and enhance the spatial accuracy of the solution. The current investigation focuses on including the effects of turbulence and extending the work to three dimensions. The modeling of turbulence is accomplished using the algebraic model of Baldwin and Lomax. Because of the large regions of axial reversed flow present in the unstart process, the turbulent backflow model of Goldberg is incorporated. Applications are to generic configurations in two and three dimensions.

A93-50051#
NUMERICAL AND EXPERIMENTAL INVESTIGATION OF TURBINE TIP GAP FLOW
G. CHEN, W. N. DAWES, and H. P. HODSON (Cambridge Univ., United Kingdom) Jun. 1993 11 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2253) Copyright

Tip leakage inside the gap between a blade tip and its endwall was studied by solving two-dimensional Navier-Stokes equations. The flow was compressible, and the Mach numbers varied from subsonic to supersonic. The Reynolds number based on the tip gap height was of the order of 10 exp 5. To verify the numerical flow solutions, a series of experiments was conducted on the same two-dimensional tip gap model. Calculated wall pressure distributions and mass flow rates agreed with measurements very well. Comparisons were also made between the discharge coefficients calculated by this numerical approach and the relevant cascade data found in different sources. Variations of the discharge coefficient with the pressure ratio and the tip gap aspect ratio were examined numerically. The effect of blade tip geometry on the discharge coefficient was demonstrated on flat and squealer types of blade tips. Both the numerical and experimental results showed that introducing an appropriate secondary jet into the tip gap had a tendency to reduce the discharge coefficient of the tip leakage. Author (revised)

A93-50053#
3-DIMENSIONAL INTERACTIONS IN THE ROTOR OF AN AXIAL TURBINE
H. P. HODSON, M. R. BANIEGHBAL (Cambridge Univ., United Kingdom), and G. M. DAILEY (Rolls-Royce, PLC, Derby, United Kingdom) Jun. 1993 10 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Research supported by Rolls-Royce, PLC and Defence Research Agency refs
(AIAA PAPER 93-2255) Copyright

This paper presents a study of the development of the three-dimensional flow field within the rotor blades of a low-speed large-scale axial flow turbine. Measurements have been performed in the rotating and stationary frames of reference. Time-mean data have been obtained using miniature 5-hole pneumatic probes while the unsteady development of the flow has been determined using 3-axis sub-miniature hot-wire anemometers. Additional information is provided by the results of blade-surface flow visualization experiments and surface mounted hot-film anemometers. The development of the stator exit flow, as it passes through the rotor blades, is described. Unsteady data suggest that the presence of the rotor secondary and tip leakage flows restrict the region of unsteady interaction to near mid-span when the stator wakes and secondary flows are adjacent to the suction surface. Surface-mounted hot-film data show that this affects the suction-side laminar-turbulent transition process.

A93-50054#
3-D EULER SIMULATION OF VANE-BLADE INTERACTION IN A TRANSONIC TURBINE
K. V. RAO and R. A. DELANEY (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN) Jun. 1993 14 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(Contract F33615-90-C-2028)
(AIAA PAPER 93-2256)

This paper presents results of a computational investigation of turbine vane-blade interaction. A 3-D unsteady Euler code developed for this study is described and predictions are presented for a transonic turbine stage which was tested in a short-duration shock tunnel. The code is based on a O-H grid system and employs an explicit five stage Runge-Kutta time-marching algorithm. Predicted airfoil surface unsteady and time-averaged vane and blade pressure distributions are compared with Kulite pressure transducer measurements and previous 2-D unsteady Euler computations. Time-averaged unsteady calculations are also compared with coupled 3-D steady vane and blade row Euler predictions in which circumferentially averaged boundary data were transferred between the rows at an interface boundary.

A93-50055#
A SIMPLIFIED REPRESENTATION OF THE OFF-DESIGN CHARACTERISTICS OF HIGH SPEED, HIGH PRESSURE RATIO AXIAL TURBOMACHINERY STAGES
R. E. GRAY and M. DAHLSTROM (USAF, Wright Lab., Wright-Patterson AFB, OH) Jun. 1993 14 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2257)

A method for calculating compressor or fan stage mean line characteristic variables and a simplifying transformation of these variables in terms of stage velocity ratio are presented. The proposed transformation yields incompressible images of the work and pressure coefficient characteristics of an axial compressor or

fan stage. The transformation makes it possible to reduce the representation of stage pressure coefficient characteristics to a single curve, even when compressibility effects are quite prominent. AIAA

A93-50086#
LOW SPEED TEST RESULTS OF SUBSONIC, TURBOFAN SCARF INLETS
T. S. CRUM, D. E. YATES, T. L. ANDREW, and N. O. STOCKMAN (GE Aircraft Engines, Cincinnati, OH) Jun. 1993 11 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2301) Copyright

A low speed, scale model test program was conducted to assess the performance characteristics of the scarf inlet concept. The primary purpose of the test program was to develop scarf inlet design sensitivities and to supplement the existing experimental database to include the range of current inlet performance requirements. The performance characteristics of two scarf inlets are compared to a conventionally designed inlet to determine the advantages and disadvantages of the concept.

A93-50087#
HIGH SPEED TEST RESULTS OF SUBSONIC, TURBOFAN SCARF INLETS
T. L. ANDREW, D. E. YATES, T. S. CRUM, N. O. STOCKMAN, and M. O. LATAPY (GE Aircraft Engines, Cincinnati, OH) Jun. 1993 13 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2302) Copyright

Three subsonic turbofan inlets were designed and tested to determine the effect of scarfing on aerodynamic performance. Relative to conventional inlets, the keel of a scarfed inlet is extended forward of the crown while maintaining a planar hilite. The scarf angles of the three inlets were zero, 10, and 20 deg. High-speed isolated scale-model wind tunnel testing was conducted to determine external profile drag and internal total pressure recovery. The test conditions varied were inlet flow rate, angle-of-attack, and freestream Mach number. Author (revised)

A93-50088#
ADVANCED SST AUXILIARY AIR INTAKES DESIGN AND ANALYSIS
THIERRY BARDAGI and JEAN-LOIC LECORDIX (SNECMA, Centre de Villaroche, Moissy-Cramayel, France) Jun. 1993 12 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Research supported by Direction Generale de l'Aviation Civile refs
(AIAA PAPER 93-2304) Copyright

Within the context of future supersonic transport propulsion, Snecma carried out a study on the variable-cycle engine aerodynamic integration. In the takeoff and subsonic flight phase, auxiliary air intakes located in the nacelle walls are necessary for the auxiliary fan air supply. This paper deals with the design and optimization of these air intakes. Aerodynamic optimization of the air intake has been realized numerically, first by Euler 2D CFD computations and boundary layer calculations, then air intake design was performed by means of CAD and 3D Euler aerodynamic calculations. The results of these calculations were used to design the final concept. A test scale model was designed to study several concepts in the ONERA transonic wind tunnel S3CH in Meudon. Instrumentation which analyzes the aerodynamic flow included wall static pressure measurement sensors and in particular a rake for flow measurement at the engine station, fitted with dynamic sensors (Kulite) which measurements are analyzed in real time. The local aerodynamic measurements were compared with calculation results. Then global performance of the system has been displayed (efficiency and distortion data).

A93-50089#
AN EXPERIMENTAL STUDY OF SUPERSONIC AIR-INTAKE WITH 5-SHOCK SYSTEM AT MACH 3
KIMIO SAKATA, RYOJI YANAGI, AKIRA MURAKAMI, SHIGEMI SHINDO (National Aerospace Lab., Tokyo, Japan), SHINJI HONAMI, TAKAAKI SHIZAWA, KAZUYUKI SAKAMOTO (Tokyo Science Univ., Japan), KAZUO SHIRAISHI, and JUNSUKE OMI (Ishikawajima-Harima Heavy Industries Co., Ltd., Tokyo, Japan) Jun. 1993 9 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Research supported by New Energy and Industrial Technology Development Organization refs
(AIAA PAPER 93-2305) Copyright

Supersonic air-intake for future high-speed air-breathing engines was investigated experimentally. The two dimensional mixed-compression air-intake model designed for Mach 3 was tested in a supersonic wind tunnel at National Aerospace Laboratory (NAL) to provide the fundamental data for design technology of supersonic air-intakes. This model is the 5-shock compression system with an isentropic compression surface on the cowl and has variable geometry passage. The ramp and cowl bleed, throat slot and sidewall bleed at the throat region were adopted to achieve the high total pressure recovery and the stability. The total pressure recovery, mass flow ratio and wall static pressure distributions were measured and the flow structure was also visualized by means of Schlieren method. The effects of sidewall configuration, bleed system modification and vortex generator in the diffuser on the total pressure recovery were evaluated experimentally and the flow characteristics were investigated. By optimizing the bleed and the passage configurations, the best case of the model demonstrated the total pressure recovery as high as 0.85, which is higher than the project target 0.81, MIL-Specification at Mach 3.

A93-50090#
TWO-DIMENSIONAL NUMERICAL SIMULATION FOR MACH-3 MULTISHOCK AIR-INTAKE WITH BLEED SYSTEMS
JUNSUKE OMI, KAZUO SHIRAISHI (Ishikawajima-Harima Heavy Industries Co., Ltd., Tokyo, Japan), KIMIO SAKATA, AKIRA MURAKAMI (National Aerospace Lab., Tokyo, Japan), SHINJI HONAMI (Tokyo Science Univ., Japan), and JUNJI SHIGEMATSU (Ishikawajima-Kogyo Co., Ltd., Tokyo, Japan) Jun. 1993 10 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Research supported by New Energy and Industrial Technology Development Organization refs
(AIAA PAPER 93-2306) Copyright

A two-dimensional numerical study for Mach-3 multishock air-intake with bleed system was carried out by solving the compressible Navier-Stokes equations. The intake model used for numerical calculations is the configuration of the wind tunnel model, which consists of five-shock mixed-compression air-intake including isentropic compression on the cowl. This simulation code is based on the implicit TVD scheme. The code is able to capture the strong discontinuities such as shock wave without spurious oscillations. In this study, the bleed systems including ramp, cowl, and throat slot bleed are closely modeled on the experimental configurations and conditions in order to evaluate these effects of the bleed system for achievement of the high total pressure recovery and flow stability. The optimization of the bleed system was executed by the numerical parametric study of the various bleed conditions. The effect of the bleed system on the intake performance such as total pressure recovery could be evaluated numerically by the present code. Author (revised)

A93-50119#
USING A DIAGONAL IMPLICIT ALGORITHM TO CALCULATE TRANSONIC NOZZLE FLOW
HONGQING HE, XIAO HOU, XINPING WU, and TIMIN CAI (Northwestern Polytechnical Univ., Xian, China) Jun. 1993 6 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Research supported by NNSFC refs
(AIAA PAPER 93-2345) Copyright

The paper presents two-dimensional unsteady Euler equations in arbitrary normal curved coordinate system, derives the implicit

difference form of their diagonal type, and, using the obtained diagonal implicit algorithm, calculates flowfields of rectangular and axisymmetric nozzles. The calculated results are compared with results of measurements and with calculations using the commonly used implicit decomposition algorithm. It is shown that, under conditions of the same mesh and precision, the diagonal implicit algorithm saves about one half of the CPU time compared with the commonly used implicit decomposition algorithm. AIAA

A93-50120#
A COMPARISON BETWEEN CENTERED AND UPWIND SCHEMES FOR TWO-PHASE COMPRESSIBLE FLOWS
E. DANIEL, R. SAUREL, M. LARINI, and J. C. LORAUD (Aix-Marseille I, Univ., Marseille, France) Jun. 1993 7 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2346) Copyright

Two different approaches are developed for the treatment of a compressible two-phase flow. Both of these approaches are Eulerian instead of mixed methods generally used (Lagrangian for the particles phase and Eulerian for the gas phase). The Eulerian approach is less computer time intensive and can be very attractive for its simplicity. We first discuss the different assumptions which lead to conservative or nonconservative systems, and to hyperbolic systems or degenerated hyperbolic systems. We solve one kind of these systems by a central scheme and another simpler system by an upwind scheme. This last method is based on a second order Godunov type scheme, and the solution for a Riemann problem for the particle phase behavior equations is proposed here. The physical problem chosen as a test case is a difficult one because the two-phase nature of the flow results from the injection of liquid droplets into a gaseous inviscid stream in a nozzle. When injection of particles in the nozzle is considered two kinds of flow are encountered: a one-phase flow upstream the injection and a two-phase flow downstream. Some difficulties appear at the frontier between the single phase and the two-phase flow. Finally, results from the two models and the two numerical schemes are compared. We conclude that the upwind scheme is more suitable for complex configurations.

A93-50121*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
A NUMERICAL ANALYSIS OF SUPERSONIC FLOW OVER AN AXISYMMETRIC AFTERBODY
P. K. TUCKER (NASA, Marshall Space Flight Center, Huntsville, AL) and WEI SHYY (Florida Univ., Gainesville) Jun. 1993 27 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2347) Copyright

The performance of a pressure-based algorithm and the k-epsilon type turbulence models, including the original formulation proposed by Jones and Launder (1972), model extensions for refined treatment of time scales, and model corrections developed for treating compressible flows is assessed by analyzing the near-wake region of a Mach 2.5 flow over an axisymmetric cylindrical afterbody. The mechanisms responsible for the different levels of performance of the various turbulence models for the flow are investigated. It is shown that the k-epsilon models extended to allow for better response to the mean strain rate and corrected for compressibility result in better flowfield predictions than the original k-epsilon model. AIAA

A93-50150#
MULTISTAGE TURBOMACHINERY FLOW SOLUTIONS USING THREE-DIMENSIONAL IMPLICIT EULER METHOD
SHIH H. CHEN and GEORGE H. PRUEGER (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA) Jun. 1993 12 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2382) Copyright

A compressible solution method for a three-dimensional multistage turbomachinery flow is described in this paper. This method is derived from the Beam and Warming implicit approximate factorization (AF) finite difference scheme. A combination of second order implicit dissipation and mixed second/fourth order explicit dissipation is adopted. A spatially varying time step is used to improve the convergence rate. A circumferential averaging procedure is implemented at the mixing planes between blade rows. This mixing plane modeling allows circumferentially nonuniform fluxes at the mixing planes, but maintain the circumferentially averaged values being seen by the two rows. The three-dimensional multistage H-type grid is generated using IGB code. Solutions from the SSME High Pressure Fuel Turbopump (HPFTP) 2-stage turbine calculation are demonstrated. Comparison is made with test data collected at NASA Marshall Space Flight Center.

A93-50151#
ESTABLISHING TWO-DIMENSIONAL FLOW IN A LARGE-SCALE CASCADE OF CONTROLLED-DIFFUSION COMPRESSOR BLADES
G. V. HOBSON, M. WEBER, and D. DOBER (U.S. Naval Postgraduate School, Monterey, CA) Jun. 1993 15 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2383) Copyright

An arrangement of suction slots was installed in the endwalls of a low-speed cascade tunnel with a set of controlled-diffusion compressor blades as the test profiles. The aim was to improve the flow two-dimensionality through the installed blades, to enable suction-side flow separation at high incidence. The slots were located 17.25 inches upstream of the test section. Measurements were taken, at a Reynolds number of 711,000 and an inlet flow angle of 44.4 deg, upstream and downstream of the test section to determine the effect of varying suction. Three-component fiber-optic laser Doppler velocimetry surveys were conducted to characterize the downstream endwall vortex system. Baseline no-suction pneumatic measurements showed that the tunnel endwall boundary layers were asymmetric. Comparison of similar measurements for varying suction with the baseline showed that the axial velocity ratio could be decreased by almost 2 percent; however the inlet flow asymmetry persisted. The laser anemometry measurements clearly showed the endwall secondary flows which resulted in an interaction of counterrotating vortices.
Author (revised)

A93-50154#
STATOR RELATIVE, ROTOR BLADE-TO-BLADE NEAR WALL FLOW IN A MULTISTAGE AXIAL COMPRESSOR WITH TIP CLEARANCE VARIATION
I. N. MOYLE, R. P. SHREEVE, and G. J. WALKER (U.S. Naval Postgraduate School, Monterey, CA) Jun. 1993 8 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Research supported by U.S. Navy refs
(AIAA PAPER 93-2389) Copyright

Large cyclical pressure excursions from stator-averaged values are observed on the suction side of a rotor blade at the case wall in a multistage compressor as the rotor moves relative to the stator. The pressure changes correlate well with stator relative position, occur in the passage away from the blade and are only slightly modified by tip clearance changes. Close to the entry and exit of the tip gap, however, the pressures remain stable. The pressures near the gap are only slightly affected by stator proximity and primarily vary with tip gap height.

A93-50221*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
A NUMERICAL STUDY OF THE UNSTEADY PROCESSES ASSOCIATED WITH THE TYPE IV SHOCK INTERACTION
CHARLES A. LIND and MARK J. LEWIS (Maryland Univ., College Park) Jun. 1993 27 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(Contract NAG1-1333-S1)
(AIAA PAPER 93-2479) Copyright

A time-dependent ADI formulation of the two dimensional Navier-Stokes equations coupled with the total variation diminishing (TVD) scheme is used to examine the type IV shock interaction time accurately. The experimentally measured and computationally calculated unsteadiness of the type IV interaction is shown to be related to the formation and shedding of shear layers in the shock layer, and the frequency of oscillation of the jet is a strong function of the shedding rate of these shear layers. For one particular geometry, an oscillation frequency of 1.4 kHz was calculated. The effects of shock impingement angle and shock strength on the location and magnitude of the peak pressure are also identified. In one case it is shown that a 1-deg change in the impinging shock angle can alter the location of the associated jet by almost 11 deg with a change in the peak surface pressure of 32 percent.
Author (revised)

A93-50222#
A STUDY OF INCIPIENT SEPARATION LIMITS FOR SHOCK-INDUCED BOUNDARY LAYER SEPARATION FOR MACH 6 HIGH REYNOLDS FLOW
D. FREW, L. GALASSI, D. STAVA (USAF, Wright Lab., Wright-Patterson AFB, OH), and D. AZEVEDO (Pratt & Whitney Group, West Palm Beach, FL) Jun. 1993 12 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2481)

The results of a recent investigation of a shock-wave/turbulent boundary layer interaction study at nominal Mach numbers between 5 and 6 are presented. The purpose of the study was to quantify the relative influence of boundary layer transition, Reynolds number, and aspect ratio on the 2D incipient separation limit. The proximity of the shock wave/boundary layer interaction to the end of the flat-plate boundary layer transition (defined as the peak heating location) has a first-order effect on time incipient separation angle. The interaction region needs to be positioned at least 50 boundary layer thicknesses downstream of the peak heating location to obtain the 'fully turbulent' trend of increasing incipient separation angle with increasing Reynolds number based on boundary layer thickness, Re-delta. By decreasing the duct aspect ratio, the incipient separation angle decreases, due to 3D effects caused by the shock/boundary layer interaction on the sidewalls.
Author (revised)

A93-50278*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
THREE-DIMENSIONAL FLOW FIELD IN A TURBINE NOZZLE PASSAGE
M. ZACCARIA, D. RISTIC, and B. LAKSHMINARAYANA (Pennsylvania State Univ., University Park) Jun. 1993 19 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(Contract NSG-3555)
(AIAA PAPER 93-2556) Copyright

Detailed measurements were taken in the nozzle of a low speed single stage axial flow turbine at two axial planes inside the nozzle and on the nozzle and endwall surfaces. Velocity, turbulence and angle measurements were taken at midchord with an LDV while a five hole probe was used to measure the pressure, velocities and angles just upstream of the trailing edge. Nozzle surface and endwall static pressures were also measured. These measurements were compared to measurements previously completed at two axial planes downstream of the nozzle. The results show that at midchord, the secondary flow seems to be weak and it is in the early stages of development. Just upstream of the trailing edge, the secondary flow is clearly visible. The radially inward flow near the suction surface augments the casing passage vortex, while counteracting the hub passage vortex. Traveling downstream, the casing passage vortex remains strong while at the hub, the radially inward flow of the suction surface boundary layer has reversed direction due to the rotating hub. The blade static pressures and the passage averaged velocities compare well with Katsanis' quasi-three-dimensional code. These and other data are presented, interpreted and synthesized to understand the nozzle flow field.

A93-50286#
3D PARC NAVIER-STOKES ANALYSIS OF AN HSCT SUPPRESSOR NOZZLE SECONDARY INLET LIP AND DUCT
JEFFREY J. BROWN (Boeing Commercial Airplane Group, Seattle, WA) Jun. 1993 9 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2568) Copyright

An innovative, hybrid body-fitted grid/embedded grid scheme has been developed to allow three-dimensional (3D) Navier-Stokes analysis of the flowfield in a secondary inlet and secondary duct in a suppressor nozzle under consideration for High Speed Civil Transport applications. The PARC code was used in these calculations, and the use of this method in the aerodynamic design of the secondary inlet and duct is discussed in this paper.

A93-50288*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
INTERNAL PERFORMANCE OF HIGHLY INTEGRATED DEPLOYABLE EXHAUST NOZZLES
JOHN G. TAYLOR (Rolls-Royce, Inc., Atlanta, GA), SCOTT C. ASBURY, MARY L. MASON, and MILTON LAMB (NASA, Langley Research Center, Hampton, VA) Jun. 1993 15 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Research supported by Defence Research Agency of United Kingdom refs
(AIAA PAPER 93-2570) Copyright

The internal performance characteristics of Highly Integrated Deployable Exhaust Nozzles (HIDEN) applicable to advanced short take-off and vertical landing aircraft have been investigated. Four nozzle concepts, designed for fan and core flow installations, were tested with varying contraction ratio and nozzle exit plane shape. In addition, two offtake duct designs, along with several centerbody and blocker geometries were tested to evaluate their effect on the static thrust and flow performance. This investigation was conducted in the static test facility of the NASA Langley 16-Foot Transonic Tunnel. A six-component strain-gage balance collected force and moment data, and static pressure, total pressure, and total temperature measurements were also made internal to the model. Room temperature, dry high-pressure air was used to simulate jet exhaust. The results indicate that the internal performance of these HIDEN concepts is comparable to previously tested nozzle concepts designed for thrust vectoring about a bearing plane. This report presents the configuration design of the HIDEN concepts and the results of the internal performance testing.

A93-50289#
DECREASING F-16 NOZZLE DRAG USING COMPUTATIONAL FLUID DYNAMICS
JEFFREY A. CATT, TRACY J. WELTERLEN (Lockheed Corp., Fort Worth, TX), and JEFFREY M. RENO (General Electric Co., Cincinnati, OH) Jun. 1993 10 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2572) Copyright

Results of a two-dimensional computational fluid dynamics sensitivity study, focused on decreasing F-16 afterbody drag, are presented. These results may allow Lockheed and General Electric to refine the F110 engine installation, with the intent of decreasing F-16 drag and securing a net increase in range. Drag increments were evaluated in comparison to the baseline F110 installation by integrating afterbody pressures predicted by Lockheed's HAWK2D full Navier-Stokes flow solver. A sensitivity study was developed to investigate the effect of lengthening the nozzle, eliminating aft-facing steps in the afterbody contour, and altering the shape of the nozzle external contour. The Design of Experiments (or Taguchi) methodology was used to approximate the results of a full parametric evaluation while evenly distributing as few as ten configurations over the entire design space. Sensitivity study results

indicate that both lengthening the nozzle and eliminating aft-facing steps have a significant impact on drag. Variations in nozzle external contour had little impact on drag, although local surface pressure variations changed significantly.

A93-50290#
AERODYNAMICS DESIGN OF CONVERGENT-DIVERGENT NOZZLES
R. REBOLO, P. ARREDONDO, A. MATESANZ, A. VELAZQUEZ (Sener Ingenieria y Sistemas, S.A., Madrid, Spain), and M. RODRIGUEZ (Sener Ingenieria y Sistemas, S.A.; Madrid, Univ. Politecnica, Spain) Jun. 1993 6 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2574) Copyright

To help in the aerodynamics design of convergent-divergent nozzles, a semiempirical method, which takes into account one-dimensional theory plus experimental correlations, is presented. Improvement over previous similar analysis consists of the implementation of the influence of convergent angles. Both velocity and discharge coefficients and loads distributions along petals are obtained from the study. The results are compared with those obtained from an experimental set up.

A93-50292#
3-D TURBOMACHINERY EULER AND NAVIER-STOKES CALCULATIONS WITH A MULTIDOMAIN CELL-CENTERED APPROACH
A. M. VUILLOT, V. COUAILLIER, and N. LIAMIS (ONERA, Chatillon, France) Jun. 1993 11 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Research supported by SNECMA refs
(AIAA PAPER 93-2576; ONERA, TP NO. 1993-106) Copyright

This paper describes a solver for the simulation of steady three-dimensional inviscid or viscous compressible flows. The theoretical models are respectively the Euler equations and the averaged Navier-Stokes equations associated with a turbulence model. This solver featuring a cell-centered approach for multidomain structured meshes, is derived from previous multidomain solvers developed at ONERA with a cell-vertex approach. It preserves their capability of dealing with adjacent domains with nodes coincident or not, and possibly overlapping domains. At the same time it avoids the typical cell-vertex difficulties raised by the multiple points, where several boundary and/or matching conditions have to be applied. The implementation of the new approach is absolutely general, independent of the domain decomposition and enhance the robustness and ease of use of the solver for complex industrial configurations. We show applications for an experimental viscous channel 2-D flow, an inviscid turbine stator 3-D flow and a viscous linear cascade 3-D flow.

A93-50293#
NUMERICAL SIMULATIONS OF FLOWS IN CENTRIFUGAL TURBOMACHINERY
DANIEL J. DORNEY, ROGER L. DAVIS (United Technologies Research Center, East Hartford, CT), and DENNIS K. MCLAUGHLIN (Pennsylvania State Univ., University Park) Jun. 1993 17 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2578) Copyright

A quasi-three-dimensional Navier-Stokes analysis has been extended and applied to flows in centrifugal turbomachinery blade rows. The numerical procedure was validated using a radial fan geometry typical of those found in fossil fuels plants and air handling systems. The predicted blade loading and performance characteristics showed excellent agreement with the experimental data. The numerical analysis was then applied to a low aspect ratio centrifugal impeller. Inviscid and viscous flow simulations were performed at three operating conditions. While steady solutions were obtained in the inviscid flow calculations, the appearance of an oscillating separation bubble on the pressure surface of the impeller necessitated that the viscous flow simulations be time dependent. By comparing the predicted and experimental circumferential distributions of the relative frame velocity and flow angle downstream of the impeller, it was hypothesized that in the experiments the end wall secondary flows energized the impeller suction surface boundary layer, making the flow locally behave like an inviscid fluid. The performance curve generated from the viscous calculations showed satisfactory agreement with the experimental data, while the inviscid calculations overpredicted the performance of the impeller. It was concluded that the physics retained in quasi-three-dimensional analysis are adequate for accurately predicting flow trends in certain types of centrifugal turbomachinery. Author (revised)

A93-50962
NONTRADITIONAL METHODS OF CONTROLLING THE STABILITY OF A LAMINAR SUBSONIC BOUNDARY LAYER [O NETRADITSIONNYKH SPOSOBAKH UPRAVLENIYA USTOJCHIVOST'YU LAMINARNOGO DOZVUKOVOGO POGRANICHNOGO SLOYA]
A. V. KAZAKOV, M. N. KOGAN, V. A. KUPAREV, and A. P. KURYACHIJ TsAGI, Trudy no. 2412 1988 p. 3-32. In RUSSIAN refs
Copyright

The paper is concerned with the possibility of increasing the stability of a laminary boundary layer and delaying the turbulent transition by accelerating a stream of a charged gas in the boundary layer by electrostatic forces or by heating part of the body in the path of flow. The characteristics of non-self-similar boundary layer flow are determined by numerical integration. The flow stability parameters for each boundary layer cross section are calculated in the plane-parallel approximation using a linear stability theory. AIAA

A93-50965
MINIMIZING THE WALL EFFECTS IN WIND TUNNELS WITH A SECTIONAL PRESSURE CHAMBER [MINIMIZATSIYA VLIYANIYA STENOK V TRUBAKH S SEKTSIONIROVANNOJ KAMEROJ DAVLENIYA]
K. G. SAYADYAN TsAGI, Trudy no. 2414 1989 p. 14-25. In RUSSIAN refs
Copyright

The induction effect of porous wind tunnel walls on flow past an airfoil is investigated theoretically for the case where the desired pressure distribution is set in an external pressure chamber with an arbitrary number of sections. For subsonic and transonic regimes with weakly developed supersonic regions, analytical expressions are obtained for the additional velocity due to the wall effect, and conditions are determined under which the velocity becomes zero with a specified accuracy. The effect of the porous walls on flow past an airfoil is analyzed, and an algorithm is developed for calculating the pressure levels in the external chamber that are required to minimize this effect. AIAA

A93-50966
SUBSTITUTION OF ORIENTED DIFFERENCES FOR CENTRAL DIFFERENCES IN A PROGRAM FOR CALCULATING SMOOTH SUPERSONIC FLOWS [ZAMENA TSENTRAL'NYKH RAZNOSTEJ NA ORIENTIROVANNYE V PROGRAMME RASCHETA GLADKIKH SVERKHZVUKOVYKH TECHENIJ]
YU. YA. MIKHAJLOV and G. G. NERSESOV TsAGI, Trudy no. 2415 1988 p. 1-26. In RUSSIAN refs
Copyright

The objective of the study was to improve a program for calculating smooth three-dimensional supersonic flows (i.e., fields without internal gasdynamic discontinuities) in order to eliminate the parasitic oscillations arising in this scheme. In particular, a method is proposed whereby symmetric central differences are replaced by nonasymmetric ones in terms of equations containing derivatives along the body surface in the cross section relative to the flow integration direction. The nonsymmetric approximation is automatically aligned in the directions of the characteristic surfaces of gas dynamics equations. AIAA

A93-50967
NUMERICAL MODELING OF FLOW IN A HYPERSONIC LAMINAR BOUNDARY LAYER [CHISLENNOE MODELIROVANIE TECHENIYA V GIPERZVUKOVOM LAMINARNOM POGRANICHNOM SLOE]
A. A. KOVALENKO TsAGI, Trudy no. 2417 1989 p. 3-39. In RUSSIAN refs
Copyright
Equations are derived which describe flow in a hypersonic laminar boundary layer under conditions of strong viscous interaction. An efficient method is proposed for solving these equations for a wide range of problems involving perturbation propagation upstream from the rear section of a body. Calculation results are presented for flow of a viscous heat-conducting gas past a flat plate and a plate with a deflected flap. The intensity of perturbation propagation is investigated as a function of the adiabatic exponent of the gas and of the surface temperature factor. AIAA

A93-50968
CALCULATION OF PERTURBATION PROPAGATION UPSTREAM IN A HYPERSONIC LAMINAR BOUNDARY LAYER [RASCHET PEREDACHI VOZMUSHCHENIJ VVERKH PO TECHENIYU V GIPERZVUKOVOM LAMINARNOM POGRANICHNOM SLOE]
A. A. KOVALENKO TsAGI, Trudy no. 2417 1989 p. 40-47. In RUSSIAN refs
Copyright
Equations are derived which describe flow in an interacting hypersonic laminar boundary layer. A method is proposed for solving the problem of flow past a flat plate and a plate with a flap for a specified pressure at the trailing edge. It is shown that the propagation of perturbations upstream across the subsonic part of the boundary layer leads to a significant restructuring of the boundary layer flow. AIAA

A93-50969
THE PROBLEM OF VISCOUS HYPERSONIC FLOW PAST BLUNT BODIES IN THE SPREADING PLANE [O ZADACHE VYAZKOGO OBTEKANIYA GIPERZVUKOVYM POTOKOM TUPYKH TEL V PLOSKOSTI RASTEKANIYA]
A. L. ANKUDINOV TsAGI, Trudy no. 2419 1988 p. 3-18. In RUSSIAN refs
Copyright
A variable transformation is proposed whereby the problem of viscous hypersonic flow past nonthin blunt bodies in the theory of a thin viscous shock layer can be formulated for a region with fixed boundaries. Such a formulation makes it possible to avoid the need for determining shock separation or an equivalent quantity. The applicability limits of the approach proposed here are defined. AIAA

A93-50972
SUPERSONIC FLOW PAST A RECTANGULAR WING OF FINITE THICKNESS [OBTEKANIE SVERKHZVUKOVYM POTOKOM PRYAMOUGOL'NOGO KRYLA, IMEYUSHCHEGO TOLSHCHINU]
S. F. PETRISHIN TsAGI, Trudy no. 2421 1988 p. 41-59. In RUSSIAN refs
Copyright
A solution in the form of an acceleration potential is presented for the problem of supersonic flow past the tip of a rectangular wing of finite thickness. It is shown that consideration of the finite thickness of the wing edge requires the formulation of an additional boundary condition in the vicinity of the wing edge. This leads to the generation of an additional lifting force on a part of the wing defined by a Mach cone with the vertex at the end of the wing tip chord. AIAA

A93-51121
A FOURTH-ORDER MUSCL FINITE-DIFFERENCE SCHEME FOR SOLVING THE UNSTEADY COMPRESSIBLE EULER EQUATIONS
SATORU YAMAMOTO, HISAAKI DAIGUJI, and KOICHI ISHIZAKA Japan Society of Mechanical Engineers, Transactions B (ISSN 0387-5016) vol. 59, no. 557 Jan. 1993 p. 43-48. In JAPANESE refs
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A fourth-order compact MUSCL (monotone upstream-centered scheme for conservation laws) total variation diminishing (TVD) scheme is proposed for solving the unsteady compressible Euler equations. The fundamental form of the present scheme is based on the second (third)-order accurate MUSCL finite-difference scheme. One of the distinctive features of this scheme is the ability to capture discontinuities such as slip lines or contact surfaces as well as shocks more sharply than the existing TVD schemes in spite of the use of a simpler algorithm than that of the so-called ENO scheme. Therefore, this scheme can be easily applied to any ordinary numerical solvers based on the second(third)-order MUSCL scheme. We also adopt this scheme into the existing Euler solver developed by the authors which can simulate unsteady inviscid flows accurately by means of the Newton iteration and the Crank-Nicholson method. In order to verify the reliability of the present scheme, an unsteady inviscid supersonic flow having oblique shocks and a slip line is computed. The results show that the slip line as well as oblique shocks can be captured completely. Author (revised)

A93-51122
A NEW TECHNIQUE FOR ANALYSIS OF UNSTEADY AERODYNAMIC RESPONSES OF CASCADE AIRFOILS WITH BLUNT LEADING EDGE - UNSTEADY AERODYNAMIC RESPONSES OF THE CASCADE IN INCOMPRESSIBLE FLOW
KEN-ICHI FUNAZAKI, KOUICHI NIHEI, ATSUSHI SASAKI, and TAKASHI WATANABE Japan Society of Mechanical Engineers, Transactions B (ISSN 0387-5016) vol. 59, no. 557 Jan. 1993 p. 49-56. In JAPANESE refs
Copyright
Unsteady aerodynamic responses of cascade airfoils with a blunt leading edge, which are subjected to incident rotational and irrotational fluctuations, are analyzed by use of the method developed previously by Funazaki and Kakudate. Most of the efforts in this study are devoted to the refinement of the method of the boundary condition imposition on the inlet/outlet and periodic boundaries by employing the analytical solutions in the upstream/downstream far-fields. Although the method presented could be applied to compressible flow problems, numerical examples employed this time are limited to incompressible flow cases. The results obtained show the usefulness of the method and reveal some of the notable features of the unsteady flow field induced within the blade-to-blade passage. Author (revised)

A93-51123
ANALYSIS OF WAKE-INDUCED UNSTEADY FLOW IN AXIAL COMPRESSORS - RADIAL VARIATIONS OF WAKE EXCITATION FORCES ESTIMATED BY STRIP THEORY
KEN-ICHI FUNAZAKI and HARUO SUZUKI Japan Society of Mechanical Engineers, Transactions B (ISSN 0387-5016) vol. 59, no. 557 Jan. 1993 p. 57-64. In JAPANESE refs
Copyright
Wake-induced unsteady flow in an axial compressor is analyzed in a quasi-three-dimensional manner by use of the extended two-dimensional flow analysis method which incorporates a wake decay model developed by the authors. In this paper, the newly developed method to the compressor stages which consist of IGV (Inlet Guide Vane)-rotor-stator blade rows is used to investigate the effects of radial variations in wake characteristics and the axial gaps between two rows on the induced aerodynamic forces. It is found that the spanwise phase relationship of incoming wakes has significant effect on the wake excitation forces and moment. Author (revised)

A93-51190
NEW DERIVATION OF RELATIONSHIP BETWEEN MACH ANGLE AND MACH NUMBER

CHUNRONG LUO (Northwestern Polytechnical Univ., Xian, China) Northwestern Polytechnical University, Journal (ISSN 1000-2758) vol. 11, no. 3 July 1993 p. 265-269. In CHINESE refs

A derivation of the relationship between Mach angle and Mach number that is much simpler than that of Bond et al. (1965) is presented. There is a marked difference in the method of establishing the required wave equation. Bond et al. superimpose a small disturbance on the steady state flow through simultaneously taking into consideration the fundamental equation of motion for fluid flow, equation of state, and the continuity equation. It is argued that an object flying in the supersonic range is a point source continuously emitting a pressure disturbance wave. With this point-source model, the required wave equation and its solution, which is called the retarded potential, are written directly. The right-hand side of the wave equation is different. That of Bond et al. is a potential function connected with the interaction between the supersonic body and the surrounding air. This potential function causes much complication, which is obviated in the present derivation. The present method is called the method of coordinate transformation of the point source. AIAA

A93-51191
VERIFICATION OF THE TOTLOS METHOD FOR CALCULATING AERODYNAMIC LOSS IN FILM-COOLED TURBINE CASCADE

TAO JIANG, WEIHONG FAN, and SONLING LIU (Northwestern Polytechnical Univ., Xian, China) Northwestern Polytechnical University, Journal (ISSN 1000-2758) vol. 11, no. 3 July 1993 p. 270-274. In CHINESE refs

The TOTLOS method is used in combination with a boundary layer code, STAN 5, to calculate aerodynamic loss in a film-cooled turbine cascade. The total loss of the cascade is predicted as the sum of three parts: boundary layer loss, mixing loss due to blowing, and the loss caused by the thickness of the trailing edge. Several examples with different diameters of the film cooling hole, different injection angles, and different blowing sites are calculated. The TOTLOS method is shown to be more suitable for cases of high blowing ratio and blowing sites located in the thin boundary layer region. AIAA

A93-51280
ON BOUNDARY-LAYER TRANSITION IN TRANSONIC FLOW

R. I. BOWLES and F. T. SMITH (Univ. College, London, United Kingdom) Journal of Engineering Mathematics (ISSN 0022-0833) vol. 27, no. 3 Aug. 1993 p. 309-342. Research supported by United Technologies Corp. and SERC refs
(Contract AF-AFOSR-89-0475)
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Boundary-layer transition in transonic external flow is addressed theoretically. The transonic area is rich in different flow structures and transition paths, and the work has wide potential application in transonic aerodynamics, including special reference to the example of flow transition over an engine nacelle. The investigation is intended partly to aid, compare with, and detect any limitations of, a quasi-parallel empirical methodology for design use in the area, especially with respect to the transonic range, and partly to develop an understanding and possible control of the nonlinear natural or bypass properties of the compressible transition present. The mechanisms behind three major factors, (1) substantial external-flow deceleration, (2) rapid boundary-layer thickening, (3) 3D nonlinear interactions, are identified. Some similarities exist with the phenomenon of buffeting on transonic airfoils, and the relevant physics and governing equations throughout are identified. Sensitive nonlinear effects are important in all the factors (1)-(3), especially a resonance linkage between shock buffeting and boundary-layer thickening, and nonlinearly enhanced 3D growth triggered by slight 3D warping for instance, peculiar to the transonic range. The implications, in the general setting as well as for the nacelle-flow context in particular, are also presented.
Author (revised)

A93-51736
A COLLOCATED FINITE VOLUME METHOD FOR PREDICTING FLOWS AT ALL SPEEDS

I. DEMIRDZIC (Sarajevo Univ., Bosnia and Hercegovina), Z. LILEK, and M. PERIC (Erlangen-Nuernberg Univ., Erlangen, Germany) International Journal for Numerical Methods in Fluids (ISSN 0271-2091) vol. 16, no. 12 June 30, 1993 p. 1029-1050. Research supported by DFG refs
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An existing two-dimensional method for the prediction of steady-state incompressible flows in complex geometry is extended to treat also compressible flows at all speeds. The primary variables are the Cartesian velocity components, pressure and temperature. Density is linked to pressure via an equation of state. The influence of pressure on density in the case of compressible flows is implicitly incorporated into the extended SIMPLE algorithm, which in the limit of incompressible flow reduces to its well-known form. Special attention is paid to the numerical treatment of boundary conditions. The method is verified on a number of test cases (inviscid and viscous flows), and both the results and convergence properties compare favorably with other numerical results available in the literature.

A93-51738
A SECOND-ORDER UPWIND FINITE-VOLUME METHOD FOR THE EULER SOLUTION ON UNSTRUCTURED TRIANGULAR MESHES

DARTZI PAN and JEN-CHIEH CHENG (National Cheng Kung Univ., Tainan, Taiwan) International Journal for Numerical Methods in Fluids (ISSN 0271-2091) vol. 16, no. 12 June 30, 1993 p. 1079-1098. refs
(Contract NSC-79-0210-D006-15)
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A scheme for the numerical solution of the two-dimensional (2D) Euler equations on unstructured triangular meshes has been developed. The basic first-order scheme is a cell-centered upwind finite-volume scheme utilizing Roe's approximate Riemann solver. To obtain second-order accuracy, a new gradient based on the weighted average of Barth and Jespersen's three-point support gradient model is used to reconstruct the cell interface values. Characteristic variables in the direction of local pressure gradient are used in the limiter to minimize the numerical oscillation around solution discontinuities. An Approximate LU (ALU) factorization scheme originally developed for structured grid methods is adopted for implicit time integration and shows good convergence characteristics in the test. To eliminate the data dependency which prohibits vectorization in the inversion process, a black-gray-white coloring and numbering technique on unstructured triangular meshes is developed for the ALU factorization scheme. This results in a high degree of vectorization of the final code. Numerical experiments on transonic Ringleb flow, transonic channel flow with circular bump, supersonic shock reflection flow and subsonic flow over multielement aerofoils are calculated to validate the methodology.

A93-51740
NUMERICAL SOLUTIONS OF EULER EQUATIONS BY USING A NEW FLUX VECTOR SPLITTING SCHEME

G.-C. ZHA and E. BILGEN (Ecole Polytechnique, Montreal, Canada) International Journal for Numerical Methods in Fluids (ISSN 0271-2091) vol. 17, no. 2 July 30, 1993 p. 115-144. refs
Copyright

A new flux vector splitting scheme has been suggested in this paper. This scheme uses the velocity component normal to the volume interface as the characteristic speed and yields the vanishing individual mass flux at the stagnation. The numerical dissipation for the mass and momentum equations also vanishes with the Mach number approaching zero. One of the diffusive terms of the energy equation does not vanish. But the low numerical diffusion for viscous flows may be ensured by using higher-order differencing. The scheme is very simple and easy to be implemented. The scheme has been applied to solve the one

dimensional (1D) and multidimensional Euler equations. The solutions are monotone and the normal shock wave profiles are crisp. For a 1D shock tube problem with the shock and the contact discontinuities, the present scheme and Roe scheme give very similar results, which are the best compared with those from Van Leer scheme and Liou-Steffen's advection upstream splitting method (AUSM) scheme. For the multidimensional transonic flows, the sharp monotone normal shock wave profiles with mostly one transition zone are obtained. The results are compared with those from Van Leer scheme, AUSM and also with the experiment.

A93-51755
SPECTRA OF PRESSURE PULSATIONS ON THE SURFACE OF A CONE IN THE TRANSITION REGION AT SUPERSONIC FLOW VELOCITIES [SPEKTRY PUL'SATSIJ DAVLENIYA NA POVERKHNOSTI KONUSA V OBLASTI PEREKHODA PRI SVERKHZVUKOVYKH SKOROSTYAKH POTOKA]
V. N. BIBKO, V. S. GURNAK, B. M. EFIMTSOV, and G. K. SHAPOVALOV TsAGI, Trudy no. 2355 1988 p. 34-41. In RUSSIAN refs
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Experimental studies of pressure pulsations on the surface of a circular cone with a half-angle of taper of 10 deg in a low-noise low-turbulence wind tunnel at M = 2.5, 3.0, and 4.0 are reported. Particular attention is given to the effect of the Reynolds number on the frequency distribution of pressure pulsation intensities in the boundary layer laminar-turbulent transition region. Maximum pressure pulsations in the acoustic frequency range, with an intensity that is a factor of 3-6 higher than that of turbulent pressure pulsations, are observed in the transition region at Reynolds numbers of 2.02 x 10 exp 6 - 2.26 x 10 exp 6. AIAA

A93-51756
SCALE-UP OF THE SPECTRA OF AERODYNAMIC PRESSURE PULSATIONS WITH NARROWBAND MAXIMA [O PRIVEDENII SPEKTROV AEHRODINAMICHESKIKH PUL'SATSIJ DAVLENIYA S UZKOPOLOSNYMI MAKSIMUMAMI K NATURNYM USLOVIYAM]
V. N. BIBKO and O. N. PUSTOVOJCHENKO TsAGI, Trudy no. 2355 1988 p. 42-45. In RUSSIAN
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The paper is concerned with some aspects of the spectral analysis of the narrowband components of the aerodynamic acoustic-range pressure pulsations on the surface of flight vehicle models and with the scale-up of the pulsation spectra. Particular attention is given to the scale-up of spectra with well defined maxima. In this case, an approach is proposed whereby a narrowband spectral analysis is carried out in frequency ranges where the process can be considered wideband. AIAA

A93-51768
STEADY TRANSONIC WEAKLY PERTURBED FLOWS IN A VIBRATIONALLY RELAXING GAS [STATSIONARNYE SLABOVOZMUSHCHENNYE TRANSZVUKOVYE TECHENIYA KOLEBATEL'NO-RELAKSIRUYUSHCHEGO GAZA]
A. N. BOGDANOV and V. A. KULIKOVSKIJ PMTF - Prikladnaya Mekhanika i Tekhnicheskaya Fizika (ISSN 0869-5032) no. 2 Mar.-Apr. 1993 p. 48-58. In RUSSIAN refs
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The behavior of steady and unsteady perturbations in transonic gas flows is considered. The stability of a transonic flow to small unsteady perturbations is determined using a nonlinear partial equation. Results show that the vibrational excitation of N2 and CO molecules results in the conversion of steady transonic flows of these gases into unsteady flows. Transonic flows of molecular O2 are steady as its vibrational excitation quickly relaxes to steady states. Results obtained can be applied to problems of transonic gas flow through a nozzle and around a body with formation of a local supersonic region. AIAA

A93-51770
OPTIMAL WING SHAPES IN A HYPERSONIC NONEQUILIBRIUM FLOW [OPTIMAL'NYE FORMY KRYL'EV V GIPERZVUKOVOM NERAVNOVESNOM POTOKE]
V. N. GOLUBKIN and V. V. NEGODA PMTF - Prikladnaya Mekhanika i Tekhnicheskaya Fizika (ISSN 0869-5032) no. 2 Mar.-Apr. 1993 p. 66-72. In RUSSIAN refs
Copyright

A variational methodology for determining a wing shape in a maximum hypersonic flow for the general case of a chemically nonequilibrium flow past a body is proposed. Results obtained make it possible to understand construction peculiarities which increase the lift-drag ratio of wings and payloads in a relaxing hypersonic flow. AIAA

A93-51771
NUMERICAL OPTIMIZATION METHODS FOR VARIATIONAL INVERSE BOUNDARY VALUE PROBLEMS OF AERODYNAMICS [RESHENIE VARIATSIONNYKH OBRATNYKH KRAEVYKH ZADACH AEHROGIDRODINAMIKI METODAMI CHISLENNOJ OPTIMIZATSII]
A. M. ELIZAROV and E. V. FEDOROV PMTF - Prikladnaya Mekhanika i Tekhnicheskaya Fizika (ISSN 0869-5032) no. 2 Mar.-Apr. 1993 p. 73-81. In RUSSIAN refs
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An aerodynamical optimization of wing profiles is considered using inverse boundary value problems. The profiles are optimized to insure nonseparated flow over most of their contours. It is shown that for a fully turbulent boundary layer a continuity condition of a flow can be met even for laminar flows in the converging part of a contour. Governing function constraints associated with the construction of one-layer wing profiles as well as aerodynamical characteristics and angle-of-attack constraints are presented. AIAA

A93-51772
DEVELOPMENT OF RESONANCE PERTURBATIONS IN A SUPERSONIC JET [REZONANSNOE RAZVITIE VOZMUSHCHENIJ V SVERKHZVUKOVOJ STRUE]
N. A. ZHELTUKHIN and N. M. TEREKHOVA PMTF - Prikladnaya Mekhanika i Tekhnicheskaya Fizika (ISSN 0869-5032) no. 2 Mar.-Apr. 1993 p. 82-89. In RUSSIAN refs
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Dynamics of wave formation in a thermally nonconducting gas outflowing from a circular nozzle is considered using a model of a nonlinear three-wave resonance system with minimum interactions relatively to initial linear processes. The dynamical model is verified taking into account realization conditions for resonance mechanisms in the development of wave processes in flows. Calculation results are applied to three cases: (1) the intensity of a spiral wave is greater than that of an axisymmetric wave; (2) the intensity of an axisymmetric wave is greater than that of a spiral wave; and (3) the intensities of all waves are different. AIAA

A93-51775
HEAT TRANSFER ON TIP FINS IN HYPERSONIC FLOW [TEPLOOBMEN NA KONTSEVYKH KILYAKH V GIPERZVUKOVOM POTOKE]
V. YA. BOROVOJ and T. V. KUBYSHINA Rossijskaya Akademiya Nauk, Izvestiya, Mekhanika Zhidkosti i Gaza (ISSN 0568-5281) no. 2 Mar.-Apr. 1993 p. 18-25. In RUSSIAN refs
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The paper is concerned with flow and heat transfer on the windward surface of a tip fin and at the wing-fin joint. The analysis is carried out for a schematized wing-fin configuration, and therefore the results cannot be directly used in practice. However, the results give an idea of some important characteristics of flow and heat transfer at the tip fins which should be taken into account in the design of hypersonic flight vehicles. AIAA

A93-51776
LAMINARIZATION OF THE BOUNDARY LAYER ON A VIBRATING WING [O LAMINARIZATSII POGRANICHNOGO SLOYA NA KRYLE, PODVERZHENNOM VIBRATSII]
S. V. MANUJLOVICH Rossijskaya Akademiya Nauk, Izvestiya, Mekhanika Zhidkosti i Gaza (ISSN 0568-5281) no. 2 Mar.-Apr. 1993 p. 26-34. In RUSSIAN refs
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In an earlier study (Belov and Litvinov, 1971), a natural Tollmien-Schlichting wave, generated near the leading edge of a wing was attenuated by a wave excited over an artificial two-dimensional irregularity formed on the surface of the vibrating wing. Here, the process of the suppression of the monoharmonic instability wave is investigated theoretically. The analysis is extended to the case of an arbitrary frequency spectrum, and it is shown that the entire packet of instability waves can be suppressed by appropriately selecting the shape of the irregularity. The case of a discrete vibration spectrum is examined in detail. The shape of an irregularity capable of suppressing two Tollmien-Schlichting waves of different frequencies is calculated as an example.
AIAA

A93-51779
NONPLANAR WINGS WITH A MINIMUM INDUCED DRAG [NEPLOSKIE KRYL'YA MINIMAL'NOGO INDUKTIVNOGO SOPROTIVLENIYA]
S. V. LYAPUNOV Rossijskaya Akademiya Nauk, Izvestiya, Mekhanika Zhidkosti i Gaza (ISSN 0568-5281) no. 2 Mar.-Apr. 1993 p. 103-109. In RUSSIAN refs
Copyright
Optimality conditions for the shape of an attached vortex are obtained by directly varying the induced drag functional. Attention is given to problems of minimizing the induced drag for given lifting force and wing span, as well as for given deflection and length of the attached vortex. Optimal vortex shapes and optimal circulation distributions along the attached vortex are obtained, and induced drag values are calculated for such configurations. In the absence of restrictions on the wing span, for given attached vortex length and lifting force, the minimum induced drag is realized for a plane wing with an elliptical circulation distribution. AIAA

A93-51780
SUPERSONIC FLOW PAST A CONE WITH HEAT TRANSFER NEAR ITS TIP [SVERKHZVUKOVOE OBTEKANIE KONUSA PRI TEPLOPODVODE V OKRESTNOSTI EGO VERSHINY]
V. A. LEVIN and L. V. TERENT'EVA Rossijskaya Akademiya Nauk, Izvestiya, Mekhanika Zhidkosti i Gaza (ISSN 0568-5281) no. 2 Mar.-Apr. 1993 p. 110-114. In RUSSIAN refs
Copyright
Supersonic flow past a cone in the wake of a spherical heat source is investigated analytically. The problem is reduced to that of solving a system of gas dynamics equations written in nondimensional form. The equations are solved numerically using the McCormack method. It is shown that heat transfer toward the nose of the body effectively reduces its wave resistance. AIAA

A93-51783
AEROTHERMODYNAMICS OF THE HIGH-ALTITUDE FLIGHT [AEHROTERMODINAMIKA VYSOTNOGO POLETA]
V. N. GUSEV Rossijskaya Akademiya Nauk, Izvestiya, Mekhanika Zhidkosti i Gaza (ISSN 0568-5281) no. 2 Mar.-Apr. 1993 p. 142-152. In RUSSIAN refs
Copyright
The high-altitude hypersonic flight of a flight vehicle is treated as a process consisting of the following three stages: a continuous stage, with the Knudsen number much less than 1; a free-molecular stage, with the Knudsen number of much more than 1; and a transition stage, with the Knudsen number approximately equal to 1. For the continuous stage, the methods used are based on Navier-Stokes equations and their models with boundary slip and temperature discontinuity conditions. For the free-molecular regime, the methods involve determining the distribution function of molecules reflected from the body surface. Numerical methods for solving the Boltzmann kinetic equation and its model equations are successfully used in the transition regime. AIAA

A93-51786
EXPERIMENTAL STUDIES OF SUPERSONIC FLOW PAST WEDGES WITH LONGITUDINAL SLOTS ON THE WINDWARD SIDE [EHKSPERIMENTAL'NYE ISSLEDOVANIYA SVERKHZVUKOVOGO OBTEKANIYA KLIN'EV S PRODOL'NYMI PAZAMI NA NAVETRENNOJ STORONE]
V. I. VORONIN, G. S. UL'YANOV, and A. I. SHVETS Rossijskaya Akademiya Nauk, Izvestiya, Mekhanika Zhidkosti i Gaza (ISSN 0568-5281) no. 2 Mar.-Apr. 1993 p. 173-175. In RUSSIAN refs
Copyright
By using a simple hypersonic lifting shape in the form of a wedge as an example, an experimental study is made of a method of increasing the lift-drag ratio of waverider configurations. The method investigated here involves the use of longitudinal slots on the windward side. It is shown that the wave drag can be reduced without any decrease in the lifting force by appropriately selecting the angle of the slot surface and the relative width of the slots. The aerodynamic characteristics of the models tested are presented as a function of the slot angle and relative width.
AIAA

A93-51818
STEADY STATE SUPERSONIC FLOWS OF A VIBRATIONALLY EXCITED GAS PAST THIN BODIES [STATSIONARNYE SVERKHZVUKOVYE TECHENIYA KOLEBATEL'NO-VOZBUZHDENNOGO GAZA OKOLO TONKIKH TEL]
A. N. BOGDANOV and V. A. KULIKOVSKIJ PMTF - Prikladnaya Mekhanika i Tekhnicheskaya Fizika (ISSN 0044-4626) no. 1 Jan.-Feb. 1993 p. 54-64. In RUSSIAN refs
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The paper is concerned with the problem of steady state supersonic flow of a vibrationally excited gas past thin plane bodies and bodies of revolution, with the gas relaxing downstream to an equilibrium. In addition to the relative thickness of the body, delta, a second small parameter, the relative nonequilibrium, epsilon, is introduced. The solution is obtained in the form of an asymptotic series expansion in terms of the small parameters. AIAA

A93-51820
A STUDY OF TURBULENT FLOW IN A VISCOUS SHOCK LAYER IN THE CASE OF GAS FLOW PAST OBLONG BLUNT BODIES [ISSLEDOVANIE TURBULENTNOGO TECHENIYA V VYAZKOM UDARNOM SLOE PRI OBTEKANII GAZOM ZATUPLENNYKH UDLINENNYKH TEL]
I. G. EREMEJTSEV, G. S. ZHURAVLEVA, and N. N. PILYUGIN PMTF - Prikladnaya Mekhanika i Tekhnicheskaya Fizika (ISSN 0044-4626) no. 1 Jan.-Feb. 1993 p. 69-75. In RUSSIAN refs
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Hypersonic flow of a gas past oblong blunt plane (a parabolic cylinder) and axisymmetric (a paraboloid of revolution) bodies is investigated numerically within the framework of a viscous shock layer model for turbulent flow conditions. Numerical calculations indicate that the dynamic and thermal characteristics of plane and axisymmetric bodies are largely determined by the body shape, flow conditions (Reynolds number), and effective angle of taper of the body. AIAA

A93-51868
MODELING THE FLOW AROUND A BODY VIA THE SOLUTION OF THE RELAXATIONAL KINETIC EQUATION [MODELIROVANIE OBTEKANIYA PRI POMOSHCHI RESHENIYA RELAKSATSIONNOGO KINETICHESKOGO URAVNENIYA]
YU. I. KHLOPKOV TsAGI, Trudy no. 2436 1990 p. 22-27. In RUSSIAN refs
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A method for the statistical modeling of rarefied gas flow based on the solution of the relaxational kinetic equations is considered. Calculation results are presented for the flow around axisymmetric bodies (a sphere and a cone). The calculation results are compared with experimental data and previous calculations. AIAA

A93-51869
APPROXIMATE CALCULATION OF THE AERODYNAMIC CHARACTERISTICS OF SIMPLE BODIES IN HYPERSONIC RAREFIED-GAS FLOW [O PRIBLIZHENNOM RASCHETE AEHRODINAMICHESKIKH KHARAKTERISTIK PROSTYKH TEL PRI GIPERZVUKOVOM OBTEKANII RAZREZHENNYM GAZOM]
P. I. GORENBUKH TsAGI, Trudy no. 2436 1990 p. 28-43. In RUSSIAN refs
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Based on available experimental data and numerical calculations of the head drag coefficients of various simple bodies, the choice of the effective characteristic size in the rarefaction criterion is justified and a correlation is obtained that takes into account the influence of the basic similarity criteria and the characteristic angle of inclination of the leading part of the body surface. In the framework of the so-called local method this correlation is used to determine the lift force and longitudinal moment coefficients. Calculation results obtained using the proposed formulas are compared with Monte Carlo calculations. AIAA

A93-51870
CALCULATION OF THE AERODYNAMIC CHARACTERISTICS OF BODIES WITH MESHLIKE SURFACES IN HYPERSONIC RAREFIED-GAS FLOW [O RASCHETE AEHRODINAMICHESKIKH KHARAKTERISTIK TEL S SETCHATYMI POVERKHNOSTYAMI V GIPERZVUKOVOM POTOKE RAZREZHENNOGO GAZA]
A. V. SHVEDOV TsAGI, Trudy no. 2436 1990 p. 44-60. In RUSSIAN refs
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It is shown that the local method with allowance for partial shading can be used for the approximate determination of the aerodynamic characteristics of bodies with meshlike surfaces (MSs) in free-molecular flow. Formulas for calculating the aerodynamic characteristics of MS samples with a single parameter subject to experimental determination are proposed and compared with experimental data. A demonstration calculation of the characteristics of a body of complex geometrical shape with an MS is performed. AIAA

A93-51871
EXPERIMENTAL SIMULATION OF THE AERODYNAMIC HEATING OF BODIES IN A MOLECULAR REGION [EHKSPERIMENTAL'NOE MODELIROVANIE *AEHRODINAMICHESKOGO NAGREVANIYA TEL* V MOLEKULYARNOJ OBLASTI]
YU. YU. KOLOCHINSKIJ, V. V. PETRAKOV, A. I. OMELIK, and A. I. TERNOVOJ TsAGI, Trudy no. 2436 1990 p. 61-67. In RUSSIAN refs
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Two types of sensors were used for experimental simulation of aerodynamic heating in free-molecular flow. A calorimetric sensor was used to perform measurements in cross sections with a comparatively high jet density, where the Reynolds number reaches a value of unity. The thermoelectric compensation-type sensor was used to perform measurements some distance from the source, in regions with an essentially free-molecular flow regime. In both cases the axial distribution of heat fluxes corresponds to a single spherical source with total recombination and accommodation of all the nonequilibria existing in the undisturbed flow. AIAA

A93-51872
CERTAIN IMPROVED ALGORITHMS FOR CALCULATING THE AERODYNAMIC CHARACTERISTICS OF FLIGHT VEHICLES IN FREE-MOLECULAR FLOW [O NEKOTORYKH USOVERSHENSTVOVANNYKH ALGORITMAKH RASCHETA AEHRODINAMICHESKIKH KHARAKTERISTIK LETATEL'NYKH APPARATOV V SVOBODNOMOLEKULYARNOM POTOKE]
M. G. ABRAMOVSKAYA, V. P. BASS, V. D. PERMINOV, and A. V. SHVEDOV TsAGI, Trudy no. 2436 1990 p. 68-74. In RUSSIAN refs
Copyright

A modification of the direct statistical modeling method is proposed for calculating the aerodynamic characteristics of a flight vehicle, taking into account the shading of some components of the vehicle by others as well as the rereflection of molecules in free-molecular flow with a finite Mach number. Also considered are two modifications of a method for calculating these characteristics on the basis of the integration of local force effects on the surface of the vehicle taking shading into account in the framework of the geometrical-optics approximation. All these modifications make it possible to increase the speed of the corresponding methods for a given calculation accuracy or to reduce the error for a given calculation time. AIAA

A93-51877
INVESTIGATION OF THE EFFECT OF PHYSICAL PROCESSES ON HEAT TRANSFER TO BLUNT BODIES AT LOW REYNOLDS NUMBERS [ISSLEDOVANIE VLIYANIYA *FIZICHESKIKH PROTSESSOV NA TEPLOPEREDACHU* K ZATUPLENNYM TELAM PRI MALYKH CHISLAKH *REJNOL'DSA*]
A. V. BOTIN, V. N. GUSEV, V. P. PROVOTOROV, V. V. RYABOV, and L. G. CHERNIKOVA TsAGI, Trudy no. 2436 1990 p. 134-144. In RUSSIAN refs
Copyright

The effect of various physical processes (e.g., nonequilibrium chemical reactions, injection, etc.) on heat transfer to blunt bodies is studied numerically and experimentally. Experimental results were obtained on heat transfer at the critical points of axisymmetric and plane models and on local heat transfer on a sphere in the presence of gas injection. The studies were conducted in a low-pressure wind tunnel in air at free-stream Mach numbers of 6.5-7, a stagnation temperature of 1000 K, and Reynolds numbers of 5.9-40. The effect of the shape of the bluntness on the drag and the total heat transfer to blunt bodies is analyzed, and parametric calculations are used to obtain approximation formulas for local heat transfer. AIAA

A93-51878
EFFECT OF REYNOLDS NUMBER ON THE AERODYNAMIC CHARACTERISTICS OF A SEMICONE WITH A WING IN THE CASE OF HYPERSONIC FLOW VELOCITIES [VLIYANIE CHISLA REJNOL'DSA NA AEHRODINAMICHESKIE KHARAKTERISTIKI POLUKONUSA S KRYLOM PRI GIPERZVUKOVYKH SKOROSTYAKH POTOKA]
P. I. GORENBUKH TsAGI, Trudy no. 2436 1990 p. 145-151. In RUSSIAN refs
Copyright

The paper presents an analysis of the effect of the viscosity and rarefaction of the medium on the aerodynamic characteristics of a semicone with a wing in a hypersonic air flow. Experimental data on the sum aerodynamic characteristics in the Reynolds number range from 250 to 3.24 x exp 5 are presented. The dependence of the maximum lift-drag ratio on Reynolds number is presented. The data are compared with numerical and approximate calculation results. AIAA

A93-51879
INVESTIGATION OF THE STRUCTURE OF A MULTICOMPONENT VISCOUS SHOCK LAYER [ISSLEDOVANIE STRUKTURY MNOGOKOMPONENTNOGO VYAZKOGO UDARNOGO SLOYA]

V. P. PROVOTOROV and V. V. RYABOV TsAGI, Trudy no. 2436 1990 p. 152-164. In RUSSIAN refs
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The paper presents a theoretical study of hypersonic flow around a blunt body during entry into the earth's atmosphere at heights from 100 to 60 km. The structure of the multicomponent thin viscous shock layer that arises is analyzed. Various models for describing diffusion flows and chemical reaction rates are examined. The flow characteristics in the viscous shock layer near a spherical bluntness are calculated for various degrees of catalytic activity of the body surface. AIAA

A93-51880
AN ECONOMICAL DIFFERENCE FACTORIZATION ALGORITHM FOR THE NUMERICAL CALCULATION OF THE SYSTEM OF EQUATIONS FOR A THIN VISCOUS SHOCK LAYER [EHKONOMICHNYJ ALGORITM PROGONKI DLYA CHISLENNOGO RASCHETA SISTEMY URAVNENIJ TONKOGO VYAZKOGO UDARNOGO SLOYA]
V. P. PROVOTOROV TsAGI, Trudy no. 2436 1990 p. 165-173. In RUSSIAN refs
Copyright
A economical matrix factorization algorithm is developed for a two-point finite-difference system of equations. This algorithm is implemented in a program for the numerical solution of parabolic systems of equations describing flow in a thick viscous shock layer or a boundary layer. The proposed algorithm is compared with a previous difference factorization method in terms of the number of required arithmetical operations. The program was tested on the example of solving the equations for a thin viscous shock layer in the presence of nonequilibrium physicochemical reactions. AIAA

A93-51881
INVESTIGATION OF SUPERSONIC SHAPED NOZZLES IN A LOW-PRESSURE WIND TUNNEL [ISSLEDOVANIE SVERKHZVUKOVYKH PROFILIROVANNYKH SOPL V VAKUUMNOJ AEHRODINAMICHESKOJ TRUBE]
A. V. LIPIN TsAGI, Trudy no. 2436 1990 p. 174-188. In RUSSIAN refs
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The paper presents results of the approximate calculation of supersonic axisymmetric shaped nozzles with Mach numbers of 5 and 8 and Reynolds numbers ranging from 1000 to 10 exp 6 (T sub 0 = 293 K). Results of an experimental study of flow fields in shaped nozzles at low Reynolds numbers are presented. The experimental data agree satisfactorily with the calculation results. Flow parameters for shaped and conical nozzles are compared. AIAA

A93-51882
A STUDY OF PRESSURE FLUCTUATIONS ON THE SURFACE OF A DELTA WING NEAR THE SHARP LEADING EDGE [ISSLEDOVANIE PUL'SATSIJ DAVLENIYA NA POVERKHNOSTI TREUGOL'NOGO KRYLA VBLIZI OSTROJ PEREDNEJ KROMKI]
R. K. KARAVOSOV and A. G. PROZOROV TsAGI, Trudy no. 2475 1990 p. 3-12. In RUSSIAN refs
Copyright
An analysis is made of pressure measurements and flow visualizations obtained for a delta wing model with a sharp leading edge at small angles of attack and Reynolds numbers of (1.4-3.3) x 10 exp 6. The dynamic loads on the wing resulting from the formation of a vortex flow over the wing surface are examined. It is found that wall pressure fluctuations along the leading edge change nonmonotonically and that the extent of pressure fluctuations depends on the Reynolds number at the initial stage of vortex core formation. AIAA

A93-51883
SELF-EXCITATION OF INTENSE OSCILLATIONS IN FLOW INSIDE A WIND TUNNEL WITH AN OPEN TEST SECTION [SAMOVOZBUZHDENIE INTENSIVNYKH KOLEBANIJ V POTOKE V AEHRODINAMICHESKOJ TRUBE S OTKRYTOJ RABOCHEJ CHAST'YU]
R. K. KARAVOSOV and A. G. PROZOROV TsAGI, Trudy no. 2475 1990 p. 13-31. In RUSSIAN refs
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Oscillations in the open test section of a wind tunnel, in its forechamber, and in a nozzle with an exit section diameter of 2.2 m are investigated experimentally. Flow regions in the boundary layer that produce intense low-frequency perturbations, giving rise to a substantial increase of pulsations in the open test section at certain flow velocities, are determined. The regimes of self-excitation of intense flow oscillations in wind tunnels of different sizes are compared. AIAA

A93-51901
PROBLEMS IN THE AERODYNAMICS OF FLIGHT VEHICLES AND THEIR COMPONENTS [VOPROSY AEHRODINAMIKI LETATEL'NYKH APPARATOV I IKH CHASTEJ]
YU. A. RYZHOV, ED. Moscow, Russia Moskovskij Aviatsionnyj Institut 1992 91 p. In RUSSIAN For individual items see A93-51902 to A93-51914
Copyright
The papers presented in this volume provide an overview of recent theoretical and experimental work in the field of flight vehicle aerodynamics and general aeromechanics. In particular, attention is given to the calculation of compressed gas flows on optimal difference grids, spline-collocation solution of a Fredholm equation of the second kind in the problem of flow past an airfoil, a study of the aerodynamics of a wing with end slots, and aerodynamic characteristics of airship models of different shapes. Other topics discussed include determination of the aerodynamic characteristics of a thin body of revolution with a piecewise linear distribution of singularities at its axis, calculation of a plane supersonic jet simulating the exhaust jet of a hypersonic flight vehicle engine, and a stability condition for the motion of a continuous incompressible medium. AIAA

A93-51902
CALCULATION OF COMPRESSIBLE GAS FLOW ON OPTIMAL DIFFERENCE GRIDS [RASCHET POTOKOV SZHIMAEMOGO GAZA NA OPTIMAL'NYKH RAZNOSTNYKH SETKAKH]
V. A. KRAJNOV *In* Problems in the aerodynamics of flight vehicles and their components Moscow, Russia Moskovskij Aviatsionnyj Institut 1992 p. 4-8. In RUSSIAN refs
Copyright
A modified finite difference method for solving Euler equations is proposed which is based on a lambda scheme. The method has been implemented in a program, written in FORTRAN, which can run on IBM AT-type computers. A comparison of calculation results with the available data for several test problems indicates that the method is suitable for calculating compressible flows. A similar approach can be applied to three-dimensional flows of a compressible gas. AIAA

A93-51903
A FINITE DIFFERENCE STUDY OF THE AERODYNAMIC CHARACTERISTICS OF WING PROFILES AT TRANSONIC VELOCITIES [ISSLEDOVANIE AEHRODINAMICHESKIKH KHARAKTERISTIK KRYL'EVYKH PROFILEJ PRI OKOLOZVUKOVYKH SKOROSTYAKH KONECHNO-RAZNOSTNYM METODOM]
G. V. KLIMENKO *In* Problems in the aerodynamics of flight vehicles and their components Moscow, Russia Moskovskij Aviatsionnyj Institut 1992 p. 8-14. In RUSSIAN refs
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A finite difference method for calculating the aerodynamic characteristics of wing profiles at transonic velocities is proposed which approximates the equation of the full potential of plane flow. The solution is sought on an orthogonal difference grid in

Cartesian coordinates. The capabilities of the method are illustrated for a supercritical airfoil, Korn 75-06-12, at a free-stream Mach of 0.7 and an angle of attack of 2. Results are also presented for subsonic symmetric airfoils NACA 0012 and NACA 0018. AIAA

A93-51904
SPLINE-COLLOCATION SOLUTION OF A FREDHOLM EQUATION OF THE SECOND KIND IN THE PROBLEM OF FLOW PAST AN AIRFOIL [RESHENIE METODOM SPLAJN-KOLLOKATSIJ URAVNENIYA FREDGOL'MA VTOROGO RODA DLYA ZADACHI OBTEKANIYA PROFILYA]
A. V. KUZNETSOV and V. D. SOFRONOV *In* Problems in the aerodynamics of flight vehicles and their components Moscow, Russia Moskovskij Aviatsionnyj Institut 1992 p. 15-20. In RUSSIAN refs
Copyright
The problem of flow of an ideal incompressible medium past an airfoil is reduced to that of solving an integral Fredholm equation of the second kind, assuming the absence of flow inside the contour. It is then shown that this equation can be solved by the spline-collocation method. The solution has a smooth first derivative and can be used directly for calculating the boundary layer on an airfoil. Results obtained for a NACA 0012 airfoil are presented as an example. AIAA

A93-51907
A STUDY OF THE AERODYNAMICS OF A WING WITH END SLOTS [ISSLEDOVANIE AEHRODINAMIKI KRYLA S KONTSEVYMI PAZAMI]
A. N. MEL'NIKOV *In* Problems in the aerodynamics of flight vehicles and their components Moscow, Russia Moskovskij Aviatsionnyj Institut 1992 p. 35-43. In RUSSIAN refs
Copyright
Wind tunnel test data are presented for wing models with various types of slotted wing tip devices. An analysis of the experimental data indicates that such wing tip devices reduce the induced drag and increase the lift-drag characteristics of the wing. The physical mechanisms of the positive effect of slotted wing tip devices are examined. AIAA

A93-51908
A STUDY OF AIR INTAKE PARAMETERS ON THE AERODYNAMIC CHARACTERISTICS OF A PARASAIL [ISSLEDOVANIE VLIYANIYA PARAMETROV VOZDUKHOZABORNIKOV NA AEHRODINAMICHESKIE KHARAKTERISTIKI PARASHYUTA-KRYLA]
A. G. VIKTORCHIK, A. A. MIKHAJLYUK, and A. S. PAVLOV *In* Problems in the aerodynamics of flight vehicles and their components Moscow, Russia Moskovskij Aviatsionnyj Institut 1992 p. 43-47. In RUSSIAN
Copyright
The aerodynamic characteristics of a rigid parasail model with an aspect ratio of 1.6 are investigated experimentally as a function of some air intake parameters, such as the relative area, the number of air intakes, and their location. It is shown that the use of suspended air intakes on a parasail makes it possible to significantly improve the lifting characteristics of the parasail without decreasing its lift-drag ratio. Possible ways of improving the lift-drag ratio are suggested. AIAA

A93-51909
AERODYNAMIC CHARACTERISTICS OF AIRSHIP MODELS OF DIFFERENT SHAPES [AEHRODINAMICHESKIE KHARAKTERISTIKI MODELEJ DIRIZHABLEJ RAZLICHNOJ FORMY]
A. N. KIRILLIN and A. B. EGOROV *In* Problems in the aerodynamics of flight vehicles and their components Moscow, Russia Moskovskij Aviatsionnyj Institut 1992 p. 48-53. In RUSSIAN refs
Copyright
Results of wind tunnel tests are presented for ten airship models of different geometrical configurations. An analysis of the results demonstrates the advantages of the classical airship shape. Changing the aspect ratio from the traditional 5-6 to 3-4.5 is examined as a possible way of improving on the traditional airship geometry. AIAA

A93-51910
CALCULATION OF SUPERSONIC FLOW PAST A BODY OF REVOLUTION WITH A PIECEWISE LINEAR DISTRIBUTION OF SINGULARITIES AT ITS AXIS [RASCHET SVERKHZVUKOVOGO OBTEKANIYA TELA VRASHCHENIYA S KUSOCHNO-LINEJNYM RASPREDELENIEM INTENSIVNOSTI OSOBENNOSTEJ NA EGO OSI]
YU. S. SOROKIN *In* Problems in the aerodynamics of flight vehicles and their components Moscow, Russia Moskovskij Aviatsionnyj Institut 1992 p. 53-61. In RUSSIAN refs
Copyright
A method for calculating supersonic flow past bodies of revolution is proposed whereby the body of revolution is modeled by sources and dipoles along the body axis with a piecewise linear law of intensity variation along the axis. This approach makes it possible to obtain finite analytical expressions for velocities and significantly reduce the computational effort. Examples of calculations are presented to demonstrate the validity of the approach. AIAA

A93-51911
DETERMINATION OF THE AERODYNAMIC CHARACTERISTICS OF THIN BODIES OF REVOLUTION WITH AN ARBITRARY NUMBER OF CANTILEVER SURFACES IN INHOMOGENEOUS FLOW [OPREDELENIE AEHRODINAMICHESKIKH KHARAKTERISTIK TONKIKH TEL VRASHCHENIYA S PROIZVOL'NYM CHISLOM KONSOLEJ OPERENIYA V NEODNORODNOM POTOKE]
V. V. SHUSTOV *In* Problems in the aerodynamics of flight vehicles and their components Moscow, Russia Moskovskij Aviatsionnyj Institut 1992 p. 61-70. In RUSSIAN refs
Copyright
The paper is concerned with the problem of determining the distributed and integral interference characteristics of thin bodies of revolution with an arbitrary number of cantilever surfaces of low aspect ratio having an n-th order symmetry axis coinciding with the axis of revolution of the body. The problem is analyzed in the context of the theory of thin bodies. A solution is obtained by using the formalism of functions of complex variables and, particularly, conformal mapping. The aerodynamic characteristics of a body with three cantilever surfaces in homogeneous and inhomogeneous flows are calculated as an example. AIAA

A93-51913
AN EXPERIMENTAL STUDY OF THE DYNAMIC EFFECT OF A SUPERSONIC UNDEREXPANDED JET ON A PLANE SURFACE PARALLEL TO THE NOZZLE AXIS [EHKSPERIMENTAL'NOE ISSLEDOVANIE DINAMICHESKOGO VOZDEJSTVIYA SVERKHZVUKOVOJ NEDORASSHIRENNOJ STRUI NA PLOSKUYU POVERKHNOST', PARALLEL'NUYU OSI SOPLA]
E. N. BONDAREV, S. S. VTULKIN, E. I. MOSPANOV, and A. V. PECHERITSA *In* Problems in the aerodynamics of flight vehicles and their components Moscow, Russia Moskovskij Aviatsionnyj Institut 1992 p. 75-80. In RUSSIAN refs
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The paper reports results of an experimental study of pressure distribution along the line of symmetry of flow on a plane surface parallel to the axis of a circular nozzle. The effect of the governing flow parameters on the magnitude and position of the pressure maximum on the obstacle is analyzed. Attention is also given to the magnitude and position of the second pressure peak. The results are presented in graphic form. AIAA

A93-51940
NEW CALCULATION METHODS CONTRIBUTION ON TURBOMACHINERY DESIGN AND DEVELOPMENT [APPORT DES NOUVELLES METHODES DE CALCUL A LA CONCEPTION ET AU DEVELOPPEMENT DES TURBOMACHINES]

GEORGES MEAUZE (ONERA, Chatillon, France) ONERA, TP no. 1993-60 1993 14 p. In FRENCH Journees Science et Defense, Paris, France, May 11, 12, 1993 refs
(ONERA, TP NO. 1993-60)

Considering only the aerodynamic and aerothermodynamic aspects, the specific flow behavior in turbomachinery and classical design methods are briefly described. The benefit and need of new calculation methods are emphasized and illustrated with some recent applications. The state-of-the-art of these new numerical tools, already or soon available, is analyzed. The required improvements and corresponding research are commented upon.
Author (revised)

A93-51999
AN EXTENDED INSIGHT INTO HYPERSONIC FLOW PHENOMENA USING NUMERICAL METHODS
C. WEILAND, W. SCHROEDER, and S. MENNE (MBB GmbH, Munich, Germany) Computers & Fluids (ISSN 0045-7930) vol. 22, no. 4-5 July-Sept. 1993 p. 407-426. refs
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Integration methods for the steady and unsteady Euler and Navier-Stokes equations that take into account equilibrium and nonequilibrium real gas effects are presented. Finite-difference 3D Euler and Navier-Stokes methods with a bow-shock-fitting capability are used to compute the flows around reentry vehicles. A variety of applications of the proposed method are described including viscous and inviscid nonequilibrium real gas flows around basic configurations, equilibrium real gas and perfect gas flows through an advanced nozzle, the stage separation of a two-stage STS and inviscid nonequilibrium real gas flows around the HERMES space vehicle.
AIAA

A93-52000
NUMERICAL SIMULATION OF SHOCK/SHOCK AND SHOCK-WAVE/BOUNDARY-LAYER INTERACTIONS IN HYPERSONIC FLOWS
G. BRENNER, T. GERHOLD, K. HANNEMANN, and D. RUES (DLR, Inst. fuer Theoretische Stroemungsmechanik, Goettingen, Germany) Computers & Fluids (ISSN 0045-7930) vol. 22, no. 4-5 July-Sept. 1993 p. 427-439. Research supported by DFG and CNES refs
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The influence of shock/shock and shock-wave/boundary-layer interactions on the flow past two model configurations, representing critical parts of hypersonic vehicles, is examined. The investigation is focused, on the one hand, on the flow field past the windward surface of a reentry vehicle with control surfaces, approximated by a flared hyperboloid, where the influence of high-temperature effects on the interaction is shown. On the other hand, the three-dimensional, turbulent flow field past a blunt fin is discussed.

A93-52001
FLUX-VECTOR SPLITTING FOR COMPRESSIBLE LOW MACH NUMBER FLOW
JOERN SESTERHENN, BERNHARD MUELLER, and HANS THOMANN (Zuerich, Eidgenoessische Technische Hochschule, Zurich, Switzerland) Computers & Fluids (ISSN 0045-7930) vol. 22, no. 4-5 July-Sept. 1993 p. 441-451. refs
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Several problems are encountered when calculating low Mach number flow. We illustrate them from different points of view and investigate two flux-vector splittings designed for this type of flow. Both splittings are applied to a quasi-1-D nozzle flow, using the explicit as well as a semi-implicit and the implicit Euler scheme with a finite-volume upwind formulation. Results at low and very low Mach numbers are compared with calculations using Roe's scheme. A von Neumann stability analysis is carried out for the more promising scheme based on a convection-pressure splitting.

A93-52005
STAGNATION POINT COMPUTATIONS OF NONEQUILIBRIUM INVISCID BLUNT BODY FLOW
M. FEY, R. JELTSCH (Zuerich, Eidgenoessische Technische Hochschule, Zurich, Switzerland), and S. MUELLER (Aachen, Rheinisch-Westfaelische Technische Hochschule, Germany) Computers & Fluids (ISSN 0045-7930) vol. 22, no. 4-5 July-Sept. 1993 p. 501-515. refs
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The numerical solution of a symmetric hypersonic blunt body flow in two space dimensions is considered, and the problem of arising chemical boundary layer is discussed. Analytical and numerical investigations are used to analyze the solution on the stagnation point streamline. We point out the necessary assumptions to obtain an equivalent system of ordinary differential equations along this line and to get a unique solution. We also describe the situation in the limiting case at the stagnation point and give a differential algebraic system from which we obtain the solution at this point. We derive the shape of the boundary layer by linearizing the equations and some of the results are different to previous ones. Then we present numerical tools to obtain a better indication of this boundary layer even in 2-D calculations.

A93-52006 National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
A TIME-ACCURATE HIGH-RESOLUTION TVD SCHEME FOR SOLVING THE NAVIER-STOKES EQUATIONS
HYUN D. KIM and NAN-SUEY LIU (NASA, Lewis Research Center, Cleveland, OH) Computers & Fluids (ISSN 0045-7930) vol. 22, no. 4-5 July-Sept. 1993 p. 517-528. Previously announced in STAR as N93-22664 refs
(Contract RTOP 505-62-52)
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A total variation diminishing (TVD) scheme has been developed and incorporated into an existing time-accurate high-resolution Navier-Stokes code. The accuracy and the robustness of the resulting solution procedure have been assessed by performing many calculations in four different areas: shock tube flows, regular shock reflection, supersonic boundary layer, and shock boundary layer interactions. These numerical results compare well with corresponding exact solutions or experimental data.

A93-52007* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
UNSTEADY AERODYNAMIC BEHAVIOR OF AN AIRFOIL WITH AND WITHOUT A SLAT
CHEE TUNG, KENNETH W. MCALISTER (U.S. Army, Aeroflightdynamics Directorate; NASA, Ames Research Center, Moffett Field, CA), and CLIN M. WANG (Georgia Inst. of Technology, Atlanta) Computers & Fluids (ISSN 0045-7930) vol. 22, no. 4-5 July-Sept. 1993 p. 529-547. refs
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Unsteady flow behavior and load characteristics of a 2D VR-7 airfoil with and without a leading-edge slat were studied in the water tunnel of the Aeroflightdynamics Directorate, NASA Ames Research Center. Both airfoils were oscillated sinusoidally between 5 and 25 deg at Re = 200,000 to obtain the unsteady lift, drag, and pitching moment data. A fluorescent dye was released from an orifice located at the leading edge of the airfoil for the purpose of visualizing the boundary layer and wake flow. The flowfield and load predictions of an incompressible Navier-Stokes code based on a velocity-vorticity formulation were compared with the test data. The test and predictions both confirm that the slatted VR-7 airfoil delays both static and dynamic stall as compared to the VR-7 airfoil alone.
Author (revised)

A93-52011* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
NUMERICAL SIMULATION AND PHYSICAL ASPECTS OF SUPERSONIC VORTEX BREAKDOWN
C. H. LIU (NASA, Langley Research Center, Hampton, VA), O. A. KANDIL, and H. A. KANDIL (Old Dominion Univ., Norfolk, VA) Computers & Fluids (ISSN 0045-7930) vol. 22, no. 4-5 July-Sept. 1993 p. 607-622. refs
(Contract NAG1-994)
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Existing numerical simulations and physical aspects of subsonic and supersonic vortex-breakdown modes are reviewed. The solution to the problem of supersonic vortex breakdown is emphasized in this paper and carried out with the full Navier-Stokes equations for compressible flows. Numerical simulations of vortex-breakdown modes are presented in bounded and unbounded domains. The effects of different types of downstream-exit boundary conditions are studied and discussed.

A93-52012
COMPUTATION OF SUBSONIC VISCOUS AND TRANSONIC VISCOUS-INVISCID UNSTEADY FLOW
U. R. MUELLER and H. HENKE (Deutsche Aerospace Airbus GmbH, Bremen, Germany) Computers & Fluids (ISSN 0045-7930) vol. 22, no. 4-5 July-Sept. 1993 p. 649-661. refs
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A new viscous-inviscid interaction scheme is introduced, which implicitly couples the unsteady Euler and the boundary-layer equations. The adequacy of an integral formulation of the viscous flow equations for use in unsteady flows is shown in comparison with experimental results and finite-difference computations, and an explanation is worked out which traces back the unsteady response of the mean and turbulence field due to the external unsteadiness to a quasi-steady behavior. The interaction computations of transonic airfoil flows by means of the Euler-boundary-layer technique are compared with the steady and unsteady experimental data sets for the RAE 2822 and the NLR 7301 supercritical airfoils, respectively.

A93-52426
AERODYNAMIC CALCULATION OF COMPLEX THREE-DIMENSIONAL CONFIGURATIONS
F. ROGGERO and R. LARGUIER (ONERA, Chatillon, France) Journal of Aircraft (ISSN 0021-8669) vol. 30, no. 5 Sept.-Oct. 1993 p. 561-570. ICAS, Congress, 17th, Stockholm, Sweden, Sept. 9-14, 1990, Proceedings. Vol. 1, p. 770-781. Previously cited in issue 09, p. 1307, Accession no. A91-24386 Research supported by Ministry of Defense of France refs
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A93-52427* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
COMPUTATIONAL EFFECTS OF INLET REPRESENTATION ON POWERED HYPERSONIC, AIRBREATHING MODELS
LAWRENCE D. HUEBNER (NASA, Langley Research Center, Hampton, VA) and KENNETH E. TATUM (Lockheed Engineering and Sciences Co., Hampton, VA) Journal of Aircraft (ISSN 0021-8669) vol. 30, no. 5 Sept.-Oct. 1993 p. 571-577. refs
Copyright

Computational results are presented to illustrate the powered aftbody effects of representing the scramjet inlet on a generic hypersonic vehicle with a fairing, to divert the external flow, as compared to an operating flow-through scramjet inlet. This study is pertinent to the ground testing of hypersonic, airbreathing models employing scramjet exhaust flow simulation in typical small-scale hypersonic wind tunnels. The comparison of aftbody effects due to inlet representation is well-suited for computational study, since small model size typically precludes the ability to ingest flow into the inlet and perform exhaust simulation at the same time. Two-dimensional analysis indicates that, although flowfield differences exist for the two types of inlet representations, little, if any, difference in surface aftbody characteristics is caused by fairing over the inlet.

A93-52429* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
EULER ANALYSIS OF FOREBODY-STRAKE VORTEX FLOWS AT SUPERSONIC SPEEDS
O. J. ROSE (Lockheed Engineering and Sciences Co., Hampton, VA) and JAMES L. PITTMAN (NASA, Langley Research Center, Hampton, VA) Journal of Aircraft (ISSN 0021-8669) vol. 30, no. 5 Sept.-Oct. 1993 p. 586-593. AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989, AIAA Paper 89-0343. Previously cited in issue 09, p. 1288, Accession no. A89-26371 refs
Copyright

A93-52430
INDUCED DRAG OF A CRESCENT WING PLANFORM
F. LAM and D. J. MAULL (Cambridge Univ., United Kingdom) Journal of Aircraft (ISSN 0021-8669) vol. 30, no. 5 Sept.-Oct. 1993 p. 594-602. Research supported by Croucher Foundation and British Aerospace, PLC refs
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Comparative study, both computational and experimental, has been carried out on the possible drag reduction at low speeds of two wings of same aspect ratio 6, but different wing planforms; one is crescent and the other is elliptic. Computational results, using two inviscid panel programs, indicate that the crescent wing planform is capable of reducing the drag, interpreted from the integrated surface pressure distributions. The benefit has been attributed to a high suction pressure loading in the tip region in the case of the crescent wing. However, such a potential in drag reduction cannot be verified experimentally at the Reynolds number based on the mean chord 0.25 x 10 exp 6. There has been no expected gain in the effective aspect ratio associated with the crescent wing, based on the results of balance tests. Detailed wake surveys at a downstream distance behind these wings reveal substantial differences in the wake structures at an approximate lift coefficient of 0.35, but the vorticity in the wake vortex cores shows similar magnitudes. One explanation for the misleading computational findings is that there exists a residue drag at no-load condition, which tends to contaminate the calculation at lifting conditions. Author (revised)

A93-52432
NUMERICAL SIMULATION OF UNSTEADY FLOW INDUCED BY A FLAT PLATE MOVING NEAR GROUND
A. O. NUHAIT and M. F. ZEDAN (King Saud Univ., Riyadh, Saudi Arabia) Journal of Aircraft (ISSN 0021-8669) vol. 30, no. 5 Sept.-Oct. 1993 p. 611-617. refs
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An aerodynamic model based on the general unsteady two-dimensional vortex-lattice method and the method of images was developed to predict the unsteady ground effect on the aerodynamic characteristics of a flat plate. The wake is computed as part of the solution by allowing it to deform and roll up into its natural force-free position. The model is not restricted by angle of attack, sink rate, and camber. The results agree perfectly with available exact (steady) solutions. It is also shown that the increase in the magnitude of C sub L and C sub M as a result of unsteady ground effect is greater for high sink rates, in a general agreement with published results. On the other hand, the effect of ground on wake shape and position is greater for lower sink rates. For large sink rates, the wake becomes very close to the flight path with its position less dependent on the height above the ground.
Author (revised)

A93-52434
EXPERIMENTAL STUDY ON THE AERODYNAMIC EFFECTS OF A FORWARD-SWEEP ANGLE
GIOVANNI LOMBARDI (Pisa Univ., Italy) Journal of Aircraft (ISSN 0021-8669) vol. 30, no. 5 Sept.-Oct. 1993 p. 629-635. refs
Copyright

An experimental study to investigate some aerodynamic features of forward-swept wings is described. Pressure distributions on two wing models with different sweep angles (0 deg and -25 deg) were evaluated by means of 320 measurement points, up to angles of attack of 28 deg, in low subsonic and transonic regimes. A comparison of the aerodynamic behavior of the two wings, both at low and high angles of attack (stall and poststall conditions), is presented. At low Mach numbers and low angles of attack, the experimental data were also compared with numerical results obtained with a panel code. Some characteristics of the forward

sweep are discussed and the benefits that can be obtained by applying it in conditions of interference with other lifting surfaces are pointed out. Author (revised)

A93-52436* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
UNSTEADY WING SURFACE PRESSURES IN THE WAKE OF A PROPELLER
R. T. JOHNSTON and J. P. SULLIVAN (Purdue Univ., West Lafayette, IN) Journal of Aircraft (ISSN 0021-8669) vol. 30, no. 5 Sept.-Oct. 1993 p. 644-651. AIAA, Aerospace Sciences Meeting and Exhibit, 30th, Reno, NV, Jan. 6-9, 1992, AIAA Paper 92-0277. Previously cited in issue 09, p. 1348, Accession no. A92-25731 Research supported by NSERC and NASA refs
Copyright

A93-52438* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
APPLICATION OF NONLINEAR SYSTEMS THEORY TO TRANSONIC UNSTEADY AERODYNAMIC RESPONSES
WALTER A. SILVA (NASA, Langley Research Center, Hampton, VA) Journal of Aircraft (ISSN 0021-8669) vol. 30, no. 5 Sept.-Oct. 1993 p. 660-668. AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference, 32nd, Baltimore, MD, Apr. 8-10, 1991, Technical Papers. Pt. 3, p. 1951-1963. Previously cited in issue 12, p. 1905, Accession no. A91-32025 refs
Copyright

A93-52439* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
EULER/EXPERIMENT CORRELATIONS OF SONIC BOOM PRESSURE SIGNATURES
SUSAN E. CLIFF (NASA, Ames Research Center, Moffett Field, CA) and SCOTT D. THOMAS (Sterling Software, Inc., Palo Alto, CA) Journal of Aircraft (ISSN 0021-8669) vol. 30, no. 5 Sept.-Oct. 1993 p. 669-675. AIAA Applied Aerodynamics Conference, 9th, Baltimore, MD, Sept. 23-25, 1991, Technical Papers. Vol. 2, p. 606-633. Previously cited in issue 23, p. 4003, Accession no. A91-53782 refs
Copyright

A93-52442* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
MULTIELEMENT AIRFOIL PERFORMANCE DUE TO REYNOLDS AND MACH NUMBER VARIATIONS
WALTER O. VALAREZO, CHET J. DOMINIK (Douglas Aircraft Co., Long Beach, CA), and ROBERT J. MCGHEE (NASA, Langley Research Center, Hampton, VA) Journal of Aircraft (ISSN 0021-8669) vol. 30, no. 5 Sept.-Oct. 1993 p. 689-694. refs
Copyright

Experimental studies have been conducted to assess Reynolds and Mach number effects on a supercritical multielement airfoil. The airfoil is representative of the stall-critical station of an advanced transport wing design. The experimental work was conducted as part of a cooperative program between the Douglas Aircraft Company and the NASA Langley Research Center to improve current knowledge of high-lift flows and to develop a validation data base with practical geometries/conditions for emerging computational methods. This article describes results obtained for both landing and takeoff multielement airfoils (four- and three-element configurations) for a variety of Mach/Reynolds number combinations up to flight conditions. Effects on maximum lift are considered for the landing configurations, and effects on both lift and drag are reported for the takeoff geometry. The present test results revealed considerable maximum lift effects on the three-element landing configuration for Reynolds number variations, and significant Mach number effects on the four-element airfoil.

A93-52445* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
INVESTIGATION OF VORTEX DEVELOPMENT ON A PITCHING SLENDER BODY OF REVOLUTION
M. J. STANEK and M. R. VISBAL (USAF, Wright Lab., Wright-Patterson AFB, OH) Journal of Aircraft (ISSN 0021-8669) vol. 30, no. 5 Sept.-Oct. 1993 p. 711-718. AIAA Applied Aerodynamics Conference, 9th, Baltimore, MD, Sept. 23-25, 1991, Technical Papers. Vol. 1, p. 571-591. Previously cited in issue 23, p. 4002, Accession no. A91-53780 Research supported by NASA refs

A93-52446* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
FLOWFIELD SIMULATION ABOUT THE STRATOSPHERIC OBSERVATORY FOR INFRARED ASTRONOMY
CHRISTOPHER A. ATWOOD and WILLIAM R. VAN DALSEM (NASA, Ames Research Center, Moffett Field, CA) Journal of Aircraft (ISSN 0021-8669) vol. 30, no. 5 Sept.-Oct. 1993 p. 719-727. AIAA, Aerospace Sciences Meeting and Exhibit, 30th, Reno, NV, Jan. 6-9, 1992, AIAA Paper 92-0656. Previously cited in issue 10, p. 1555, Accession no. A92-28217 refs
Copyright

A93-52448* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
EFFICIENT SIMULATION OF INCOMPRESSIBLE VISCOUS FLOW OVER SINGLE AND MULTIELEMENT AIRFOILS
STUART E. ROGERS, N. L. WILTBERGER, and DOCHAN KWAK (NASA, Ames Research Center, Moffett Field, CA) Journal of Aircraft (ISSN 0021-8669) vol. 30, no. 5 Sept.-Oct. 1993 p. 736-743. AIAA, Aerospace Sciences Meeting and Exhibit, 30th, Reno, NV, Jan. 6-9, 1992, AIAA Paper 92-0405. Previously cited in issue 09, p. 1352, Accession no. A92-26258 refs
Copyright

A93-52451
UNSTEADY PRESSURE AND LOAD MEASUREMENTS ON AN F/A-18 VERTICAL FIN
B. H. K. LEE and F. C. TANG (Inst. for Aerospace Research, Ottawa, Canada) Journal of Aircraft (ISSN 0021-8669) vol. 30, no. 5 Sept.-Oct. 1993 p. 756-762. AIAA Applied Aerodynamics Conference, 10th, Palo Alto, CA, June 22-24, 1992, Technical Papers. Pt. 2, p. 588-599. Previously cited in issue 19, p. 3249, Accession no. A92-45529 Research supported by Inst. for Aerospace Research and DND refs
Copyright

A93-52456* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
TRANSONIC NAVIER-STOKES FLOW COMPUTATIONS OVER WING-FUSELAGE GEOMETRIES
S. AGRAWAL (McDonnell Douglas Corp., Saint Louis, MO), V. N. VATSA (NASA, Langley Research Center, Hampton, VA), and T. A. KINARD (Lockheed Corp., Marietta, GA) Journal of Aircraft (ISSN 0021-8669) vol. 30, no. 5 Sept.-Oct. 1993 p. 791-793. Abridged. AIAA Applied Aerodynamics Conference, 9th, Baltimore, MD, Sept. 23-25, 1991, Technical Papers. Vol. 1, p. 32-42. Previously cited in issue 23, p. 3998, Accession no. A91-53730 Research supported by McDonnell Douglas Independent Research and Development Program refs
Copyright

A93-52457
EFFECT OF LEADING-EDGE GEOMETRY ON DELTA WING UNSTEADY AERODYNAMICS
L. E. ERICSSON and H. H. KING (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) Journal of Aircraft (ISSN 0021-8669) vol. 30, no. 5 Sept.-Oct. 1993 p. 793-795. Abridged. AIAA, Aerospace Sciences Meeting and Exhibit, 30th, Reno, NV, Jan. 6-9, 1992, AIAA Paper 92-0173. Previously cited in issue 08, p. 1169, Accession no. A92-23784 refs
Copyright

A93-52459
NAVIER-STOKES INVESTIGATION OF BLUNT TRAILING-EDGE AIRFOILS USING O GRIDS
M. KHALID and D. J. JONES (National Research Council of

Canada, Inst. for Aerospace Research, Ottawa) Journal of Aircraft (ISSN 0021-8669) vol. 30, no. 5 Sept.-Oct. 1993 p. 797-800. refs
Copyright

It is noted that the Baldwin-Lomax code ARC2D can be used to obtain the flowfield of blunt trailing-edge airfoils, when the computational domain is configured as an O ring, in place of the complex C-H grid. Four different airfoils are investigated. While in principle unsuited for the wake region immediately behind the trailing edge, the ARC2D code yields accurate results on O-grid-based airfoil meshes. AIAA

A93-52594
A SUMMARY OF FURTHER MEASUREMENTS OF STEADY AND OSCILLATORY PRESSURES ON A RECTANGULAR WING
D. G. MABEY, B. L. WELSH, and C. R. PYNE (Defence Research Agency, Aerospace Div., Bedford, United Kingdom) Aeronautical Journal (ISSN 0001-9240) vol. 97, no. 966 June-July 1993 p. 195-207. refs
Copyright

This report describes a series of steady and time dependent pressure measurements on a half-model of a rectangular wing of aspect ratio 4. The wing was mounted on a halfbody attached to a sidewall of the RAE 8 ft x 8 ft windtunnel and the tests were made at Mach numbers of 0.60, 0.70, and 0.80 with fixed transition and a Reynolds number of about 2.4 x 10 exp 6 at the highest Mach number. The wing was oscillated about its mid-chord axis at four frequencies giving frequency parameters up to 0.27 at M = 0.80. The static angle of incidence was varied from -10 deg to +10 deg; here interest is centered on angles of incidence for which the flow on the upper surface of the wing is separated. Selected mean and oscillatory measurements are offered as a challenge to computational fluid dynamicists for this simple three-dimensional configuration. The measurements are of particular interest because the transonic flows include both incipient and well developed separations.

A93-52642
NONLINEAR ASPECTS OF TRANSONIC AEROELASTICITY
H. S. MURTY (Ottawa Univ.; National Research Council of Canada, High Speed Aerodynamics Lab.) and G. W. JOHNSTON (Toronto Univ., Canada) Canadian Aeronautics and Space Journal (ISSN 0008-2821) vol. 39, no. 2 June 1993 p. 78-84. CASI, Canadian Symposium on Aerodynamics, 3rd, Toronto, Canada, Nov. 20, 21, 1991 refs

Linear flutter analysis has been traditionally used in studies of transonic flow. A study of the effects of nonlinear transonic flow on the flutter characteristics of an airfoil is reported. The object was to determine the aerodynamic conditions under which the aerodynamic forces are essentially linear functions of airfoil motion and whether the effect of nonlinear aerodynamic forces of flutter are significant enough to invalidate the linear assumptions in traditional flutter analysis. Nonlinear effects were found to be significant for cases in which the amplitude of shock wave motion, over one cycle of unsteady oscillatory motion was greater than 5 percent chord. Assuming linearity of the transonic loads, a linear flutter analysis was carried out to determine neutral stability conditions. A time response analysis of the system at these neutral stability conditions revealed that in cases of strong aerodynamic nonlinearities, the neutral stability condition determined by traditional methods was not correct.

03

AIR TRANSPORTATION AND SAFETY

Includes passenger and cargo air transport operations; and aircraft accidents.

A93-49280
EFFORTS TO REDUCE CFIT ACCIDENTS SHOULD ADDRESS FAILURES OF THE AVIATION SYSTEM ITSELF
DANIEL MAURINO (International Civil Aviation Organization, Air Navigation Bureau, Montreal, Canada) ICAO Journal (ISSN 0018-8778) vol. 48, no. 4 May 1993 p. 18, 19.
Copyright

Solutions aimed at reducing CFIT occurrences are discussed. The pervasiveness of human factors human error suggests that human factor training is only a partial solution to the problem. Accidents are caused not only by human errors but also by shortcomings in the aviation system. It is concluded that the solution rests in securing a maximum level of system 'safety fitness' by eliminating latent system failures and other organizational deficiencies that may lie behind aviation accidents. AIAA

A93-49518*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
THE CHALLENGES OF SIMULATING WAKE VORTEX ENCOUNTERS AND ASSESSING SEPARATION CRITERIA
R. E. DUNHAM, ROBERT A. STUEVER, and DAN D. VICROY (NASA, Langley Research Center, Hampton, VA) Aug. 1993 9 p. AIAA, Atmospheric Flight Mechanics Conference, Monterey, CA, Aug. 9-11, 1993 refs
(AIAA PAPER 93-3568) Copyright

During landings and take-offs, the longitudinal spacing between airplanes is in part determined by the safe separation required to avoid the trailing vortex wake of the preceding aircraft. Safe exploration of the feasibility of reducing longitudinal separation standards will require use of aircraft simulators. This paper discusses the approaches to vortex modeling, methods for modeling the aircraft/vortex interaction, some of the previous attempts of defining vortex hazard criteria, and current understanding of the development of vortex hazard criteria. AIAA

A93-52168
HAND-HELD CABIN FIRE EXTINGUISHERS - TRANSPORT AIRCRAFT
SAE Aerospace Recommended Practice SAE ARP 4712 Sept. 29, 1992 6 p. refs
(SAE ARP 4712) Copyright

The paper presents the specifications of the SAE Aerospace Recommended Practice concerning the minimum requirements of hand-held portable fire extinguishers (water, carbon-dioxide, halogenated-agent, and dry-chemical classes) fire extinguishers for use on passenger-cabin fires aboard transport aircraft. Particular attention is given to the classes of fires that may occur, the appropriate extinguishing agents in each class, the location and installation of fire extinguishers, the design considerations for hand-held fire extinguishers, the information to be marked on the individual extinguisher nameplate or label/tag on the fire extinguisher, and the precautions recommended to the user. AIAA

04

AIRCRAFT COMMUNICATIONS AND NAVIGATION

Includes digital and voice communication with aircraft; air navigation systems (satellite and ground based); and air traffic control.

A93-49278
ONGOING GPS EXPERIMENTS DEMONSTRATE POTENTIAL OF SATELLITE NAVIGATION TECHNOLOGY
JOHNNY NILSSON (Swedavia, AB, Norrkoping, Sweden) and KENNETH EIDEBERG (Swedish Civil Aviation Authority, Air Navigation Services Dept., Sweden) ICAO Journal (ISSN 0018-8778) vol. 48, no. 4 May 1993 p. 12-15.
Copyright

The potential impact of a newly developed, satellite-based technology on future CNS/ATM and ATN systems are being evaluated and verified in Sweden. Experiments are focused on a prototype transponder for use with the U.S. GPS navigation satellites that consists of a high-precision multichannel receiver, communications processors, and a transmitter receiver. The transponder is capable of automatically changing between absolute and differential GPS modes, as well as between autonomous and ground-controlled modes. It uses an intelligent data link designed to provide necessary capacity and redundancy. The digital communications is synchronized with the GPS satellite atomic clock providing a global time base with an accuracy of 100 nanoseconds. AIAA

A93-49351* *National Aeronautics and Space Administration.* Ames Research Center, Moffett Field, CA.
VISION BASED TECHNIQUES FOR ROTORCRAFT LOW ALTITUDE FLIGHT
BANAVAR SRIDHAR, RAY SUORSA, and PHILIP SMITH (NASA, Ames Research Center, Moffett Field, CA) *In* Intelligent robotics; Proceedings of the International Symposium, Bangalore, India, Jan. 2-5, 1991 New Delhi Tata McGraw-Hill Publishing Co., Ltd. 1991 p. 27-37. refs
Copyright

An overview of research in obstacle detection at NASA Ames Research Center is presented. The research applies techniques from computer vision to automation of rotorcraft navigation. The development of a methodology for detecting the range to obstacles based on the maximum utilization of passive sensors is emphasized. The development of a flight and image data base for verification of vision-based algorithms, and a passive ranging methodology tailored to the needs of helicopter flight are discussed. Preliminary results indicate that it is possible to obtain adequate range estimates except at regions close to the FOE. Closer to the FOE, the error in range increases since the magnitude of the disparity gets smaller, resulting in a low SNR. AIAA

A93-49479
AN INTERNETWORKING BROUTER FOR AVIONICS APPLICATIONS
KENNETH D. FERRIS and DENNIS R. GATENS (FiberCom., Inc., Roanoke, VA) *In* Specialty fiber optic systems for mobile platforms and plastic optical fibers; Proceedings of the Meeting, Boston, MA, Sept. 9-11, 1992 Bellingham, WA Society of Photo-Optical Instrumentation Engineers 1993 p. 231-233.
Copyright

A brouter (bridge/router) is a unit with the capability to bridge some protocols and route others. A brouter can be configured to provide a transparent and/or source routing bridging function as well as routing services for OSI, TCP/IP, and IPX protocols. A summary of the various brouter environmental parameters is presented in tabular form. AIAA

A93-49590
AUTOMATIC CARRIER LANDING SYSTEM UTILIZING AIRCRAFT SENSORS
JOHN L. CRASSIDIS, D. J. MOOK, and JAMES M. MCGRATH (New York State Univ., Buffalo) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090) vol. 16, no. 5 Sept.-Oct. 1993 p. 914-921. AIAA Guidance, Navigation and Control Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers. Vol. 1, p. 595-605. Previously cited in issue 21, p. 3586, Accession no. A91-49637 refs
Copyright

A93-50636
CORRELATION FILTERS FOR AIRCRAFT IDENTIFICATION FROM RADAR RANGE PROFILES
SCOTT HUDSON (Washington State Univ., Pullman) and DEMETRI PSALTIS (California Inst. of Technology, Pasadena) IEEE Transactions on Aerospace and Electronic Systems (ISSN 0018-9251) vol. 29, no. 3 July 1993 p. 741-748. Research supported by Litton Corp. and USAF refs
Copyright

The potential for identifying aircraft using one or more radar range profiles, in conjunction with a correlator, is investigated. Two types of filters are described which maximize the expected value of certain correlation peaks. The effectiveness of one type of filter was investigated in identification experiments using an extensive data set of real radar range profiles of 24 different aircraft. The results suggest that reliable identification is possible provided aircraft aspect information is used and identifications are based on multiple profiles.

A93-50643* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
ELECTRO-OPTICAL NAVIGATION FOR AIRCRAFT
P. K. A. MENON (Georgia Inst. of Technology, Atlanta), GANO B. CHATTERJI, and BANAVAR SRIDHAR (NASA, Ames Research Center, Moffett Field, CA) IEEE Transactions on Aerospace and Electronic Systems (ISSN 0018-9251) vol. 29, no. 3 July 1993 p. 825-833. refs
(Contract NCC2-575)
Copyright

Low altitude flight is extremely demanding on the rotorcraft pilots. This fact has motivated the research in automating various components of low altitude rotorcraft flight operations. Concurrent with the development of guidance laws, efforts are underway to develop systems for locating the terrain and the obstacles using inputs from passive electro-optical sensors such as TV cameras and infrared imagers. A passive obstacle location algorithm that uses image sequences from cameras undergoing translational and rotational motion is developed. The algorithm is in a general form and can operate in multicamera imaging environments. Performance results using an image sequence from an airborne camera are given.

A93-50660
EFFECT OF WET SNOW ON THE NULL-REFERENCE ILS SYSTEM
ERIC K. WALTON (Ohio State Univ., Columbus) IEEE Transactions on Aerospace and Electronic Systems (ISSN 0018-9251) vol. 29, no. 3 July 1993 p. 1030-1035. refs
Copyright

The null-reference instrument landing system (ILS) uses a horizontally polarized antenna on a tower to produce an elevation angle null which forms the VHF glide slope signal used in instrument approaches to a runway. Under certain combinations of snow and earth wetness, there is a severe reduction in the amplitude of the ground reflected signal component. This can severely degrade the glide slope null and thus the ILS system.

A93-51421#
CONTROL THEORETIC APPROACH TO AIR TRAFFIC CONFLICT RESOLUTION
P. K. A. MENON (Optimal Synthesis, Palo Alto, CA) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 3 Washington American Institute of Aeronautics and Astronautics 1993 p. 1168-1178.

refs
(AIAA PAPER 93-3832) Copyright

Aircraft operating in high-density air traffic control environment can sometimes approach unacceptably close to each other over short time periods. If the inter-aircraft distance falls below 2000 feet in altitude or 5 nautical miles along track at any point on the flight path, a conflict is said to have occurred. Preliminary research into the use of system theoretic methods for resolving such conflicts are discussed. The approach employs kinematic vehicle models together with linear multivariable system theory for generating control corrections to the flight plan generated by existing air traffic automation tools. Numerical results illustrating the system performance are given for a few conflict resolution scenarios.

A93-51422#
DEVELOPMENT OF ADVANCED APPROACH AND DEPARTURE PROCEDURES
LOUIS J. J. ERKELENS and JAN-HEIN VAN DRONKELAAR (National Aerospace Lab., Amsterdam, Netherlands) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 3 Washington American Institute of Aeronautics and Astronautics 1993 p. 1179-1190. refs
(AIAA PAPER 93-3833) Copyright

A flight simulator program carried out with 19 airline crews to evaluate various test scenarios concerning curved approaches and departures is discussed. The simulation hardware and software are described and four approach scenarios beneficial from an ATC point of view are summarized and recommendations based on them are made. Failure scenarios involving incorrectly stored waypoint data, flight director divergency failure, and bank angle bias switching failure are considered. Obvious failure scenarios involving computer failure and one-engine inoperative procedure are also examined. AIAA

A93-51423#
STATISTICAL TECHNIQUES FOR TRAFFIC FLOW MANAGEMENT
JAMES S. DEARMON (Mitre Corp., McLean, VA) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 3 Washington American Institute of Aeronautics and Astronautics 1993 p. 1191-1201. refs
(Contract DTFA01-89-C-00001)
(AIAA PAPER 93-3834) Copyright

In the field of air traffic control, traffic flow management (TFM) seeks to expedite air traffic by managing aggregate flows or rates, not individual aircraft. An understanding of the characteristics and interdependencies of these flows will aid in the effort to provide an improved automation system. This paper describes, via actual applications, how statistical techniques can be used to further this understanding.

A93-51424#
THE DEPENDENT CONVERGING INSTRUMENT APPROACH PROCEDURE
ARTHUR P. SMITH, III and ANAND D. MUNDRA (Mitre Corp., McLean, VA) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 3 Washington American Institute of Aeronautics and Astronautics 1993 p. 1202-1207. refs
(AIAA PAPER 93-3835) Copyright

When an airport experiences low ceiling or visibility conditions the arrival capacity is significantly reduced. This is particularly true at airports that use both their main runway and their crosswind runway in Visual Meteorological Conditions (VMC). The consequence of this is an increase in delays. A concept for continuing to conduct approaches in Instrument Meteorological Conditions (IMC) to converging runways has been proposed which calls for controlling the approaches to the two runways such that a stagger between the aircraft is maintained. This procedure is known as Dependent Converging Instrument Approaches (DCIA). This paper describes the DCIA procedure applicable to any runway geometry. The procedure is defined and modeled to capture its safety critical aspects.

A93-51425#
OVERVIEW OF THE FAA'S DIFFERENTIAL GPS CAT III TECHNICAL FEASIBILITY DEMONSTRATION PROGRAM
ROBERT LOH, CURTIS SHIVELY (Mitre Corp., Center for Advanced Aviation Systems Development, McLean, VA), and RAY SWIDER (FAA, Satellite Program Office, Washington) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 3 Washington American Institute of Aeronautics and Astronautics 1993 p. 1208-1213. refs
(AIAA PAPER 93-3836)

FAA and NASA have established a joint program to evaluate the technical feasibility of using guidance from the satellite-based NAVSTAR Global Positioning System (GPS) for Category III (CAT III) precision approaches. A combination of analyses, simulation tests and flight tests will be used to evaluate Differential GPS (DGPS) techniques for CAT III applications. Emphasis will be placed on meeting accuracy and integrity requirements for a complete DGPS-based CAT III autoland capability. Contractors will be requested to supply the ground and airborne equipment for computing the DGPS-based aircraft position and velocity. Contractors will also provide their own aircraft completely equipped with a DGPS-based capability. Feasibility will be demonstrated by meeting either sensor accuracy requirements for Instrument Landing System (ILS) CAT III applications or Total System Error (TSE) requirements currently under development. Additionally, the existing FAA Advisory Circulars for CAT II, CAT III and autoland approaches should be used as a guide for System development. It is expected that meeting TSE requirements would place less demand on the performance of the DGPS-based sensor than meeting ILS-based navigation sensor requirements. This paper gives an overview of the DGPS CAT III system architecture, requirements and demonstration program.

A93-51457*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
VISION BASED OBSTACLE DETECTION AND GROUPING FOR HELICOPTER GUIDANCE
BANAVAR SRIDHAR and GANO CHATTERJI (NASA, Ames Research Center, Moffett Field, CA) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 3 Washington American Institute of Aeronautics and Astronautics 1993 p. 1538-1548. refs
(AIAA PAPER 93-3871) Copyright

Electro-optical sensors can be used to compute range to objects in the flight path of a helicopter. The computation is based on the optical flow/motion at different points in the image. The motion algorithms provide a sparse set of ranges to discrete features in the image sequence as a function of azimuth and elevation. For obstacle avoidance guidance and display purposes, these discrete set of ranges, varying from a few hundreds to several thousands, need to be grouped into sets which correspond to objects in the real world. This paper presents a new method for object segmentation based on clustering the sparse range information provided by motion algorithms together with the spatial relation provided by the static image. The range values are initially grouped into clusters based on depth. Subsequently, the clusters are modified by using the K-means algorithm in the inertial horizontal plane and the minimum spanning tree algorithms in the image plane. The object grouping allows interpolation within a group and enables the creation of dense range maps. Researchers in robotics have used densely scanned sequence of laser range images to build three-dimensional representation of the outside world. Thus, modeling techniques developed for dense range images can be extended to sparse range images. The paper presents object segmentation results for a sequence of flight images.

A93-51967 National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
A PARALLEL IMPLEMENTATION OF A MULTISENSOR FEATURE-BASED RANGE-ESTIMATION METHOD
RAYMOND E. SUORSA and BANAVAR SRIDHAR (NASA, Ames Research Center, Moffett Field, CA) *In* 1993 IEEE Computer Society Conference on Computer Vision and Pattern Recognition, New York, June 15-18, 1993, Proceedings Los Alamitos, CA IEEE Computer Society 1993 p. 379-385. Previously announced in STAR as N93-18883 refs
(Contract RTOP 505-64-13)

There are many proposed vision based methods to perform obstacle detection and avoidance for autonomous or semi-autonomous vehicles. All methods, however, will require very high processing rates to achieve real time performance. A system capable of supporting autonomous helicopter navigation will need to extract obstacle information from imagery at rates varying from ten frames per second to thirty or more frames per second depending on the vehicle speed. Such a system will need to sustain billions of operations per second. To reach such high processing rates using current technology, a parallel implementation of the obstacle detection/ranging method is required. This paper describes an efficient and flexible parallel implementation of a multisensor feature-based range-estimation algorithm, targeted for helicopter flight, realized on both a distributed-memory and shared-memory parallel computer.

A93-52593
AUTOMATIC NAVIGATION IN THE AIR AND AT SEA
S. G. SMITH (Royal Aircraft Establishment, Farnborough, United Kingdom) Aeronautical Journal (ISSN 0001-9240) vol. 97, no. 966 June-July 1993 p. 183-194.
Copyright

A development history and current status evaluation is conducted for automated aeronautical and naval technologies for automated navigation. The inertial (electromechanical and laser gyro), sidereal, radio, and satellite methods of long-range navigation are covered, with attention to the significance of the more recent and sophisticated techniques for the guidance of highly accurate ordnance. Plausible development trends based on satellite navigation are discussed. AIAA

05

AIRCRAFT DESIGN, TESTING AND PERFORMANCE

Includes aircraft simulation technology.

A93-48059
THE CUSP CATASTROPHE AND THE STABILITY PROBLEM OF HELICOPTER GROUND RESONANCE
D. AFOLABI (Purdue Univ., Indianapolis, IN) Royal Society (London), Proceedings, Series A - Mathematical and Physical Sciences (ISSN 0962-8444) vol. 441, no. 1912 May 8, 1993 p. 399-406. refs
Copyright

Catastrophe theory is used to derive closed form expressions for the critical speeds of helicopters in ground resonance. The results are obtained for an adaptation of Coleman's model of helicopters with soft, in-plane hingeless rotors. It is shown that the characteristic polynomial of the rotorcraft system is diffeomorphic to a versal unfolding of the cusp catastrophe germ. Expressions are computed for the equilibrium manifold and the bifurcation set. The expression for the bifurcation set is then used to obtain a frequency equation for finding the exact critical speeds.

A93-48261*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
FLUID-STRUCTURAL INTERACTIONS USING NAVIER-STOKES FLOW EQUATIONS COUPLED WITH SHELL FINITE ELEMENT STRUCTURES
GURU P. GURUSWAMY and CHANSUP BYUN (NASA, Ames Research Center, Moffett Field, CA) Jul. 1993 11 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-3087) Copyright

A computational procedure is presented to study fluid-structural interaction problems for three-dimensional aerospace structures. The flow is modeled using the three-dimensional unsteady Euler/Navier-Stokes equations and solved using the finite-difference approach. The three dimensional structure is modeled using shell/plate finite-element formulation. The two disciplines are coupled using a domain decomposition approach. Accurate procedures both in time and space are developed to combine the solutions from the flow equations with those of the structural equations. Time accuracy is maintained using aeroelastic configuration-adaptive moving grids that are computed every time step. The work done by aerodynamic forces due to structural deformations is preserved using consistent loads. The present procedure is validated by computing the aeroelastic response of a wing and comparing with experiment. Results are illustrated for a typical wing-body configuration.

A93-48265#
NUMERICAL SIMULATION OF A BLAST INSIDE A BOEING 747
JOSEPH D. BAUM, HONG LUO (Science Applications International Corp., McLean, VA), and RAINALD LOEHNER (George Washington Univ., Washington) Jul. 1993 9 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 Research supported by DNA refs
(AIAA PAPER 93-3091) Copyright

The application of a recently developed 3D adaptive finite element scheme on unstructured tetrahedral grids to the simulation of a blast within the passenger compartment of a Boeing 747 is described. The results demonstrate the complex shock wave diffraction inside the passenger compartment and show that the failure of the forward doors during the early phases of the explosion inside the compartment would not lead to a loss of control or the breakup of the aircraft. The devastating effect of the shock systems inside the cabin as compared to a closed cabin were only diminished slightly. AIAA

A93-48337*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
NONSMOOTH TRAJECTORY OPTIMIZATION - AN APPROACH USING CONTINUOUS SIMULATED ANNEALING
PING LU and M. A. KHAN (Iowa State Univ. of Science and Technology, Ames) *In* AIAA Atmospheric Flight Mechanics Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers Washington American Institute of Aeronautics and Astronautics 1993 p. 353-361. refs
(Contract NAG1-1255)
(AIAA PAPER 93-3657) Copyright

An account is given of the properties of a continuous simulated annealing algorithm that can function as a global optimization tool for nonsmooth dynamic systems, as shown in the case of a trajectory-optimization program implementation. The approach is shown to successfully solve the problem of nonsmooth trajectory optimization for a high performance rigid-body aircraft. The results obtained demonstrate the superiority of the simulated annealing algorithm over widely used algorithms. AIAA

A93-48341#
RESULTS AND LESSONS LEARNED FROM TWO WRIGHT LABORATORY FLIGHT RESEARCH PROGRAMS
DAVID J. MOORHOUSE, LAWRENCE A. WALCHLI (USAF, Flight Dynamics Directorate, Wright-Patterson AFB, OH), and JOSEPH L. KRUMENACKER (Grumman Corp., Aircraft Systems Div.,

Bethpage, NY) *In* AIAA Atmospheric Flight Mechanics Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers Washington American Institute of Aeronautics and Astronautics 1993 p. 388-405. refs
(AIAA PAPER 93-3661)

Wright Laboratory and its forerunners have a long history of sponsoring flight research programs to advance a variety of technologies. Two of the most recent programs are the X-29 Technology Demonstrator and the STOL and Maneuver Technology Demonstrator (S/MTD). Over a period of nine years of flying, the X-29 validated its suite of technologies throughout a large performance envelope with subsonic and supersonic conditions as well as the high-angle-of-attack (alpha) poststall regime. The flight tests here reported validated pneumatic control of its nose vortices to enhance directional control at high alpha. The S/MTD could be considered a complementary program in some ways. Benefits from 2D exhaust nozzles with thrust vectoring and reversing, integrated to form an Integrated Flight/Propulsion Control System, were demonstrated. These technologies provided an F-15B with both short field performance and enhanced performance and maneuvering across the conventional aircraft flight envelope.
Author (revised)

A93-49012 National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
THREE-DIMENSIONAL TIME-MARCHING AEROELASTIC ANALYSES USING AN UNSTRUCTURED-GRID EULER METHOD
RUSS D. RAUSCH (Purdue Univ., West Lafayette, IN), JOHN T. BATINA (NASA, Langley Research Center, Hampton, VA), and HENRY T. Y. YANG (Purdue Univ., West Lafayette, IN) AIAA Journal (ISSN 0001-1452) vol. 31, no. 9 Sept. 1993 p. 1626-1633. AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference, 33rd, Dallas, TX, Apr. 13-15, 1992, Technical Papers. Pt. 4, p. 2214-2224. Previously cited in issue 13, p. 2097, Accession no. A92-34500 refs
(Contract NGT-50406)
Copyright

A93-49105
COMPOSITE AIRFRAME STRUCTURES. PRACTICAL DESIGN INFORMATION AND DATA
MICHAEL C.-Y. NIU (Lockheed Aeronautical Systems Co., Burbank, CA) Hong Kong Conmilit Press, Ltd. 1992 687 p. refs
(ISBN 962-7128-06-6) Copyright

A comprehensive survey is conducted of advanced composite structural component design and manufacture in the aerospace industry. Attention is given to organic resin and metal-matrix composites, laminated and sandwich structures, metallic and nonmetallic tooling, thermoforming and pultrusion, and mechanical fastening and bonding methods. Also discussed are laminate strength analyses and fatigue and impact damage characteristics, structural testing practices, NDI methods for composite quality assurance, and composite airframe component applications to military and commercial aircraft. Innovative design approaches are noted.
AIAA

A93-49337
BEYOND STEEL - TMCS FOR LIGHTER LANDING GEAR
RICHARD PIELLISCH Aerospace America (ISSN 0740-722X) vol. 31, no. 7 July 1993 p. 42, 43.
Copyright

An account is given of titanium matrix composite (TMC) landing gear components that weigh half as much as steel components of comparable performance. These TMC components are generally produced by sandwiching SiC continuous fibers between layers of Ti alloy foil that are then consolidated by HIP through the diffusion bonding of the foil layers.
AIAA

A93-49697#
ANALYSIS OF A HIGH BYPASS RATIO ENGINE INSTALLATION USING THE CHIMERA DOMAIN DECOMPOSITION TECHNIQUE
MARK J. OSTRANDER and RICHARD D. CEDAR (GE Aircraft Engines, Cincinnati, OH) Jun. 1993 13 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-1808) Copyright

This paper describes the work performed at GE Aircraft Engines to develop an analytical capability to assess the aerodynamic performance of engine installations. The paper starts by discussing the choices of gridding and solution procedures that are available. This is followed by a brief descriptions of the chimera domain decomposition technique that has been adopted at GE Aircraft Engines. To demonstrate the method, the gridding and solution of a wind tunnel model of a modern high bypass ratio engine installed on an advanced wing is described. The results from the CFD analysis are compared with the wind tunnel test data and conclusions are drawn about the aerodynamic interaction between the nacelle and wing.

A93-49698#
MATCHING ENGINE AND AIRCRAFT LAPSE RATES FOR THE HSCT
C. R. SALAY and D. W. ELLIOTT (GE Aircraft Engines, Cincinnati, OH) Jun. 1993 8 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993
(AIAA PAPER 93-1809) Copyright

To meet the High Speed Civil Transport (HSCT) environmental and economic goals, which are more challenging than those of any preceding commercial aircraft program, all aspects of the program must be optimized as a system, including the propulsion system, airframe, operational procedure, and requirements. The choice of engine cycle type is driven primarily by nozzle philosopy. A high specific thrust engine will require a complex high-risk exhaust nozzle, while a high flow engine will have a simpler nozzle but a larger and more complex engine. Within either engine type, the selection of fan pressure ratio, throttle ratio, and overall pressure ratio is driven by the airframe thrust lapse requirements. The HSCT takeoff gross weight will be at a minimum if the engine and airframe lapses are matched.
AIAA

A93-49708*# National Aeronautics and Space Administration. Hugh L. Dryden Flight Research Facility, Edwards, CA.
PRELIMINARY FLIGHT TEST RESULTS OF A FLY-BY-THROTTLE EMERGENCY FLIGHT CONTROL SYSTEM ON AN F-15 AIRPLANE
FRANK W. BURCHAM, JR., TRINDEL A. MAINE, C. G. FULLERTON (NASA, Flight Research Center, Edwards, CA), and EDWARD A. WELLS (McDonnell Douglas Aerospace, Saint Louis, MO) Jun. 1993 16 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-1820) Copyright

A multi-engine aircraft, with some or all of the flight control system inoperative, may use engine thrust for control. NASA Dryden has conducted a study of the capability and techniques for this emergency flight control method for the F-15 airplane. With an augmented control system, engine thrust, along with appropriate feedback parameters, is used to control flightpath and bank angle. Extensive simulation studies have been followed by flight tests. This paper discusses the principles of throttles-only control, the F-15 airplane, the augmented system, and the flight results including landing approaches with throttles-only control to within 10 ft of the ground.

A93-49796#
WIND TUNNEL RESULTS FOR AN ADVANCED FIGHTER CONFIGURATION EMPLOYING TRANSVERSE THRUST FOR ENHANCED STOL CAPABILITY
RICHARD R. RAIFORD and HANS J. DALL (Northrop Advanced Technology and Design Center, Pico Rivera, CA) Jun. 1993 17 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs

(Contract F33615-83-C-3011)
(AIAA PAPER 93-1933) Copyright

A low speed wind tunnel test was conducted to evaluate a propulsive lift concept applicable to advanced fighter aircraft with short takeoff and landing requirements. The Transverse Thrust for Lift Augmentation (TTLA) concept utilizes engine exhaust gases discharged laterally behind the wing's deflected trailing-edge flap to generate additional aerodynamic lift. The experimental investigation was performed in the Northrop 7 by 10-foot Low Speed Wind Tunnel using the NASA Ames 0.095-scale horizontal attitude takeoff and landing (HATOL) model as an advanced fighter configuration employing transverse thrust. A parametric assessment of the sensitivity of transverse thrust-induced effects to nozzle position and jet orientation was made for blowing coefficients ranging from 0 to 2.25. An optimum location and orientation of the jets was determined for the HATOL model based on these data. The impact of transverse thrust on longitudinal and lateral/directional stability and control was studied with the optimum nozzle configuration. In addition, the sensitivity of transverse thrust effectiveness to the magnitude of the flap deflection was determined. Ground proximity effects with TTLA and transition to reverse thrust in a simulated ground roll mode were also investigated. Flow visualization of the transverse jets was accomplished by injecting water into the jets upstream of the nozzles.

A93-49969#
DEVELOPMENT OF THE F/A-18 E/F AIR INDUCTION SYSTEM
G. R. HALL, W. M. HURWITZ, G. S. TIEBENS (Northrop Corp., Aircraft Div., Hawthorne, CA), W. P. NORBY (McDonnell Douglas Corp., Saint Louis, MO), P. SINGSHINSUK, and C. E. WILT (U.S. Navy, Naval Air Systems Command, Arlington, VA) Jun. 1993 18 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2152) Copyright

The F/A-18 E/F is an evolutionary upgrade to the existing F/A-18 C/D weapon system and will serve as the Navy's next strike fighter well into the 21st century. The E/F upgrade features several airframe improvements, including a new inlet design, known as a caret inlet. The wind tunnel development program has been successfully completed and the inlet has been integrated into the overall E/F aircraft configuration. The development program is described and includes a description of the inlet and a chronology of wind tunnel tests, utilizing both isolated inlet and fully integrated inlet/airframe models. Design iterations are reviewed, which have evolved to the current inlet configuration. Validation testing and data analysis for subsonic and transonic flight conditions have been completed and results are presented. The final supersonic test was completed in May 1993.

A93-50429
CARBON COMPOSITE REPAIRS OF HELICOPTER METALLIC PRIMARY STRUCTURES
MICHAEL L. OVERD (Westland Helicopters, Ltd., Yeovil, United Kingdom) Composite Structures (ISSN 0263-8223) vol. 25, no. 1-4 1993 p. 557-565. Composite structures; Proceedings of the 7th International Conference, Univ. of Paisley, United Kingdom, July 5-7, 1993. A93-50376 21-24
Copyright

Four case studies illustrating simple methods used to design and carry out carbon composite repairs of helicopter metallic primary structures are presented, together with their fatigue performance to date. The case study experience is translated into general design rules which could be used in service. The applicability and limitations of the techniques are also discussed. The techniques are found to be viable for in-service use. AIAA

A93-50487
X-29 HIGH-ANGLE-OF-ATTACK FLIGHT TESTING
Aerospace Engineering (ISSN 0736-2536) vol. 13, no. 7 July 1993 p. 11-17.
Copyright

The X-29-2 high-alpha-research forward-swept wing (FSW) experimental aircraft has been used by NASA and the USAF Flight Test Center to conduct an envelope-expansion test phase, as well as trials of this aircraft's military utility and a vortex-flow control (VFC) experiments. These testing efforts gave attention to the high-alpha control advantages associated with the FSW configuration and to combat maneuver capabilities. The VFC experiment attempted to validate pneumatic forebody vortex control as an effective yaw-force-generating method at moderate and high alpha. AIAA

A93-51338*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
HODOGRAPH ANALYSIS IN AIRCRAFT TRAJECTORY OPTIMIZATION
EUGENE M. CLIFF (Virginia Polytechnic Inst. and State Univ., Blacksburg, VA), HANS SEYWALD (Analytical Mechanics Associates, Inc., Hampton, VA), and ROBERT R. BLESS (Lockheed Engineering and Sciences Co., Hampton, VA) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 1 Washington American Institute of Aeronautics and Astronautics 1993 p. 363-371. Research supported by USAF refs
(Contract NAG1-1244; NAS1-18935; NAS1-19000)
(AIAA PAPER 93-3742) Copyright

An account is given of key geometrical concepts involved in the use of a hodograph as an optimal control theory resource which furnishes a framework for geometrical interpretation of the minimum principle. Attention is given to the effects of different convexity properties on the hodograph, which bear on the existence of solutions and such types of controls as chattering controls, 'bang-bang' control, and/or singular control. Illustrative aircraft trajectory optimization problems are examined in view of this use of the hodograph. AIAA

A93-51349*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
AN INVESTIGATION OF THE FUEL-OPTIMAL PERIODIC TRAJECTORIES OF A HYPERSONIC VEHICLE
LARRY D. DEWELL and JASON L. SPEYER (California Univ., Los Angeles) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 1 Washington American Institute of Aeronautics and Astronautics 1993 p. 466-473. refs
(Contract NAG1-1256)
(AIAA PAPER 93-3753) Copyright

Periodic trajectories were found to minimize the range-averaged fuel consumption. For a realistic hypersonic aircraft modeled as a point mass over a nonrotating, spherical Earth, the periodic orbit yielded a 15 percent improvement in fuel consumption over static cruise. Moreover, vehicle dynamic loading was contained within a realistic survivability envelope of 8 g's. The resulting periodic orbit is composed of very distinct flight regimes (Keplerian arc, atmospheric glide and powered climb), which may offer mission advantages over the static path.

A93-51359*# National Aeronautics and Space Administration. Hugh L. Dryden Flight Research Facility, Edwards, CA.
IDENTIFICATION OF INTEGRATED AIRFRAME-PROPULSION EFFECTS ON AN F-15 AIRCRAFT FOR APPLICATION TO DRAG MINIMIZATION
GERALD S. SCHKOLNIK (NASA, Flight Research Center, Edwards, CA) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 1 Washington American Institute of Aeronautics and Astronautics 1993 p. 569-592. refs
(AIAA PAPER 93-3764) Copyright

The application of an adaptive real-time measurement-based performance optimization technique is being explored for a future flight research program. The key technical challenge of the approach is parameter identification, which uses a perturbation-search technique to identify changes in performance caused by forced oscillations of the controls. The controls on the NASA F-15 highly integrated digital electronic control (HIDEC)

aircraft were perturbed using inlet cowl rotation steps at various subsonic and supersonic flight conditions to determine the effect on aircraft performance. The feasibility of the perturbation-search technique for identifying integrated airframe-propulsion system performance effects was successfully shown through flight experiments and postflight data analysis. Aircraft response and control data were analyzed postflight to identify gradients and to determine the minimum drag point. Changes in longitudinal acceleration as small as 0.004 g were measured, and absolute resolution was estimated to be 0.002 g or approximately 50 lbf of drag. Two techniques for identifying performance gradients were compared: a least-squares estimation algorithm and a modified maximum likelihood estimator algorithm. A complementary filter algorithm was used with the least squares estimator.

A93-51360*# National Aeronautics and Space Administration. Hugh L. Dryden Flight Research Facility, Edwards, CA.
PERFORMANCE-SEEKING CONTROL - PROGRAM OVERVIEW AND FUTURE DIRECTIONS
GLENN B. GILYARD and JOHN S. ORME (NASA, Flight Research Facility, Edwards, CA) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 2 Washington American Institute of Aeronautics and Astronautics 1993 p. 593-609. refs
(AIAA PAPER 93-3765) Copyright

A flight test evaluation of the performance-seeking control (PSC) algorithm on the NASA F-15 highly integrated digital electronic control research aircraft was conducted for single-engine operation at subsonic and supersonic speeds. The model-based PSC system was developed with three optimization modes: minimum fuel flow at constant thrust, minimum turbine temperature at constant thrust, and maximum thrust at maximum dry and full afterburner throttle settings. Subsonic and supersonic flight testing were conducted at the NASA Dryden Flight Research Facility covering the three PSC optimization modes and over the full throttle range. Flight results show substantial benefits. In the maximum thrust mode, thrust increased up to 15 percent at subsonic and 10 percent at supersonic flight conditions. The minimum fan turbine inlet temperature mode reduced temperatures by more than 100 F at high altitudes. The minimum fuel flow mode results decreased fuel consumption up to 2 percent in the subsonic regime and almost 10 percent supersonically. These results demonstrate that PSC technology can benefit the next generation of fighter or transport aircraft. Author (revised)

A93-51401*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
A COMPARATIVE STUDY OF MULTIVARIABLE ROBUSTNESS ANALYSIS METHODS AS APPLIED TO INTEGRATED FLIGHT AND PROPULSION CONTROL
JOHN D. SCHIERMAN, T. A. LOVELL, and DAVID K. SCHMIDT (Arizona State Univ., Tempe) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 2 Washington American Institute of Aeronautics and Astronautics 1993 p. 984-994. refs
(Contract NAG3-998)
(AIAA PAPER 93-3809) Copyright

Three multivariable robustness analysis methods are compared and contrasted. The focus of the analysis is on system stability and performance robustness to uncertainty in the coupling dynamics between two interacting subsystems. Of particular interest is interacting airframe and engine subsystems, and an example airframe/engine vehicle configuration is utilized in the demonstration of these approaches. The singular value (SV) and structured singular value (SSV) analysis methods are compared to a method especially well suited for analysis of robustness to uncertainties in subsystem interactions. This approach is referred to here as the interacting subsystem (IS) analysis method. This method has been used previously to analyze airframe/engine systems, emphasizing the study of stability robustness. However, performance robustness is also investigated here, and a new measure of allowable uncertainty for acceptable performance robustness is introduced. The IS methodology does not require plant uncertainty models to measure the robustness of the system, and is shown to yield valuable information regarding the effects of subsystem interactions. In contrast, the SV and SSV methods allow for the evaluation of the robustness of the system to particular models of uncertainty, and do not directly indicate how the airframe (engine) subsystem interacts with the engine (airframe) subsystem. Author (revised)

A93-51480#
OPTIMAL PERFORMANCE OF AIRPLANES FLYING THROUGH WINDSHEAR
JOSE L. R. BELDERRAIN and PEDRO PAGLIONE (Inst. Tecnologico de Aeronautica, Sao Jose dos Campos, Brazil) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 3 Washington American Institute of Aeronautics and Astronautics 1993 p. 1753-1762. refs
(AIAA PAPER 93-3846) Copyright

This paper is an application of optimal control theory to the climbing flight of an aircraft through windshear after take-off. In order to alleviate the effect of the airmass decelerating force - which may be as large as the total aircraft drag - the minimization of actual flight-path deviations with respect to a reference flight-path was chosen as a performance index, The mathematical modeling is realistic; of particular importance was the choice of a rigid-body model for the aircraft. The resulting mathematical problem (system of ordinary differential equations with multiple boundary conditions) was solved by means of the multiple-shooting method together with a modified continuation method. Several optimal trajectories were obtained, which show that the control strategy is basically to keep the groundspeed at a constant value, as long as the maximum angle-of-attack is not exceeded.

A93-51752
DETERMINATION OF THE NATURAL VIBRATIONS OF AN ACOUSTIC MEDIUM IN THE CABIN OF A PASSENGER AIRCRAFT BY THE FINITE ELEMENT METHOD [OPREDELENIE SOBSTVENNYKH KOLEBANIJ AKUSTICHESKOJ SREDY V SALONE PASSAZHIRSKOGO SAMOLETA METODOM KONECHNYKH ELEMENTOV]
A. G. DASHEVSKIJ TsAGI, Trudy no. 2355 1988 p. 15-19. In RUSSIAN refs
Copyright

An analog of a two-dimensional acoustic element is proposed which makes it possible to use a numerical method to solve the problem of the natural vibrations of an acoustic medium in a closed cylindrical volume of an arbitrary cross sectional area with absolutely rigid walls. The natural frequencies and modes in the cabin of a typical passenger aircraft are determined. A comparison is made with exact solutions for regular geometrical volumes that are commonly used as approximation models. AIAA

A93-51758
CORRECTION OF A METHOD FOR CALCULATING THE NOISE LEVELS OF AIRCRAFT AT CONTROL POINTS DURING ACOUSTIC FLIGHT TESTING [O KORREKTSII METODIKI RASCHETA UROVNEJ SHUMA SAMOLETA V KONTROL'NYKH TOCHKAKH PRI LETNYKH AKUSTICHESKIKH ISPYTANIYAKH]
I. S. ZAGUZOV TsAGI, Trudy no. 2355 1988 p. 53-58. In RUSSIAN refs
Copyright

A method is presented for calculating aircraft noise levels at control points from acoustic flight test data, with modifications introduced to allow for the requirements of the existing standards. The method allows for interference effects due to the effect of the earth surface. The modified method facilitates the task of aircraft certification based on noise monitored at control points on the ground. AIAA

A93-51905
CALCULATION OF AERODYNAMIC LOADS ON THE WING OF RIGID AND ELASTIC AIRCRAFT WITH ALLOWANCE FOR LOAD CORRECTION FROM EXPERIMENTAL DATA [RASCHET AEHRODINAMICHESKIKH NAGRUZOK NA KRYLO ZHESTKOGO I UPRUGOGO SAMOLETA S UCHETOM KORREKTSII NAGRUZOK EHKSPERIMENTAL'NYMI DANNYMI]
N. A. PODBOLOTOVA *In* Problems in the aerodynamics of flight vehicles and their components Moscow, Russia Moskovskij Aviatsionnyj Institut 1992 p. 20-28. In RUSSIAN
Copyright

A method and software have been developed for calculating aerodynamic loads on aircraft during flight with allowance for the effects of static aeroelasticity. The software implements an iteration method for calculating aerodynamic loads on an elastic aircraft in subsonic flight. The aerodynamic computation scheme is based on the discrete vortex method. Details of the computation procedure and examples of calculations are presented. AIAA

A93-51912
CALCULATION OF A PLANE SUPERSONIC JET SIMULATING THE EXHAUST JET OF A HYPERSONIC FLIGHT VEHICLE ENGINE [RASCHET PLOSKOJ SVERKHZVUKOVOJ STRUI, MODELIRUYUSHCHEJ VYKHLOPNUYU STRUYU DVIGATELYA GIPERZVUKOVOGO LA]
V. V. SILAEV *In* Problems in the aerodynamics of flight vehicles and their components Moscow, Russia Moskovskij Aviatsionnyj Institut 1992 p. 70-75. In RUSSIAN refs
Copyright

The main differential equation of gas dynamics for a plane steady state potential nonviscous flow is solved by the layer-by-layer method of characteristics. The method combines the properties of orthogonal grid methods and those of the traditional version of the method of characteristics. A full system of equations is then derived which includes differential equations of characteristics, compatibility conditions, the Bernoulli equation, and the equation of state. Based on this approach, a program has been developed for calculating plane supersonic jets simulating the exhaust flow of the engines of hypersonic flight vehicles. A calculation example is included. AIAA

A93-52165
WHEEL AND BRAKE DESIGN AND TEST REQUIREMENTS FOR MILITARY AIRCRAFT
SAE Aerospace Recommended Practice SAE ARP 1493 Aug. 7, 1992 35 p. refs
(SAE ARP 1493) Copyright

An overview is given of recommended design and testing practices for military aircraft wheels and brakes. These recommendations are addressed to both engineering and military personnel engaged in the detailed formulation of design and performance specifications. Both SAE and MIL specifications documents pertinent to the topic are covered. AIAA

A93-52166
CABIN ACCOMMODATIONS FOR PASSENGERS WITH AMBULATORY DISABILITIES - TRANSPORT CATEGORY AIRCRAFT
SAE Aerospace Recommended Practice SAE ARP 4387 Sept. 29, 1992 3 p. refs
(SAE ARP 4387) Copyright

The present design considerations for handicapped passengers apply to all transport-category aircraft conforming to DOT Regulations CFR382. The guidelines presented are intended to furnish cabin service comparable to that available to normal passengers without compromising the safety of all passengers occupying the cabin in question. The accommodations to be tailored for passengers with ambulatory disabilities encompass lavatories, wheelchairs, special videotaped briefings for handicapped passengers concerning safety practices, and cabin stowage of personal wheelchairs. AIAA

A93-52175
CRASHWORTHY LANDING GEAR DESIGN
SAE Aerospace Information Report SAE AIR 4566 July 10, 1992 41 p. refs
(SAE AIR 4566) Copyright

The paper documents the requirements for and approaches to the crashworthy design of aircraft landing gear of the commercial and military fixed-wing and rotory-wing aircraft. Particular attention is given to the requirements and the documents containing the requirements for crashworthy design features of landing gear; the reasons for and approaches to the crashworthy landing gear design; and the applications of crashworthy landing gear designs, with particular attention given to specific fixed-wing and rotary-wing aircraft applications. Design diagrams of landing gear illustrating the design solutions for these specific applications are presented. AIAA

A93-52435
IDENTIFICATION OF ACTUATION SYSTEM AND AERODYNAMIC EFFECTS OF DIRECT-LIFT-CONTROL FLAPS
R. V. JATEGAONKAR (DLR, Inst. fuer Flugmechanik, Braunschweig, Germany) Journal of Aircraft (ISSN 0021-8669) vol. 30, no. 5 Sept.-Oct. 1993 p. 636-643. AIAA, Aerospace Sciences Meeting and Exhibit, 30th, Reno, NV, Jan. 6-9, 1992, AIAA Paper 92-0171. Previously cited in issue 08, p. 1172, Accession no. A92-23782 refs
(Contract DFG-SFB-212)
Copyright

A93-52440* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
EXPERIMENTAL STUDY OF PYLON CROSS SECTIONS FOR A SUBSONIC TRANSPORT AIRPLANE
DINESH A. NAIK (Vigyan, Inc., Hampton, VA), ANTHONY M. INGRALDI, and ODIS C. PENDERGRAFT, JR. (NASA, Langley Research Center, Hampton, VA) Journal of Aircraft (ISSN 0021-8669) vol. 30, no. 5 Sept.-Oct. 1993 p. 676-681. AIAA, Aerospace Sciences Meeting and Exhibit, 30th, Reno, NV, Jan. 6-9, 1992, AIAA Paper 92-0153. Previously cited in issue 08, p. 1172, Accession no. A92-23768 refs
(Contract NAS1-17919)
Copyright

A93-52443* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
EFFICIENT FINITE ELEMENT METHOD FOR AIRCRAFT DEICING PROBLEMS
J. R. HUANG, THEO G. KEITH, JR., and KENNETH J. DE WITT (Toledo Univ., OH) Journal of Aircraft (ISSN 0021-8669) vol. 30, no. 5 Sept.-Oct. 1993 p. 695-704. AIAA, Aerospace Sciences Meeting and Exhibit, 30th, Reno, NV, Jan. 6-9, 1992, AIAA Paper 92-0532. Previously cited in issue 12, p. 1905, Accession no. A92-31670 Research supported by NASA refs
Copyright

A93-52450
MONITORING LOAD EXPERIENCE OF INDIVIDUAL AIRCRAFT
J. B. DE JONGE (National Aerospace Lab., Amsterdam, Netherlands) Journal of Aircraft (ISSN 0021-8669) vol. 30, no. 5 Sept.-Oct. 1993 p. 751-755. Previously announced in STAR as N92-15065 refs
Copyright

The actual service load experience of aircraft may differ appreciably from design assumptions. The necessity to monitor service loads is generally recognized now for military aircraft. A general review of the overall life management procedure commonly used today is given. Specific elements in this procedure are discussed in some detail. Specific attention is paid to the amount of scatter in severity between different flights and the required sample sizes of flight load measurements for obtaining reliable average load spectrum data. Possible causes for variation in load experience between different aircraft flying the same duty are

analyzed. It is concluded that Individual Aircraft Tracking (IAT), if necessary at all, can usually be adequately accomplished by administrative means, indicated as Usage Monitoring.

A93-52454* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
FINITE STATE AEROELASTIC MODEL FOR USE IN ROTOR DESIGN OPTIMIZATION
CHENGJIAN HE and DAVID A. PETERS (Georgia Inst. of Technology, Atlanta) Journal of Aircraft (ISSN 0021-8669) vol. 30, no. 5 Sept.-Oct. 1993 p. 777-784. refs
(Contract NAG1-710)
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In this article, a rotor aeroelastic model based on a newly developed finite state dynamic wake, coupled with blade finite element analysis, is described. The analysis is intended for application in rotor blade design optimization. A coupled simultaneous system of differential equations combining blade structural dynamics and aerodynamics is established in a formulation well-suited for design sensitivity computation. Each blade is assumed to be an elastic beam undergoing flap bending, lead-lag bending, elastic twist, and axial deflections. Aerodynamic loads are computed from unsteady blade element theory where the rotor three-dimensional unsteady wake is described by a generalized dynamic wake model. Correlation of results obtained from the analysis with flight test data is provided to assess model accuracy.

06

AIRCRAFT INSTRUMENTATION

Includes cockpit and cabin display devices; and flight instruments.

A93-48345*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
A METHOD OF WIND SHEAR DETECTION FOR POWERED-LIFT STOL AIRCRAFT
KOHEI FUNABIKI, TOSHIO BANDO, KEIJI TANAKA (National Aerospace Lab., Tokyo, Japan), CHARLES S. HYNES, and GORDON H. HARDY (NASA, Ames Research Center, Moffett Field, CA) *In* AIAA Atmospheric Flight Mechanics Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers Washington American Institute of Aeronautics and Astronautics 1993 p. 442-447. refs
(AIAA PAPER 93-3667) Copyright

A new wind shear warning system for powered-lift STOL aircraft was evaluated by using a flight simulator. Wind shear warning systems for CTOL aircraft have been designed to detect horizontal shear only. Because the approach air speed of STOL aircraft is lower than that for CTOL aircraft, STOL aircraft are more vulnerable to vertical wind due to (1) a gradient of horizontal shear that is smaller for STOL than for CTOL aircraft because of slower airspeed; (2) STOL aircraft spend longer time in a downdraft; and (3) vertical wind causes a more radical change in the STOL aircraft's flight path because of its lower airspeed. In order to detect the vertical wind, the wind shear warning system proposed calculates the difference between potential flight path measured on-board during shear traversal and trimmed flight path estimated from aircraft status. The most characteristic feature of this new system is that it utilizes only inertial information and pitot-static airspeed data; this yields a convenient means of on-board implementation. Simulation test results confirm that the new system can detect the vertical shear. Author (revised)

A93-49340
DEVELOPMENT METHODOLOGY FOR CONTEMPORARY AVIONICS SYSTEMS
ANDREW C. CRUCE (SBS Engineering, Inc., Houston, TX) *In* 1993 Aerospace Avionic Systems Division Conference, 3rd, Denver, CO, Apr. 22, 1993, Proceedings Warrendale, PA Society of Automotive Engineers, Inc. 1993 p. 7-15.
(SAE PAPER 931591) Copyright

Program development methodologies, based on new concepts and innovative test facilities, aimed at providing increased system design and analysis prior to committing to hardware are reviewed. These methodologies also provide a level of laboratory-based development, test, and evaluation support which makes it possible to test realistic integrated systems in the laboratory as a supplement to costly and increasingly scarce flight testing. Particular attention is given to test system facility designs to support these methodologies. AIAA

A93-49344
STANAG 3910 - THE DATA BUS FOR THE NEXT GENERATION OF EUROPEAN AVIONICS SYSTEMS
GUY D'HERVILLY (Dassault Electronique, Saint-Cloud, France) *In* 1993 Aerospace Avionic Systems Division Conference, 3rd, Denver, CO, Apr. 22, 1993, Proceedings Warrendale, PA Society of Automotive Engineers, Inc. 1993 p. 35-42. refs
(SAE PAPER 931595) Copyright

STANAG 3910, a NATO-standardized data bus that guarantees an intrinsic openness to each architecture that will be built upon it, is discussed. It can be applied to the two major European fighter programs: EFA and Rafale. It is concluded that this low-risk, low-cost data bus is based on properly certified and validated tools, parts, and components. AIAA

A93-49345
JIAWG COMPATIBLE DEVELOPMENT BOARDS FOR THE I960
TRACY MARKIE (Tronix Product Development Corp., Phoenix, AZ) *In* 1993 Aerospace Avionic Systems Division Conference, 3rd, Denver, CO, Apr. 22, 1993, Proceedings Warrendale, PA Society of Automotive Engineers, Inc. 1993 p. 43-47.
(SAE PAPER 931596) Copyright

The modular avionics suites in the next generation aircraft, the F-22 Advanced Tactical Fighter and the RAH-66 Comanche, have been specifically defined by JIAWG to provide the highest levels of commonality and interoperability. Both of these programs have chosen the i960 MX as their processor of choice. In order to support the needs of system integrators for early hardware and software prototype development, the PI960MX-JXV JIAWG Execution Vehicle has been created. The PI960MX-JXV is the first board product to combine the i960MX Instruction Set Architecture (ISA) with the Pi Bus Backplane protocol and a MIL-STD-1553B serial data bus. In addition, the PI960MX-JXV fully supports the Ada language tools and emulators from the leading Ada vendors. This paper describes the system architecture of the PI960MX-JXV via block diagrams and system descriptions. The paper also describes the general nature of the PI960MX-JXV's core design and its applicability to a wide variety of high-performance i960 applications, such as its being used in the design of VME-based single beard computers and stand alone i960 execution vehicles. Author (revised)

A93-49432
POSITION SENSOR WITH TWO WAVELENGTH TIME DOMAIN MULTIPLEXING FOR CIVIL AIRCRAFT APPLICATION
ERIC PERRAUD (ONERA, Toulouse, France) *In* Distributed and multiplexed fiber optic sensors; Proceedings of the Meeting, Boston, MA, Sept. 4, 5, 1991 Bellingham, WA Society of Photo-Optical Instrumentation Engineers 1992 p. 155-163. Research supported by Aerospatiale refs
Copyright

The different multiplexing techniques are reviewed and their aeronautical applications are discussed. A new TDM approach is then presented: a second pulse at another wavelength is used as a clock signal. The application for a network of position sensors is then investigated.

A93-49462
SPECIALTY FIBER OPTIC SYSTEMS FOR MOBILE PLATFORMS AND PLASTIC OPTICAL FIBERS; PROCEEDINGS OF THE MEETING, BOSTON, MA, SEPT. 9-11, 1992
LUIS FIGUEROA, ED. (Boeing Defense & Space Group, Seattle, WA), MOTOTAKA KITAZAWA, ED. (Mitsubishi Rayon America, Inc., Los Angeles, CA), NORRIS E. LEWIS, ED. (Litton Poly-Scientific, Blacksburg, VA), ROBERT E. STEELE, ED. (General Motors Corp., Packard Electric Div., Warren, OH), and DEEPAK VARSHNEYA, ED. (Teledyne Ryan Electronics, San Diego, CA) Bellingham, WA Society of Photo-Optical Instrumentation Engineers (SPIE Proceedings. Vol. 1799) 1993 262 p. For individual items see A93-49463 to A93-49481
(SPIE-1799; ISBN 0-8194-0978-2) Copyright

The present volume on specialty fiber-optic systems for mobile platforms and plastic optical fibers discusses plastic optical fiber components and systems, plastic optical fiber characterization, fly-by-light requirements, ladar-based fiber-optic sensors, and fiber-optic data networks for moving platforms. Attention is given to recent developments in plastic optical fiber components for automotive applications, excitation-dependent losses in plastic optical fibers, multimode dispersion in step-index polymer optical fibers, and fiber-optic position sensors. Topics addressed include desirable characteristics for rotorcraft optical components, a ladar fiber-optic sensor system for aircraft applications, implementation of fiber-optic technology in flight controls, and optical sensors and multiplexing for aircraft engine control. Also discussed are optical actuators for fly-by-light applications, flight testing of a fiber-optic temperature sensor, and new concepts for fiber-optic position sensors. AIAA

A93-49465
FIBER OPTIC POSITION SENSORS
GLEN E. MILLER (Boeing Defense & Space Group, Seattle, WA) *In* Specialty fiber optic systems for mobile platforms and plastic optical fibers; Proceedings of the Meeting, Boston, MA, Sept. 9-11, 1992 Bellingham, WA Society of Photo-Optical Instrumentation Engineers 1993 p. 94-102. refs
Copyright

The field of fiber-optic position sensors is reviewed. The various types of sensors are categorized, their relative advantages and disadvantages are discussed, and problem areas which are still to be solved before the technology is likely to find the predicted widespread use are outlined. Attention is given to analog and digital fiber-optic position sensors, wavelength-division digital, time-division digital, digital sensor problems, and electrically active fiber-optic sensors. AIAA

A93-49467
LADAR FIBER OPTIC SENSOR SYSTEM FOR AIRCRAFT APPLICATIONS
G. L. ABBAS, M. DE LA CHAPELLE, F. DONES, D. L. MARTIN, C. R. PORTER, R. S. TEAL, and E. J. VERTATSCHITSCH (Boeing Defense & Space Group, Seattle, WA) *In* Specialty fiber optic systems for mobile platforms and plastic optical fibers; Proceedings of the Meeting, Boston, MA, Sept. 9-11, 1992 Bellingham, WA Society of Photo-Optical Instrumentation Engineers 1993 p. 120-124. refs
Copyright

A ladar fiber optic sensor (LFOS) for aircraft applications is described. Chirped intensity-modulated ranging is used to estimate linear position. LFOS technology offers several advantages over other fiber-optic sensor techniques proposed for aircraft position sensing applications, including small and robust transducer heads, inherent multiplexing capability, and inherent fault isolation capability. LFOS sensors have been integrated inside a flight control surface hydraulic actuator and inside a pilot's sidestick controller. Closed loop operation of the actuator using the LFOS sensor for position feedback was successfully demonstrated in the laboratory. The LFOS sensors in the sidestick controller were used as inputs to fly a flight simulator. The current LFOS interface electronics is contained on two VME circuit cards, with the capability to service four multiplexed sensors. Excellent performance has been achieved. Deviation from linearity over a 7-in. stroke is better than 0.05 percent of full scale. The RMS measurement noise is less than 15 microns for a 1 millisecond measurement interval.
Author (revised)

A93-49471
OPTICAL TEMPERATURE COMPENSATION SCHEMES OF SPECTRAL MODULATION SENSORS FOR AIRCRAFT ENGINE CONTROL
E. BERKCAN (General Electric Co., Schenectady, NY) *In* Specialty fiber optic systems for mobile platforms and plastic optical fibers; Proceedings of the Meeting, Boston, MA, Sept. 9-11, 1992 Bellingham, WA Society of Photo-Optical Instrumentation Engineers 1993 p. 149-158. refs
Copyright

Optical temperature compensation schemes for the ratiometric interrogation of spectral modulation sensors for source temperature robustness are presented. We have obtained better than 50-100x decrease of the temperature coefficient of the sensitivity using this type of compensation. We have also developed a spectrographic interrogation scheme that provides increased source temperature robustness; this affords a significantly improved accuracy over FADEC temperature ranges as well as temperature coefficient of the sensitivity that is substantially and further reduced. This latter compensation scheme can be integrated in a small E/O package including the detection, analog and digital signal processing. We find that these interrogation schemes can be used within a detector spatially multiplexed architecture.

A93-49473
IMPLEMENTATION OF FIBER OPTIC TECHNOLOGY IN FLIGHT CONTROLS
DEEPAK VARSHNEYA (Teledyne Ryan Electronics, San Diego, CA) *In* Specialty fiber optic systems for mobile platforms and plastic optical fibers; Proceedings of the Meeting, Boston, MA, Sept. 9-11, 1992 Bellingham, WA Society of Photo-Optical Instrumentation Engineers 1993 p. 170-175. refs
Copyright

The potential subsystem architectures along with preferred interface and sensor designs for fiber-optic technology implementation for flight controls are described, and an architecture design which exploits most the benefits of fiber-optic technology is selected. It is argued that subsystem architecture design should be chosen on the basis of the system requirements. Electroopotic interface design should be selected on the basis of maximum multiplexing capability, high system reliability/low maintainability, miniumum I/O pin count, minimum optical path loss, and impact due to temperature changes. Sequentially pulsed optical system with digital TDM sensors is the preferred architecture design for flight controls. AIAA

A93-49474
OPTICAL SENSORS AND MULTIPLEXING FOR AIRCRAFT ENGINE CONTROL
E. BERKCAN (General Electric Co., Schenectady, NY) *In* Specialty fiber optic systems for mobile platforms and plastic optical fibers; Proceedings of the Meeting, Boston, MA, Sept. 9-11, 1992 Bellingham, WA Society of Photo-Optical Instrumentation Engineers 1993 p. 176-186. refs
Copyright

Time division multiplexing of spectral modulation fiber optic sensors for aircraft engine control is presented. The paper addresses the architectural properties, the accuracy, the benefits and problems of differenttype of sources, the spectral stability and update times using these sources, the size, weight, and power issues, and finally the technology needs regarding FADEC mountability. The fiber optic sensors include temperature, pressure, and position spectral modulation sensors.

A93-49476 National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
FLIGHT TESTING OF A FIBER OPTIC TEMPERATURE SENSOR

M. J. FINNEY, G. W. TREGAY, and P. R. CALABRESE (Conax Buffalo Corp., NY) *In* Specialty fiber optic systems for mobile platforms and plastic optical fibers; Proceedings of the Meeting, Boston, MA, Sept. 9-11, 1992 Bellingham, WA Society of Photo-Optical Instrumentation Engineers 1993 p. 194-203. Research supported by NASA, Conax Buffalo Corp., and Simmonds Precision Engine Systems refs
Copyright

A fiber optic temperature sensor (FOTS) system consisting of an optical probe, a flexible fiber optic cable, and an electro-optic signal processor was fabricated to measure the gas temperature in a turbine engine. The optical probe contained an emissive source embedded in a sapphire lightguide coupled to a fiber-optic jumper cable and was retrofitted into an existing thermocouple probe housing. The flexible fiber optic cable was constructed with 200 micron core, polyimide-coated fiber and was ruggedized for an aircraft environment. The electro-optic signal processing unit was used to ratio the intensities of two wavelength intervals and provided an analog output value of the indicated temperature. Subsequently, this optical sensor system was installed on a NASA Dryden F-15 Highly Integrated Digital Electronic Control (HIDEC) Aircraft Engine and several flight tests were conducted. Over the course of flight testing, the FOTS system's response was proportional to the average of the existing thermocouples sensing the changes in turbine engine thermal conditions.

A93-49477
NEW CONCEPTS FOR FIBER OPTIC POSITION SENSORS
PERRAUD ERIC (ONERA, Centre d'Etudes et de Recherches de Toulouse, France) *In* Specialty fiber optic systems for mobile platforms and plastic optical fibers; Proceedings of the Meeting, Boston, MA, Sept. 9-11, 1992 Bellingham, WA Society of Photo-Optical Instrumentation Engineers 1993 p. 209-214. refs
Copyright

Digital or ladar fiber optic position sensors may be a promising alternative to electrical LVDT or RVDT for aeronautics. They are rugged devices, they do not need some form of referencing to avoid any error arising from random in-line loss, and they give absolute measurement results. Besides, they are to date, the sensors which are the most advanced in tests for aeronautical applications. In this paper we present new concepts for these sensors which make them easier to implement on an aircraft. One of these ideas consists in referencing the optical fiber length from the emitter/receiver to the ladar sensing head, thus making the sensor acquisition independent of the optical fiber length. The other principles which are discussed in this paper concern digital fiber optic sensors. The second concept consists in adding a checksum to each position encoding word in order to test if the measure is valid or not. We propose a specific quantization law.
Author (revised)

A93-51391#
THE LN-200 FIBER GYRO BASED TACTICAL GRADE IMU
GEORGE A. PAVLATH (Litton Guidance and Control Systems, Woodland Hills, CA) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 2 Washington American Institute of Aeronautics and Astronautics 1993 p. 898-904. refs
(AIAA PAPER 93-3798) Copyright

Litton's Guidance and Control Systems Division is in production with the LN-200, the world's first fiber gyro based tactical grade IMU that performs over the entire military operating environment. The fiber gyros provide 1.0 deg/hr bias error and 100 ppm scale factor error. The LN-200 can be manufactured at low cost due to the automatic equipment used in its production. The LN-200 IMU provides the core for diverse military applications. It is used in the LN-210, which is the AHRS for the RAH-66 Comanche helicopter and in the LN-201, which is the AIM-120 AMRAAM missile IMU. The top-level mechanization and the performance of the LN-200, LN-201, and the LN-210 is reviewed, especially the performance in high dynamic thermal and vibration environments. Production yields and performance statistics of production fiber gyros are covered. Fiber gyro based systems are very reliable. Predicted MTBFs of fiber gyro triaxs exceed 100,000 hrs in rugged airborne and missile environments. Reliability data obtained on Litton fiber gyros are presented.
Author (revised)

07

AIRCRAFT PROPULSION AND POWER

Includes prime propulsion systems and systems components, e.g., gas turbine engines and compressors; and on-board auxiliary power plants for aircraft.

A93-48503
EFFECT OF STEADY-STATE CIRCUMFERENTIAL PRESSURE AND TEMPERATURE DISTORTIONS ON COMPRESSOR STABILITY
XIAOCHUN LIAN, FUQUN CHEN (Northwestern Polytechnical Univ., Xian, China), and LI'AN WANG (Flight Test Research Inst., China) Journal of Aerospace Power (ISSN 1000-8055) vol. 8, no. 2 April 1993 p. 105-108. In CHINESE refs

A model for predicting the effect of inlet steady-state circumferential total pressure distortion on compressor stability presented in Melick (1971) has been improved by considering the variation in compressor efficiency due to the distortion. The improved model is applicable to the case of the inlet steady-state circumferential total temperature distortion. Based on this model, a method has been developed for estimating the effects of combined pressure and temperature distortions on the compressor stability. A numerical analysis was conducted for a two-spool turbojet engine with pressure and temperature distortions as well as the combined distortions. The results show that the variation in compressor efficiency due to distortion cannot be negligible for large-amplitude pressure distortion. For the combined distortions, the pressure and temperature distortion orientations play a certain role in the compressor stall. The maximum loss in the compressor stall margin occurs at superimposed (180 deg overlap) combined distortion. Conversely, the effect is minimum for the opposite combined distortion.
Author (revised)

A93-48506
EXPERIMENTAL STUDY ON TURBULENT TWO-PHASE FLOW IN A DUAL-INLET SIDE DUMP COMBUSTOR
CHANGMING LIAO, XIONG SHEN, and LIXING ZHOU (Tsinghua Univ., Beijing, China) Journal of Aerospace Power (ISSN 1000-8055) vol. 8, no. 2 April 1993 p. 117-120. In CHINESE refs

Measurements of turbulent gas-particle two-phase flows in two types of side dump combustors have been made. One of the combustors is of the blade-inlet type, the other is of the central-tube tangential-inlet type. Experimental investigations have been carried out by using a TSI 2D LDV system. The time-averaged and RMS fluctuation velocity of gas and particle phases in axial and tangential directions have been measured. It can be seen that strong recirculating flows of two phases exist in the head zone of both combustors, and swirling flows of two phases exist in the tangential-inlet combustor; the time-averaged velocity slip between two phases and the fluctuation velocity of two phases are sufficiently high. These flow characteristics can be favorable for ignition, flame stabilization, and combustion intensification.
Author (revised)

A93-48511
SIMPLIFIED MATHEMATICAL MODEL AND DIGITAL SIMULATION OF AEROENGINE
ZIYUAN ZHAO, HUA YAO, and WEIYE LI (Nanjing Aeronautical Inst., China) Journal of Aerospace Power (ISSN 1000-8055) vol. 8, no. 2 April 1993 p. 138-142. In CHINESE refs

Two real-time, large-deviation mathematical models of an aeroengine are investigated to develop an airborne simulator,

Full-Authority Digital Electronic Control (FADEC) system. This study includes three parts: (a) the derivation of two mathematical models based on aerothermodynamics; (b) an evaluation of the engine performance by the method of digital simulation; and (c) a discussion of the theoretical range of the calculated interval of the dynamic cycle and the model influenced by the fuel-control regulation law. Two models are nonlinear, noniterative, and full range. Simulation results show that the accuracy of models is quite good, and most relative errors are less than 3 percent, the biggest being about 5 percent. The calculated interval was reduced to 16 ms (on the PC/AT with an Intel 80287 floating point coprocessor and C language programming). Author (revised)

A93-48520
ON ENGINE PARAMETER ESTIMATION WITH FLIGHT TEST DATA
SIQI FAN, XIANGJUN RONG (Northwestern Polytechnical Univ., Xian, China), SHUREN LI, and XIAOWEN XIN (Flight Test Research Inst., China) Journal of Aerospace Power (ISSN 1000-8055) vol. 8, no. 2 April 1993 p. 173-176. In CHINESE refs

This paper introduces the parameter estimation research for the turbine inlet temperature and compressor exit pressure by using the engine variables measured under different flight conditions. The parameter estimation method is multiple linear regression analysis. The independent variables in the regression equations have been selected from six measured engine variables based on the comprehensive optimal principle about variable selection. The regression models which have been established only include three measured engine variables. The curves of the parameter estimation results shown in this paper demonstrate that the estimation accuracies of these models are satisfactory. This paper also presents the data treatment methods of engine variables recorded on-line with special equipment. Author (revised)

A93-48523
PERFORMANCE IMPROVEMENT OF GAS TURBINE WITH STEAM INJECTION
YANSHENG QIAN (Wuxi Aeroengine Research Inst., China) and HUAITI LI (China Light Weight Gas Development Center) Journal of Aerospace Power (ISSN 1000-8055) vol. 8, no. 2 April 1993 p. 187-190. In CHINESE refs

This paper describes how to choose and modify the WZ-5 gas turbine for steam injection testing and how to evaluate testing parameters and programs. Testing results indicate that when the steam is injected 3.6t/h into the WZ-5 gas turbine, its power output and thermal efficiency increase by 40 and 25 percent respectively. Moreover, the steam injection does not deteriorate the exit temperature profile in the turbine, which ensures long-term reliability of operation for the engine. Author (revised)

A93-48524
EXPERIMENTAL RESEARCH ON A SEMIWATER-GAS-FIRED GAS-TURBINE
KANGCHENG ZHOU (Wuxi Aeroengine Research Inst., China) Journal of Aerospace Power (ISSN 1000-8055) vol. 8, no. 2 April 1993 p. 191-194. In CHINESE

A turboshaft aeroengine WZ5 was modified into a gas turbine working with semiwater-gas. The features of its modification and its fuel gas supply system are described, testing program and results of its performance tests are discussed. It is shown that its starting reliability, burning stability, acceleration response, distributional quality of the exit temperature field, and operating performance are reasonable. Some of these characteristics are even better than the original WZ5 engine operating on aviation kerosene. Author (revised)

A93-48525
EXHAUST SYSTEM MODEL TEST AND RESEARCH
LIDE CHEN (Chengdu Engine Co., China) Journal of Aerospace Power (ISSN 1000-8055) vol. 8, no. 2 April 1993 p. 195-198. In CHINESE refs

At Mach numbers ranging from 0.2 to 0.35, two schemes of 1/5th scale models of exhaust diffusers and elbow-exhausts have been researched. The first scheme was a diffuser with a wide cone angle. In order to reduce the separation losses, the concentric splitter cones were set to augment the diffusibility. The splitter cones were made by subdividing the short wide-angle diffuser into a series of smaller, more optimal ones. The second scheme was a diffuser with a smaller cone angle; in order to reduce the length, the diffuser ratio was distributed between the linear diffuser and the turning vane to improve the overall performance. The results of the model test show that total pressure recovery coefficient Cp of the second scheme is rather high and the pressure loss coefficient DeltaP/Q1 is reduced. At the same time, the DeltaP/Q1 of different constructions of the first scheme were measured separately, and the measurements were analyzed. The function of the splitter cones was demonstrated. Several test curves were used to prove the certain effect of the preswirl cascade in some diffuser angle ranging. Author (revised)

A93-48555
IMPROVING THE DESIGN OF THE MAIN FUEL PUMP OF TURBO-JET 7
CHENGLIN DU (Nanjing Univ. of Aeronautics and Astronautics, China) Nanjing University of Aeronautics and Astronautics, Journal (ISSN 1000-1956) vol. 25, no. 3 June 1993 p. 399-404. In CHINESE refs

This article depicts the investigation of the possibility of replacing ZB-21Phi by ZB-21Phi(G). The basic idea of the improvement is the replacing of the rotor of the main pump ZB-21Phi by that of the pump ZB-22Phi and the replacing the plunger of spherical head by plunger with slippers. Through kinematic and dynamic analysis and construction design,it is proved that the replacement is possible, and only a small amount of new parts and machining in excess are required. Even the shell of the main pump ZB-21Phi is not necessary altered. The improved design not only extends the service life of ZB-21Phi, but also increases the capacity of the pump. This means that a more reliable fuel pump with larger capacity is presented for the high-thrust engine.

A93-48828
AN EXPERIMENTAL STUDY OF THE THRUST AND AERODYNAMIC CHARACTERISTICS OF AN OPERATING RAMJET ENGINE IN A BLOWDOWN WIND TUNNEL [EHKSPERIMENTAL'NOE ISSLEDOVANIE TYAGOVO-AEHRODINAMICHESKIKH KHARAKTERISTIK RABOTAYUSHCHEGO PVRD V IMPUL'SNOJ AEHRODINAMICHESKOJ TRUBE]
V. I. ZVEGINTSEV (RAN, Inst. Teoreticheskoj i Prikladnoj Mekhaniki, Novosibirsk, Russia) Sibirskij Fiziko-Tekhnicheskij Zhurnal (ISSN 0869-1339) no. 2 Mar.-Apr. 1993 p. 37-40. In RUSSIAN refs

Results of the testing of a hypersonic flight vehicle model with an operating ramjet engine in a blowdown wind tunnel at Mach 7.9 are presented. Methods for determining the thrust and aerodynamic characteristics of the model are described. The results demonstrate the feasibility and efficiency of investigating the integral aerodynamic characteristics of hypersonic flight vehicles by testing models with a working powerplant in hypersonic external flow in a blowdown wind tunnel. AIAA

A93-49187
A BLADE ELEMENT METHOD FOR PREDICTING THE OFF-DESIGN PERFORMANCE OF COMPRESSORS
DIYI TANG (Northwestern Polytechnical Univ., Xian, China) and YONGMING WANG (Sichuan Aeroengine Research Inst., China) Journal of Aerospace Power (ISSN 1000-8055) vol. 8, no. 3 Oct. 1992 p. 217-220. In CHINESE refs

A method for predicting the off-design performance of an axial flow compressor is presented. The fundamental of the calculation is incorporation of three flow phenomena: annulus flow, cascade flow, and annulus wall boundary layer flows. The calculation of the annulus flow is based on the radial equilibrium of mainstream and neglects the existence of cascades and the effects of annulus wall boundary layers, so it aims at calculating

the mainstream axial velocity distribution. The calculation of the cascade flow is intended to obtain lift and drag coefficients of cascade airfoil and to calculate the incremental of total enthalpy and entropy across cascades. The calculation of the annulus wall boundary layer provides the blockage effect and the losses caused by annulus wall boundary layer. For obtaining the total losses of the compressors, the loss models of shock waves, blade wake and secondary flow/clearance leakage should be coupled with the above mentioned calculations. As examples, the off-design performance curves of compressors have been calculated; one of them gives the effect of the annulus wall boundary layer on the compressor characteristics. Author (revised)

A93-49190
VIBRATION CHARACTERISTICS OF MISTUNED BLADED DISK
YUNJU YAN and JIALIU GU (Northwestern Polytechnical Univ., Xian, China) Journal of Aerospace Power (ISSN 1000-8055) vol. 8, no. 3 Oct. 1992 p. 234-240. In CHINESE refs

A mathematical model based on the Substructure Mode Synthesis Method is provided for coupling vibration of a mistuned bladed disk. Several low order modes of each substructure are obtained by means of Experimental Modal Analysis and modifying calculation of the modes. Relying on the small perturbation of blade modal stiffness, real mistuned bladed disk and several kinds of theoretical mistuned models are set up. Model parameters and mathematical formulas are checked by use of an induced vibration experiment on a real mistuned disk-bladed on a vibrostand. Analytical results reveal that the mistuning of blades is the reason why the resonant response of some blades on the same stage disk is much greater than that of other blades. Author (revised)

A93-49195
AN OPTIMIZATION METHOD FOR STATISTICAL ASCERTAINMENT OF THE MOST PROBABLE PEAK TEMPERATURE AT COMBUSTOR EXIT
YISHENG DING and XIURONG LIN (Northwestern Polytechnical Univ., Xian, China) Journal of Aerospace Power (ISSN 1000-8055) vol. 8, no. 3 Oct. 1992 p. 259-262. In CHINESE refs

Based on the principles of statistical analysis, a very simple and effective two-dimensional optimization method is employed to process the multi-measured temperature data taken at an annular combustion chamber exit under specified operating conditions. An optimum fitting Weibull equation is obtained, which can meet the preset accuracy requirement of evaluation by applying the least square method. A calculation formula is then derived, which can be used to ascertain the most probable exit peak temperature value with confidence. A numerical example shows that the most probable exit peak temperature (namely the real hot-spot temperature) is higher than the maximum value measured. Some other potential applications of this method are also mentioned.
Author (revised)

A93-49200
ADAPTIVE ENGINE STALL MARGIN CONTROL
JIANGUO SUN and JINQUAN HUANG (Nanjing Aeronautical Inst., China) Journal of Aerospace Power (ISSN 1000-8055) vol. 8, no. 3 Oct. 1992 p. 279-282. In CHINESE refs

This paper proposes an adaptive engine stall margin control (AESMC) for the integration of flight and propulsion controls. Using the model reference adaptive control (MRAC) technique, the AESMC is employed to adjust exhaust nozzle area to uptrim the engine pressure ratio so that the engine stall margin remains a small constant value in all operation conditions and in the full flight envelope. The benefit of the control system is to increase engine thrust and to reduce aircraft acceleration time. In order to evaluate the performance of the AESMC, a nonlinear integrated flight/propulsion model is developed. Digital simulation of the IFPC system is performed. The simulation results show that the IFPC system with the adaptive controller developed has good effectiveness for all operation conditions and for a full flight envelope. For example, the thrusts of two engines increased 16 percent, and aircraft acceleration time is reduced 23 percent at an altitude of 10 km and Mach number from 0.65 to 0.9.
Author (revised)

A93-49202
FRONTALLY TAPERED SQUARED TRENCH CASING TREATMENT FOR IMPROVEMENT OF COMPRESSOR PERFORMANCE
ZHAOHUI DU (Shanghai Jiao Tong Univ., China) and ZHIWEI LIU (Northwestern Polytechnical Univ., Xian, China) Journal of Aerospace Power (ISSN 1000-8055) vol. 8, no. 3 Oct. 1992 p. 291-293. In CHINESE refs

A new type of frontally tapered squared trench casing treatment was designed and tested over the rotor tip in a single axial-flow compressor. Variations in the rotor tip penetration into the trench and the distance of the trench front from the blade leading edge were investigated. Through the measurements of velocity and pressure, the effects of each geometric parameter upon compressor efficiency and stall margin were evaluated. An optimal configuration has been found which gives not only 0.4 percent improvement in efficiency but 2 percent in stall margin in comparison with the smooth wall baseline. The mechanism of enhancement in the efficiency and the reason for the existence of an optimum configuration for frontally tapered squared trench casing treatment are considered. Author (revised)

A93-49204
A NEW TYPE OF FUEL CONTROL MODEL
GENLIANG LOU Journal of Aerospace Power (ISSN 1000-8055) vol. 8, no. 3 Oct. 1992 p. 297-299. In CHINESE

A new type of fuel control model is developed without the conventional fuel cock and pressure drop valve. It consists of a high-precision electronic block, a microcomputer, and an actuator. The actual fuel flow calculated on the microcomputer or checked from the data chart against the parametric signals fed out from the digital-type transducer in relation to the fuel supply is compared with the required fuel flow, and the actuator then balances the actual flow with the required by adjusting the pumping flow or return flow according to the amount of deviation. The fuel control unit built with the new model features high precision, low weight, compact size, and good adaptability, and is especially suitable to the application of digital control on aircraft and engines. The new type of fuel control model has been tested for about 100 hours on a digital control research test bed for aeroengines.
Author (revised)

A93-49329# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
SCREENING STUDIES OF ADVANCED CONTROL CONCEPTS FOR AIRBREATHING ENGINES
PETER J. OUZTS, CARL F. LORENZO, and WALTER C. MERRILL (NASA, Lewis Research Center, Cleveland, OH) Jul. 1992 21 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 28th, Nashville, TN, July 6-8, 1992 Previously announced in STAR as N93-25079 refs
(Contract RTOP 505-62-50)
(AIAA PAPER 92-3320)

The application of advanced control concepts to airbreathing engines may yield significant improvements in aircraft/engine performance and operability. Accordingly, the NASA Lewis Research Center has conducted screening studies of advanced control concepts for airbreathing engines to determine their potential impact on turbine engine performance and operability. The purpose of the studies was to identify concepts which offered high potential yet may incur high research and development risk. A target suite of proposed concepts was formulated by NASA and industry. These concepts were evaluated in a two phase study to quantify each concept's impact on desired engine characteristics. To aid in the evaluation, three target aircraft/engine combinations were considered: a military high performance fighter mission, a high speed civil transport mission, and a civil tiltrotor mission. Each of the advanced control concepts considered in the study were defined and described. The concept's potential impact on

engine performance was determined. Relevant figures of merit on which to evaluate the concepts were also determined. Finally, the concepts were ranked with respect to the target aircraft/engine missions.

A93-49508* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
A REVIEW OF CHEMICALLY REACTIVE TURBULENT FLOW MIXING MECHANISMS AND A NEW DESIGN FOR A LOW NO(X) COMBUSTOR
GIORGIO MCBEATH, BAHMAN GHORASHI (Cleveland State Univ., OH), and KUE CHUN (NASA, Lewis Research Center, Cleveland, OH) *In* Heat Transfer and Fluid Mechanics Institute, 33rd, California State Univ., Sacramento, June 3, 4, 1993, Proceedings Sacramento, CA California State University 1993 p. 55-67. refs
Copyright

A review of chemically reactive flow analysis is presented. Key studies are reviewed. The approaches to modeling chemically reactive flows that are discussed are PDF, conserved PDF, conserved scalar, stochastic, and mixing length. Turbulent mixing mechanisms are also discussed and a model is formulated that could be used for optimizing non-premixed gas reacting systems. Consequently, a re-examination of the NO(x) reduction concepts for nonpremixed reactants are suggested together with two new designs for low NO(x) subsonic combustor research.

A93-49610
EFFECTS OF SIDE-INLET ANGLE IN A THREE-DIMENSIONAL SIDE-DUMP COMBUSTOR
RUEY-HOR YEN and TZU-HSIANG KO (National Taiwan Univ., Taipei) Journal of Propulsion and Power (ISSN 0748-4658) vol. 9, no. 5 Sept.-Oct. 1993 p. 686-693. refs
(Contract NSC-81-0401-E002-584)
Copyright

A numerical study is performed on the flowfield in a three-dimensional side-dump combustor with dual opposite side-inlets, with emphasis on the effect of the side-inlet angle on the flow structures. It is found that the side-inlet angle has a great influence on the recirculation structures which play a decisive role on the combustion characteristics. The larger side-inlet angles are found to strengthen the structures of dome recirculation and cause more fluid to recirculate toward the dome region after it is dumped into the combustor. The smaller side-inlet angles are beneficial to the continuous development of the recirculation structures from the dome region, across the entrance region, and further to the downstream of the side-inlet. The effects of the side-inlet angle on recirculations in the dome region or downstream of the side-inlet are both contrary to the situation in two-dimensional cases, which clarifies several points of conflict existing from previous investigations of this aspect. Author (revised)

A93-49612* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
MIXING IN THE DOME REGION OF A STAGED GAS TURBINE COMBUSTOR
W. A. SOWA, R. A. BRADY, and G. S. SAMUELSEN (California Univ., Irvine) Journal of Propulsion and Power (ISSN 0748-4658) vol. 9, no. 5 Sept.-Oct. 1993 p. 702-707. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 28th, Nashville, TN, July 6-8, 1992, AIAA Paper 92-3089. Previously cited in issue 20, p. 3549, Accession no. A92-48734 refs
(Contract NAG3-1124)
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A93-49616
VALIDATION STUDIES OF SCRAMJET NOZZLE PERFORMANCE
TOHRU MITANI, SHUICHI UEDA, KOICHIRO TANI, SHIGERU SATO, HIROSHI MIYAJIMA (National Aerospace Lab., Kakuda, Japan), MASASHI MATSUMOTO, and SHOUHACHI YASU (Ishikawajima-Harima Heavy Industries Co., Ltd., Tokyo, Japan) Journal of Propulsion and Power (ISSN 0748-4658) vol. 9, no. 5 Sept.-Oct. 1993 p. 725-730. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 28th, Nashville, TN, July 6-8, 1992, AIAA Paper 92-3290. Previously cited in issue 20, p. 3480, Accession no. A92-48879 refs
Copyright

A93-49659#
EFFECT OF GEOMETRY, BLEED RATES AND FLOW SPLITS ON PRESSURE RECOVERY OF A CANTED HYBRID VORTEX-CONTROLLED DIFFUSER
GEOFF MYERS, MANUEL CARDENAS, RAM SRINIVASAN (AlliedSignal Propulsion Engines, Phoenix, AZ), and CARLOS ARANA (USAF, Wright Lab., Wright-Patterson AFB, OH) Jun. 1993 13 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(Contract F33615-87-C-2839)
(AIAA PAPER 93-1762) Copyright

The effects of geometric and flow parameters on the performance of a canted hybrid vortex-controlled diffuser were evaluated in a full-annular test rig designed to reproduce the flow path of an advanced core engine from the deswirl exit of the high stage compressor to the inlet of the turbine nozzle. The test rig included a down-canted, hybrid-vortex controlled diffuser (HVCD), bled from both the hub and the shroud surface at the inlet. Prediffuser and combustor/diffuser geometry was varied to optimize performance. The effect of vortex-control bleed rate, and the flow splits between the combustor dome and annuli was also investigated, over a range of diffuser inlet Mach numbers between 0.45 and 0.75. System performance was evaluated using detailed measurements of wall static pressure distributions and pressure probe surveys. The HVCD system matched the excellent pressure recovery (C sub p(1-4) greater than 0.75) of a previously tested curved-wall diffuser operating at similar inlet conditions, using only half the axial length of the earlier design. Author (revised)

A93-49660*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
AN EFFICIENT LINER COOLING SCHEME FOR ADVANCED SMALL GAS TURBINE COMBUSTORS
MARC D. PASKIN, HUKAM C. MONGIA (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN), and WALDO A. ACOSTA (U.S. Army, Vehicle Propulsion Directorate; NASA, Lewis Research Center, Cleveland, OH) Jun. 1993 14 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Research supported by U.S. Army refs
(AIAA PAPER 93-1763) Copyright

A joint Army/NASA program was conducted to design, fabricate, and test an advanced, small gas turbine, reverse-flow combustor utilizing a compliant metal/ceramic (CMC) wall cooling concept. The objectives of this effort were to develop a design method (basic design data base and analysis) for the CMC cooling technique and then demonstrate its application to an advanced cycle, small, reverse-flow combustor with 3000 F burner outlet temperature. The CMC concept offers significant improvements in wall cooling effectiveness resulting in a large reduction in cooling air requirements. Therefore, more air is available for control of burner outlet temperature pattern in addition to the benefits of improved efficiency, reduced emissions, and lower smoke levels. The program was divided into four tasks. Task 1 defined component materials and localized design of the composite wall structure in conjunction with development of basic design models for the analysis of flow and heat transfer through the wall. Task 2 included implementation of the selected materials and validated design models during combustor preliminary design. Detail design of the selected combustor concept and its refinement with 3D aerothermal analysis were completed in Task 3. Task 4 covered detail drawings, process development and fabrication, and a series of burner rig tests. The purpose of this paper is to provide details of the investigation into the fundamental flow and heat transfer characteristics of the CMC wall structure as well as implementation

of the fundamental analysis method for full-scale combustor design. Author (revised)

A93-49668#
COMBUSTION CHARACTERISTICS AND PASSIVE CONTROL OF AN ANNULAR DUMP COMBUSTOR
E. GUTMARK, K. J. WILSON, K. C. SCHADOW, R. A. STALNAKER, and R. A. SMITH (U.S. Navy, Naval Air Warfare Center, China Lake, CA) Jun. 1993 11 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-1772)

It is shown here that the efficiency of an annular combustor's operation is highly dependent on the fuel injection scheme, the mixing of fuel with the annular air stream, and the mixing with the recirculating hot combustion produced downstream of the dump. Injection far into the coaxial air stream without mixing with recirculation zone gases results in poor combustion, especially for lean mixtures. Fuel injection into the recirculation zone results in poorer performance due to the lack of mixing with the air jet. In regular-circular dump tests the highest efficiency is obtained when the fuel is injected into the tapered section upstream of the dump with relatively low velocity, so that the fuel mixes with the air near the central body surface and after separation mixes also with the hot gases in the recirculation zone. The combustor performance enhancement resulting from three different geometries of the dump plane is shown. AIAA

A93-49685*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
EXPERIMENTAL EVALUATION OF A COOLED RADIAL-INFLOW TURBINE
LIZET TIRRES (Sverdrup Technology, Inc., Brook Park, OH), L. D. DICICCO, and BRENT C. NOWLIN (NASA, Lewis Research Center, Cleveland, OH) Jun. 1993 18 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Previously announced in STAR as N93-28697 refs
(AIAA PAPER 93-1795)

Two 14.4 inch tip diameter rotors were installed and tested in the Small Engines Component Turbine Facility (SECTF) at NASA Lewis Research Center. The rotors, a solid and a cooled version of a radial-inflow turbine, were tested with a 15 vane stat or over a set of rotational speeds ranging from 80 to 120 percent design speed (17,500 to 21,500 rpm). The total-to-total stage pressure ratios ranged from 2.5 to 5.5. The data obtained at the equivalent conditions using the solid version of the rotor are presented with the cooled rotor data. A Reynolds number of 381,000 was maintained for both rotors, whose stages had a design mass flow of 4.0 lbm/sec, a design work level of 59.61 Btu/lbm, and a design efficiency of 87 percent. The results include mass flow data, turbine torque, turbine exit flow angles, stage efficiency, and rotor inlet and exit surveys.

A93-49703#
LIGHTWEIGHT AIRCRAFT TURBINE PROTECTION
J. J. DELUCA (U.S. Army, Research Lab., Watertown, MA), B. C. FENTON (FAA, Technical Center, Atlantic City, NJ), S. P. PETRIE (Massachusetts Univ., Lowell), and J. T. SALVINO (U.S. Navy, Naval Air Warfare Center, Trenton, NJ) Jun. 1993 9 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-1815)

Lightweight armor material technology is investigated as a potential alternative to the traditional steel containment technology for turbine rotor burst protection. The material systems investigated include glass/polyester, glass/phenolic, aramid/phenolic, steel-glass/polyester, steel-glass/phenolic, titanium-aramid/phenolic, and titanium. Of the systems investigated, glass/phenolic is found to be the most efficient on a weight basis, and the all titanium system is the most efficient on a thickness basis. The variable that controls whether the composite ring will contain the rotor burst is the number of fabric wraps. AIAA

A93-49704#
FIBER REINFORCED STRUCTURES FOR TURBINE ENGINE FRAGMENT CONTAINMENT
JOHN N. PEPIN (Pepin Associates, Inc., Scarborough, ME) Jun. 1993 19 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-1816) Copyright

An experimental characterization has been conducted of two lightweight, fiber-reinforced containment structures for rotor disk failures; the first of these is a hybrid-core sandwich panel which can be used as both part of the airframe or nacelle structure or as a containment panel, while the second is a collar or ring that can be placed near the engine hot section. Spin chamber trihub rotor tests were performed with a second-stage power turbine failing at 20,000 rpm. Three triangular structures formed with flat panels and one lenticular structure formed with two curved panels were tested. AIAA

A93-49705#
ANALYSIS OF TURBINE ENGINE ROTOR CONTAINMENT AND SHIELDING STRUCTURES
J. A. MATHIS, S. C. PARDUHN, and P. ALVAREZ (Wichita State Univ., KS) Jun. 1993 5 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-1817) Copyright

An evaluation is presently made of the ability of several FEM analysis codes to model structural configurations representative of containment rings or shielding components of a kind applicable to containment and shielding against engine failure in gas turbines. Fragment kinetic energies representative of gas turbine engine sizes from those of APUs to 50,000 lbs of thrust are treated, and this, only for the case of metallic structures. The geometries studied are circular containment rings and flat plates subject to direct impact; two different material models are used. Time histories of structure displacement and maximum reaction forces are obtained. AIAA

A93-49706#
TURBINE ENGINE DIAGNOSTICS (TED) SYSTEM
RONALD L. DE HOFF and CHRISTINA MALTBAEK (Systems Control Technology, Inc., Palo Alto, CA) Jun. 1993 10 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(Contract DTRS67-92-C-00011)
(AIAA PAPER 93-1818) Copyright

A series of operational and maintenance aids, the Turbine Engine Diagnostics (TED), is being developed for commercial aviation in order to provide portable engine diagnostics and technical information to pilots, air crews, ground maintenance persons. The TED design philosophy is based on the notion that a useful system should provide a platform which allows the user to consistently apply a variety of diagnostic methods to data collected during operation of the aircraft. The diagnostic and data delivery software is implemented in a commercially available ruggedized pen-based microcomputer platform. Specialized interfaces are being developed for aircraft-mounted flight data recorders, ground networks, and remote communications. Pen-based computers allow cockpit in-flight data acquisition, delivery of technical data, first-level troubleshooting, and emergency procedures. Embedded artificial intelligence is used to assist in troubleshooting and performing data trending and analysis. AIAA

A93-49709*# National Aeronautics and Space Administration. Hugh L. Dryden Flight Research Facility, Edwards, CA.
DUAL ENGINE APPLICATION OF THE PERFORMANCE SEEKING CONTROL ALGORITHM
F. D. MUELLER, S. G. NOBBS (McDonnell Douglas Aerospace, Saint Louis, MO), and J. F. STEWART (NASA, Flight Research Center, Edwards, CA) Jun. 1993 13 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th,

Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-1822) Copyright

The Dual Engine Performance Seeking Control (PSC) flight/propulsion optimization program has been developed and will be flown during the second quarter of 1993. Previously, only single engine optimization was possible due to the limited capability of the on-board computer. The implementation of Dual Engine PSC has been made possible with the addition of a new state-of-the-art, higher throughput computer. As a result, the single engine PSC performance improvements already flown will be demonstrated on both engines, simultaneously. Dual Engine PSC will make it possible to directly compare aircraft performance with and without the improvements generated by PSC. With the additional thrust achieved with PSC, significant improvements in acceleration times and time to climb will be possible. PSC is also able to reduce deceleration time from supersonic speeds. This paper traces the history of the PSC program, describes the basic components of PSC, discusses the development and implementation of Dual Engine PSC including additions to the code, and presents predictions of the impact of Dual Engine PSC on aircraft performance.

A93-49710*# National Aeronautics and Space Administration. Hugh L. Dryden Flight Research Facility, Edwards, CA.
ON THE ESTIMATION ALGORITHM FOR ADAPTIVE PERFORMANCE OPTIMIZATION OF TURBOFAN ENGINES
MARTIN D. ESPANA (NASA, Flight Research Center, Edwards, CA) Jun. 1993 20 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-1823) Copyright

The performance seeking control (PSC) algorithm is designed to continuously optimize the performance of propulsion systems. The PSC algorithm uses a nominal propulsion system model and estimates, in flight, the engine deviation parameters (EDPs) characterizing the engine deviations with respect to nominal conditions. In practice, because of measurement biases and/or model uncertainties, the estimated EDPs may not reflect the engine's actual off-nominal condition. This factor has a direct impact on the PSC scheme exacerbated by the open-loop character of the algorithm. In this paper, the effects produced by unknown measurement biases over the estimation algorithm are evaluated. This evaluation allows for identification of the most critical measurements for application of the PSC algorithm to an F100 engine. An equivalence relation between the biases and EDPs stems from the analysis; therefore, it is undecided whether the estimated EDPs represent the actual engine deviation or whether they simply reflect the measurement biases. A new algorithm, based on the engine's (steady-state) optimization model, is proposed and tested with flight data. When compared with previous Kalman filter schemes, based on local engine dynamic models, the new algorithm is easier to design and tune and it reduces the computational burden of the onboard computer.

A93-49724#
CFD VALIDATION FOR SCRAMJET COMBUSTOR AND NOZZLE FLOWS. I
HOUSHANG B. EBRAHIMI (Sverdrup Technology, Inc., Arnold AFB, TN) Jun. 1993 17 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-1840)

The work reported here involved three efforts: identification of computer models applicable to hypersonic flow phenomena involving thermal and chemical nonequilibrium, identification of data sets for the establishment of a standard data base for the validation of selected models, and direct comparison of model results with the data base. Several CFD computer programs were identified for evaluation and validation. This paper documents the results of the first code, TUFF (Three-dimensional Upwind-differenced Finite-volume Flow solver) code, to be evaluated using the database. TUFF is compared to experimental data for five selected data sets including: (1) supersonic flow over a rearward facing step, (2) supersonic two-dimensional nozzle flow, (3) combustion in a two-dimensional supersonic flow with tangential hydrogen injection, (4) combustion of a supersonic concentric hydrogen/air flow, and (5) hypersonic flow over a biconic model with perpendicular hydrogen injection. Validation of other selected codes against the data base will be reported in future papers.
Author (revised)

A93-49727#
MODERN PROPELLER SYSTEMS FOR ADVANCED TURBOPROP AIRCRAFT
COLMAN SHATTUCK and JON YOUNG (United Technologies Corp., Hamilton Standard Div., Windsor Locks, CT) Jun. 1993 11 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-1846) Copyright

The paper examines the technology of a family of advanced propellers introduced in 1990, which incorporate the latest technologies, making it possible to reduce operating costs and improve passenger comfort. The propellers are designed for a range of modern 1500-6000 shp engines available for the 1990's new generation of turboprop aircraft. The benefits these propellers will bring to regional airlines include better aerodynamic efficiency, lower weight, reduced noise, higher reliability, and lower maintenance cost.
AIAA

A93-49742#
VANE OPTIMIZATION FOR MAXIMUM EFFICIENCY USING DESIGN OF EXPERIMENTS
PAUL T. KERNEY (USAF, Aero Propulsion & Power Directorate, Wright-Patterson AFB, OH) Jun. 1993 8 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-1867)

The paper discusses the optimization of vane and bleed settings in a multistage axial compressor. Specifically, it will optimize seven variable vanes and one variable bleed on the five-stage Pratt & Whitney XTC66 compressor at aerodynamic design point (ADP) for maximum efficiency using Design of Experiments (DOX). DOX are statistical methods for changing process inputs in a systematic way and analyzing the resulting outputs in order to improve a response to an acceptable or optimum value, find a less expensive design, material, or method providing equivalent results, or understanding process sensitivities. Along with developing a model for maximum efficiency, the project also developed models for predicting pressure ratio and mass flow. Results show the number of Steady State Data Points (SSDPs) to be significantly reduced, as well as, the total test time without sacrificing data integrity.

A93-49746#
APPLICATION OF A DYNAMIC COMPRESSION SYSTEM MODEL TO A LOW ASPECT RATIO FAN - CASING TREATMENT AND DISTORTION
S. E. GORRELL (USAF, Aero Propulsion and Power Directorate, Wright-Patterson AFB, OH) and M. W. DAVIS, JR. (Sverdrup Technology, Inc., Arnold AFB, TN) Jun. 1993 11 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Research supported by USAF refs
(AIAA PAPER 93-1871) Copyright

A dynamic compression system model (DYNTECC) has been calibrated for the ADLARF two-stage, low aspect ratio fan and used to perform a parametric study that shows how casing treatments affect the stage and overall stalling airflow capability of the fan. The Compressor Research Facility at Wright-Patterson Air Force Base will be testing the ADLARF fan, and one of the phases will be an evaluation of five different casing treatments over the first rotor. From a previous test of the ADLARF fan, it was determined that the second stage was the critical stalling stage over a wide range of speeds. Therefore, this study focused on showing what improvements were necessary to the second stage stalling airflow in order to realize gains from applying various casing treatment to the first stage. The model showed that applying

casing treatment in combination with changing the variable vanes is an effective way to lower the stage stalling airflow. DYNTECC predicted that these methods will need to provide as much as 14-percent improvement in the second stage stalling airflow capability to get a 20-percent increase in stalling airflow capability from the first stage. In addition, the model showed that casing treatments are an effective means of overcoming stall airflow losses due to distortion. Author (revised)

A93-49747#
AN APPROACH TO THE STALL MONITORING IN A SINGLE STAGE AXIAL COMPRESSOR
H. WANG, D. K. HENNECKE, A. KOENIG, P. WINDIRSCH, and M. GLESNER (*Darmstadt Univ. of Technology, Germany*) Jun. 1993 10 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(Contract DFG-SFB-241)
(AIAA PAPER 93-1872) Copyright

In view of utilizing the wasteful large stall margin in compressors, both passive and active closed-loop control systems have been tested by many researchers on models and real gas turbines. This paper presents the first phase of the development of a compressor stall margin indicator. Measurements aimed at describing an impending stall were taken using a single-stage axial compressor. Large turbulence and disappearing autocorrelation of the air flow velocity from blade to blade characterize the compressor flow shortly before stall inception. The estimation of operating point of the compressor was simulated on a workstation. Author (revised)

A93-49748#
AERO-ENGINE COMPONENT DAMPING ESTIMATION FROM FULL-SCALE AEROMECHANICAL TEST DATA
JAMES A. FABUNMI (Aedar Corp., Landover, MD), TIEJUN BAI, OM PURI, KOFI BOTA (Atlanta Univ., GA), and CAROLYN SUNDERLAND (*USAF, Aeropropulsion Lab., Wright-Patterson AFB,* OH) Jun. 1993 8 p AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Research sponsored by USAF refs
(AIAA PAPER 93-1873) Copyright

The forced response measurements from strain gages during engine aeromechanical testing contain information which can reveal the effective damping of the component's resonant modes. Knowledge of the effective damping is important for detecting trends in the fluid/structure interaction during operation. This paper presents the formulation and application of techniques which have previously been developed for modal testing and analysis, to the analysis of the forced response of structural components of high-performance aircraft jet engines. Time traces of strain gage data are transformed into linear spectra by FFT. Zoom FFT transforms in the neighborhood of a resonant frequency are used to fit modal circles. This local spectrum technique is valid under the assumptions that the modes are separated well enough and are lightly damped. It is also assumed that the spectra of the excitation forces does not vary rapidly near the resonant frequency. Using data gathered from full-scale engine aeromechanical tests, it is shown that these assumptions are plausible, and that the proposed technique is feasible for estimating the modal damping of engine components from forced vibration data.
Author (revised)

A93-49790#
CFD APPLICATIONS IN AN AEROPROPULSION TEST ENVIRONMENT
GREG D. POWER and BONNIE D. HEIKKINEN (Sverdrup Technology, Inc., Arnold AFB, TN) Jun. 1993 16 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-1924)

The growing complexity of aircraft propulsion systems has increased the importance of hardware testing. Several applications of CFD to large-scale propulsion system test and analysis processes are here discussed. The test articles range from subscale supersonic nozzles to full-scale commercial high bypass turbofans. Attention is given to free-jet nozzle flow quality, icing spray-bar analysis, scramjet flowfield probes, and aeroacoustic analyses. AIAA

A93-49828#
PROPFAN ENGINES
N. D. KUZNETSOV (NPO Trud, Samara, Russia) Jun. 1993 7 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993
(AIAA PAPER 93-1981) Copyright

The paper examines technical/economical conditions and current situation in development of air transport, which are the main reasons causing the necessity to develop various concepts of highly efficient propfan engines. Turboprop NK-12 engine created m the 50's can be regarded as SSSPE TRUD's early activities in the area of such engines development, both ducted and unducted versions, namely NK-62, NK-63, NK-110, NK-93 featuring big thrust. The diagrams of these engines are given and the main development problems are discussed. The paper presents main technical data of SSSPE TRUD propfan engines and describes methodology on experimental development of engine components.

A93-49830*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
STRUCTURAL DESIGN AND ANALYSIS OF A MACH ZERO TO FIVE TURBO-RAMJET SYSTEM
KEVIN A. SPOTH and PAUL L. MOSES (Lockheed Engineering and Sciences Co.; NASA, Langley Research Center, Hampton, VA) Jun. 1993 13 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(Contract NAS1-19000)
(AIAA PAPER 93-1983)

The paper discusses the structural design and analysis of a Mach zero to five turbo-ramjet propulsion system for a Mach five waverider-derived cruise vehicle. The level of analysis detail necessary for a credible conceptual design is shown. The results of a finite-element failure mode sizing analysis for the engine primary structure is presented. The importance of engine/airframe integration is also discussed.

A93-49832*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
NUMERICAL SIMULATIONS OF A PULSED DETONATION WAVE AUGMENTATION DEVICE
JEAN-LUC CAMBIER (Eloret Inst., Palo Alto; NASA, Ames Research Center, Moffett Field, CA), HENRY ADELMAN (Eloret Inst., Palo Alto, CA), and GENE P. MENEES (NASA, Ames Research Center, Moffett Field, CA) Jun. 1993 21 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-1985)

We present here the concept of a hybrid engine for Single Stage To Orbit (SSTO) air-breathing hypersonic vehicle. This concept relies on the use of pulsed detonation waves, both for thrust generation and mixing/combustion augmentation. We describe the principles behind the engine concept, which we call the Pulsed Detonation Wave Augmentor (PDWA). We demonstrate the principles of operation for two possible configurations through numerical simulations. We also attempt a first approximation to engine design, and propose various applications.

A93-49834#
THE STUDY OF EXPERIMENTAL TURBORAMJETS - HEAT STATE AND COOLING PROBLEMS
V. A. SOSUNOV, V. I. SOLONIN, M. M. TSKHOVREBOV, P. A. KADYARDUSOV, and V. A. PALKIN (Central Inst. of Aviation Motors, Moscow, Russia) Jun. 1993 12 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-1989) Copyright

The paper presents the second part of a Russian experimental turboramjet study results (the first part was presented by Sosounov et al., 1992). The results include those of investigations of the heat state of the afterburner-ram combustion chamber, the problems of cooling both the afterburner-ram combustion chamber and the nozzle at flight Mach numbers between 2 and 4, and the operability of transmission. The results obtained constitute the initial base for the development of propulsion systems for hypersonic flying vehicles and aerospace planes. AIAA

A93-49860#
ADVANCING THE STATE OF THE ART HYPERSONIC TESTING - HYTEST/MTMI
M. J. BULMAN, J. LEONARD, R. KEENAN (Aerojet, Propulsion Div., Sacramento, CA), and MICHAEL T. WADE (Pratt & Whitney Group, Government Engines & Space Propulsion Div., West Palm Beach, FL) Jun. 1993 9 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2023) Copyright

Ground testing of large hypersonic air breathing engines is now required for Aerospaceplane development. These tests will only be meaningful if the facility can aerodynamically start and establish uniform flow approaching the engine inlet and provide suitably low pressures surrounding the model that simulate real flight conditions. The HYTEST facility accomplished these requirements and successfully completed the NASP module-to-module interaction test series. The tests represent the highest level of free jet blockage (ratio of test module frontal area to facility nozzle exit area) ever tested (73 percent). HYTEST produces one of the best mixed flow environments. Analyses, design, techniques, and facilities that resulted in the HYTEST performance are discussed, giving attention to the CFD and subscale analyses that resulted in the well mixed flow, the shock expansion calculations used for aeroappliance design, flow measurements made in HYTEST firings, and a general description of the exhaust system that allows for testing with high blockage levels. Author (revised)

A93-49870#
COMPARISON OF NO AND OH PLIF TEMPERATURE MEASUREMENTS IN A SCRAMJET MODEL FLOWFIELD
B. K. MCMILLIN, J. M. SEITZMAN, and R. K. HANSON (Stanford Univ., CA) Jun. 1993 16 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Research supported by USAF refs
(AIAA PAPER 93-2035) Copyright

The use of nitric oxide (NO) and the hydroxyl radical (OH) as temperature tracers, in a two-line planar laser-induced fluorescence technique, is examined in the context of a supersonic mixing and combustion flowfield. The temperature measurements were based on the sequential excitation of two transitions, either in the A - X (0,0) band of NO near 226 nm or the A - X (1,0) band of OH near 283 nm. The measurements were obtained for each species through the use of two lasers and two cameras, with each camera integrating signal induced from only one of the lasers. Both temporally resolved and frame-averaged temperature measurements of each species are presented. Additional results include simultaneous NO and OH visualizations in which seeded NO marks the fuel jet fluid and nascent OH marks the reaction zones and entrained combustion gases. A detailed temperature comparison shows good agreement in the common measurement regions and indicates that shot-noise is the largest source of uncertainty. The comparison also illustrates the importance of a careful interpretation of the measurements since, depending on the origin of the tracer and the degree of mixing, the measurements may be biased toward the fuel, freestream, or reaction zone temperatures. Author (revised)

A93-49876*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
AN ANALYTICAL STUDY OF DILUTION JET MIXING IN A CYLINDRICAL DUCT
V. L. OECHSLE, H. C. MONGIA (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN), and J. D. HOLDEMAN (NASA, Lewis Research Center, Cleveland, OH) Jun. 1993 40 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Previously announced in STAR as N93-27160 refs
(Contract NAS3-25950)
(AIAA PAPER 93-2043) Copyright

The mixing performance in a mixing section of a rich burn/quick mix/lean burn (RQL) combustor was calculated using a 3-D numerical model in a non-reacting environment. The numerically calculated results were compared with the measured data reported by Hatch, Sowa, Samuelsen, and Holdeman, 1992. The numerical 3-D temperature fields qualitatively agree with the experimental data. Also, the development of the mixing flow and temperature non-uniformity trends throughout the mixing section for the numerically calculated results quantitatively agree with the measured data. The numerical model predicts less mixing and enhances the temperature gradients as compared to the measured data for the cases reported by Hatch et al. (1992) which include circular and slot orifice shapes (with different slant angles and aspect ratios). The predicted and measured results generally agree in the selection of the slanted slot orifice configuration yielding the best overall mixing performance (based on temperature uniformity) of all the configurations analyzed.

A93-49882#
RAPID COMPUTER SIMULATION OF RAMJET PERFORMANCE
D. P. PETTERS and J. L. LEINGANG (USAF, Wright Lab., Wright-Patterson AFB, OH) Jun. 1993 9 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2049)

The paper describes a methodology for rapid calculations of ramjet performance, based on a course taught by Curran at the Aero Propulsion Laboratory in 1970-1971. The methodology is used to develop a computer code. The output consists of thrust coefficient and specific impulse along with dynamic pressure and flight velocity. AIAA

A93-49902#
SMOKE MEASUREMENTS INSIDE A GAS TURBINE COMBUSTOR
C. D. HURLEY (Defence Research Agency, Farnborough, United Kingdom) Jun. 1993 10 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2070) Copyright

A technique has been developed to quantitatively measure smoke as carbon loading in mgm-3 (at STP), inside gas turbine combustors. Detailed internal traversing of an RB211 combustion chamber in a four burner sector rig has been undertaken. The effect of combustor inlet air pressure and temperature on soot formation was also investigated.

A93-49903*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
COMPUTATION OF THE FLOW FIELD IN AN ANNULAR GAS TURBINE COMBUSTOR
MICHAEL C. CLINE (Los Alamos National Lab., NM), JOHN M. DEUR (Sverdrup Technology, Inc., Brook Park, OH), GERALD J. MICKLOW, MICHAEL R. HARPER (Florida Univ., Gainesville), and KRISHNA P. KUNDU (NASA, Lewis Research Center, Cleveland, OH) Jun. 1993 13 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(Contract NASA ORDER C-30050-R; NAG3-1113)
(AIAA PAPER 93-2074)

The KIVA-II code was modified to calculate the 3D flow field in a typical annular gas turbine combustor. The airblast fuel nozzle, cooling baffle, cooling slots, primary and dilution jets, and effusion cooling (bleed) pads were accounted for in this calculation. The turbulence and combustion were modeled using the k-epsilon model

and laminar Arrhenius kinetics, respectively. The fuel was modeled as an evaporating liquid spray. The results illustrate the complicated flow fields present in such combustors. From the results obtained to date it appears that the modified KIVA-II code can be used to study the effects of different annular combustor designs and operating conditions. Author (revised)

A93-49904#
EVALUATION OF A NONLINEAR PSC ALGORITHM ON A VARIABLE CYCLE ENGINE
SHRIDER ADIBHATLA and KARLA L. JOHNSON (GE Aircraft Engines, Evendale, OH) Jun. 1993 8 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2077) Copyright

Performance Seeking Control (PSC) is an algorithm used to optimize steady-state engine schedules in flight by accounting for such parameters as flight conditions, scheduling compromises, engine to engine variations, and deterioration. This paper describes the results of a PSC algorithm evaluation in the minimum SFC mode on the GE YF120 variable cycle jet engine. A nonlinear component level model (CLM) of the nominal YF120 demonstrator engine was used by the PSC algorithm. A three-input, three-output tracking filter was used to tune the model on-line. The PSC algorithm then used this updated engine model to optimize SFC while constraining thrust to its present value subject to all the same constraints the control design engineer uses offline. The optimization algorithm used here is a nonlinear constrained gradient algorithm designed for real-time applications. Testing of this algorithm was conducted at the Air Force's Arnold Engineering Development Center's (AEDC) altitude testing facility in Tullahoma, TN in December, 1990. The test process and SFC improvements obtained are described.

A93-49911*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
BLADE ROW INTERACTION EFFECTS ON FLUTTER AND FORCED RESPONSE
DANIEL H. BUFFUM (NASA, Lewis Research Center, Cleveland, OH) Jun. 1993 18 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2084) Copyright

In the flutter or forced response analysis of a turbomachine blade row, the blade row in question is commonly treated as if it is isolated from the neighboring blade rows. Disturbances created by vibrating blades are then free to propagate away from this blade row without being disturbed. In reality, neighboring blade rows will reflect some portion of this wave energy back toward the vibrating blades, causing additional unsteady forces on them. It is of fundamental importance to determine whether or not these reflected waves can have a significant effect on the aeroelastic stability or forced response of a blade row. Therefore, a procedure to calculate intra-blade-row unsteady aerodynamic interactions has been developed which relies upon results available from isolated blade row unsteady aerodynamic analyses. In addition, an unsteady aerodynamic influence coefficient technique is used to obtain a model for the vibratory response in which the neighboring blade rows are also flexible. The flutter analysis shows that interaction effects can be destabilizing, and the forced response analysis shows that interaction effects can result in a significant increase in the resonant response of a blade row.

A93-49912*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
AN ITERATIVE MULTIDISCIPLINARY ANALYSIS FOR ROTOR BLADE SHAPE DETERMINATION
APARAJIT J. MAHAJAN and GEORGE L. STEFKO (NASA, Lewis Research Center, Cleveland, OH) Jun. 1993 12 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(Contract NAG3-1068)
(AIAA PAPER 93-2085) Copyright

A CFD solver called ADPAC-APES is coupled with a NASTRAN structural analysis and a MARC thermal/heat transfer analysis to determine rotor blade shape. Nonlinear blade displacements due to centrifugal loads, aerodynamic pressures, and nonuniform temperature distribution are determined simultaneously. The effect of blade displacements on aerodynamic pressures and temperatures is then analyzed. These calculations are iterated till a steady state is reached across all the disciplines. This iterative procedure is applied to a ducted fan rotor blade and the manufactured shape is determined from a given operating shape. Effect of a part-span shroud on blade deflections is also analyzed. Author (revised)

A93-49957#
SCRAMJET FUEL MIXING ENHANCEMENT BY CROSS-STREAM PRESSURE GRADIENTS
D. L. DAVIS (USAF, Wright Lab., Wright-Patterson AFB, OH) Jun. 1993 10 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2139)

This report summarizes an investigation into the enhancement of fuel air mixing in supersonic flows by cross stream pressure gradients. The vorticity generated by a shock wave or an expansion fan interacting with a mixing layer was investigated using a 3-D Parabolized Navier-Stokes (PNS) Code. Also the installation effects of curving a scramjet combustor to generate the cross stream pressure gradients was investigated by Nose-to-Tail CFD simulations. It was found that an expansion fan was slightly more effective at generating vorticity than a shock wave and that the installation advantages of the curved combustor increased net thrust.

A93-49958#
THRUST LOSS DUE TO SUPERSONIC MIXING
DIMITRI PAPAMOSCHOU (California Univ., Irvine) Jun. 1993 8 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2140) Copyright

The maximum thrust developed by a device in which two streams mix in a parallel configuration at supersonic velocities is estimated. Total pressure profiles in a two-dimensional, compressible shear layer are calculated by assuming turbulent Prandtl and Lewis numbers of unity. As the convective Mach number Mc rises, the total pressure acquires a defect that becomes large for Mc greater than 1. For shear layers with equal freestream total pressures, an analytical relation for the defect versus Mc is found. The extent and magnitude of the defect agrees well with experimental data. The loss in total pressure is connected to the loss in thrust of a simplified model of a scramjet. The thrust loss is about 30 percent for Mc = 2 and 50 percent for Mc = 3. The trends are insensitive to details of the shear-layer velocity profile and to the ratios of freestream quantities. The role of turbulent-energy dissipation in the reduction of total pressure is discussed. Author (revised)

A93-49960#
MIXING ENHANCEMENT AND COMBUSTION OF GASEOUS FUEL IN A SUPERSONIC COMBUSTOR
T. J. MADDEN and W. C. SOLOMON (Illinois Univ., Urbana) Jun. 1993 29 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2143) Copyright

A three dimensional Navier-Stokes computer code was used to simulate supersonic mixing and reacting flows. The approach and resulting data were validated against high resolution experimental data. An investigation of supersonic mixing enhancement was then performed and results were compared against the validation case. The mixing enhancement mechanisms were applied to reacting supersonic flows incorporating the addition of a recently developed 7 specie, 7 reaction finite rate

hydrogen-oxygen kinetics mechanism. Reacting flow results were then compared with two other supersonic mixing enhancement schemes under investigation for use in supersonic combustors.

A93-49961*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
VORTEX GENERATION AND MIXING IN THREE-DIMENSIONAL SUPERSONIC COMBUSTORS
D. W. RIGGINS (Missouri-Rolla, Univ., Rolla) and P. H. VITT (Analytical Services and Materials, Inc., Hampton, VA) Jun. 1993 12 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(Contract NAG1-189)
(AIAA PAPER 93-2144) Copyright

The generation and evolution of the flow vorticity established by instream injector ramps in a high Mach number/high enthalpy scramjet combustor flow-field are described in detail for a number of computational cases. Classical fluid dynamic circulation is presented for these cases in order to clarify the spatial distribution and convection of the vorticity. The ability of the simulations to accurately represent Stokes Law of circulation is discussed and shown. In addition, the conservation of swirl (effectively the moment-of-momentum theorem) is presented for these flows. The impact of both turbulent diffusion and the vortex/ramp non-uniformity on the downstream mixing rate is clearly illustrated. A correlation over the length of the combustor between fuel-air mixing and a parameter called the vortex stirring length is demonstrated. Finally, computational results for a representative ramp injector are compared with experimental data. Influence of the stream vorticity on the effective turbulent Prandtl number used in the simulation is discussed.

A93-49962#
GASDYNAMICS OF HYDROGEN-FUELED SCRAMJET COMBUSTORS
V. A. SABEL'NIKOV, O. V. VOLOSHENKO, V. N. OSTRAS, V. N. SERMANOV (TsAGI, Zhukovski, Russia), and R. WALTHER (MTU Motoren- und Turbinen-Union Muenchen GmbH, Munich, Germany) Jun. 1993 12 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2145) Copyright

The paper presents results of tests investigating performance characteristics of two scramjet combustors (SCs) differing in geometry and duct expansion ratio. The tests were carried out in the TsAGI hypersonic facility T-131A using a direct-connect technique. The results of tests are analyzed, demonstrating the effects of geometry and of the location and mode of hydrogen supply on the combustion efficiency and pressure losses in the SCs. AIAA

A93-49972#
PARTICLE DYNAMICS SIMULATIONS IN INLET SEPARATOR WITH AN EXPERIMENTALLY BASED BOUNCE MODEL
A. HAMED, Y. D. JUN, and J. J. YEUAN (Cincinnati Univ., OH) Jun. 1993 11 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(Contract NSF CTS-90-12309)
(AIAA PAPER 93-2156) Copyright

This paper presents a probabilistic simulation methodology for the particle dynamics through a helicopter engine's inlet separator with an experimentally based particle bounce model. The flow field is determined from the numerical solution of the compressible Navier-Stokes equations with a two-equation turbulence model. The probabilistic simulations of the particle dynamics take into consideration the experimentally measured variance in the particle bounce conditions after surface interactions. Results are presented for the particle trajectories through the inlet and for the separator effectiveness over a range of sand particle sizes and also for C-spec. sand.

A93-49987#
STUDIES INTO THE HAIL INGESTION CHARACTERISTICS OF TURBOFAN ENGINES
P. M. RENDER, H. PAN (Loughborough Univ. of Technology, United Kingdom), M. SHERWOOD, and S. J. RILEY (Rolls-Royce, PLC, Derby, United Kingdom) Jun. 1993 12 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Research supported by Rolls-Royce, PLC, SERC, and Civil Aviation Authority of United Kingdom refs
(AIAA PAPER 93-2174) Copyright

The possible effects of hail ingestion on a turbofan aeroengine are briefly discussed. A program of work to develop an understanding of hail ingestion is described and the progress to date is presented. Patternator and high-speed photography have been used to investigate hailstone impact characteristics on a flat plate and an engine spinner. Results have shown that the approach angle of the hailstones, relative to the impact surface, has a significant effect on the distribution of ice following impact. Approach velocity of the hailstones, target temperature and spinner rotation have no significant effect on the distribution. Results are being used to define inputs for a computer model which originates from the flow visualization facility of existing Computational Fluids Dynamics (CFD) software. The methods used in the computer model are outlined. As part of a facility for testing aeroengines at full scale, an ice gun has been designed and developed. The design methodology is described and the current status of the gun is reported.

A93-50008*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
INTEGRATED CFD MODELING OF GAS TURBINE COMBUSTORS
E. J. FULLER and C. E. SMITH (CFD Research Corp., Huntsville, AL) Jun. 1993 22 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(Contract NAS3-26616)
(AIAA PAPER 93-2196) Copyright

3D, curvilinear, multi-domain CFD analysis is becoming a valuable tool in gas turbine combustor design. Used as a supplement to experimental testing. CFD analysis can provide improved understanding of combustor aerodynamics and used to qualitatively assess new combustor designs. This paper discusses recent advancements in CFD combustor methodology, including the timely integration of the design (i.e. CAD) and analysis (i.e. CFD) processes. Allied Signal's F124 combustor was analyzed at maximum power conditions. The assumption of turbulence levels at the nozzle/swirler inlet was shown to be very important in the prediction of combustor exit temperatures. Predicted exit temperatures were compared to experimental rake data, and good overall agreement was seen. Exit radial temperature profiles were well predicted, while the predicted pattern factor was 25 percent higher than the harmonic-averaged experimental pattern factor.

A93-50052*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
OPTIMIZATION OF BLADE ARRANGEMENT IN A RANDOMLY MISTUNED CASCADE USING SIMULATED ANNEALING
EDWARD A. THOMPSON and GEORGES A. BECUS (Cincinnati Univ., OH) Jun. 1993 8 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(Contract NAG3-1173)
(AIAA PAPER 93-2254) Copyright

This paper presents preliminary results of an investigation on mistuning of bladed-disk assemblies aimed at capturing the benefits of mistuning on stability, while at the same time, minimizing the adverse effects on response by solving the following problem: given a set of N turbine blades, each being a small random perturbation of the same nominal blade, determine the best arrangement of the N blades in a mistuned cascade with regard to aeroelastic response. In the studies reported here, mistuning of

the blades is restricted to small differences in torsional stiffness. The large combinatorial optimization problem of seeking the best arrangement by blade exchanges is solved using a simulated annealing algorithm.

A93-50103*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
REVIEW OF NASA'S HYPERSONIC RESEARCH ENGINE PROJECT
EARL H. ANDREWS (NASA, Langley Research Center, Hampton, VA) and ERNEST A. MACKLEY (Analytical Services and Materials, Inc., Hampton, VA) Jun. 1993 12 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2323) Copyright

The goals of the NASA Hypersonic Research Engine (HRE) Project, which began in 1964, were to design, develop, and construct a hypersonic research ramjet/scramjet engine for high performance and to flight-test the developed concept over the speed range from Mach 3 to 8. The project was planned to be accomplished in three phases: project definition, research engine development, and flight test using the X-15A-2 research aircraft, which was modified to carry hydrogen fuel for the research engine. The project goal of an engine flight test was eliminated when the X-15 program was canceled in 1968. Ground tests of engine models then became the focus of the project. Two axisymmetric full-scale engine models having 18-inch-diameter cowls were fabricated and tested: a structural model and a combustion/propulsion model. A brief historical review of the project with salient features, typical data results, and lessons learned is presented. Author (revised)

A93-50104*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
IN-STREAM MEASUREMENTS OF COMBUSTION DURING MACH 5 TO 7 TESTS OF THE HYPERSONIC RESEARCH ENGINE (HRE)
ERWIN A. LEZBERG, ALLEN J. METZLER, and WILLIAM D. PACK (NASA, Lewis Research Center, Cleveland, OH) Jun. 1993 21 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2324) Copyright

Results of in-stream combustion measurements taken during Mach 5 to 7 true simulation testing of the Hypersonic Research Engine/Aerothermodynamic Integration Model (HRE/AIM) are presented. These results, the instrumentation techniques, and configuration changes to the engine installation that were required to test this model are described. In test runs at facility Mach numbers of 5 to 7, an exhaust instrumentation ring which formed an extension of the engine exhaust nozzle shroud provided diagnostic measurements at 10 circumferential locations in the HRE combustor exit plane. The measurements included static and pitot pressures using conventional conical probes, combustion gas temperatures from cooled-gas pyrometer probes, and species concentration from analysis of combustion gas samples. Results showed considerable circumferential variation, indicating that efficiency losses were due to nonuniform fuel distribution or incomplete mixing. Results using the Mach 7 facility nozzle but with Mach 6 temperature simulation, 1590 to 1670 K, showed indications of incomplete combustion. Nitric oxide measurements at the combustor exit peaked at 2000 ppmv for stoichiometric combustion at Mach 6. Author (revised)

A93-50105#
STANDING NORMAL DETONATIONS AND OBLIQUE DETONATIONS FOR PROPULSION
E. K. DABORA and J.-C. BRODA (Connecticut Univ., Storrs) Jun. 1993 10 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2325) Copyright

The paper describes the investigations of detonation waves produced in normal and oblique detonation experiments at the facility built at the University of Michigan for investigating the feasibility of using detonative combustion for supersonic/hypersonic propulsion. The results of tests showed that the application of normal detonation for propulsion purposes is a questionable proposition because of considerable stagnation pressure loss through the attendant shock wave. The results of using oblique detonations at hypersonic velocities (up to M = 10) showed that they are very similar to normal detonations. AIAA

A93-50106#
A REVIEW OF SUPERSONIC COMBUSTION RESEARCH AT AEDC WITH HYPERSONIC APPLICATION
P. M. RUBINS (Engineering Management Consultants, Niskayuna, NY) and R. C. BAUER (Arvin/Calspan Corp., Arnold AFB, TN) Jun. 1993 12 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2326) Copyright

This paper focuses on the research done at the Arnold Engineering Development Center (AEDC) in supersonic combustion and combustion kinetics in high speed flow some years ago, and the application of the resulting conclusions to hypersonic propulsion. The analysis discusses both advantages and problems for premixing the fuel and employing shock-induced combustion as an ignition method for a scramjet flying at a high Mach number. The experimental tests are discussed, including implications to the chemical kinetics of the high velocity combustion process. Test conditions were confined to relatively low pressure, less than 2 atmospheres. The results were considered to be mainly applicable at high altitudes, low static pressures, where chemical reaction distances will be long. At these lower pressures, 'shock-induced combustion' may be the predominant effect in a scramjet application, and has some advantages which are discussed. The relation between 'shock-induced combustion' and 'detonation' is also discussed.

A93-50108#
AN APPROACH TO IN-SITU ANALYSIS OF SCRAMJET COMBUSTOR BEHAVIOR
WILLIAM T. PESCHKE (United Technologies Research Center, East Hartford, CT) Jun. 1993 9 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Research supported by United Technologies Corp refs
(AIAA PAPER 93-2328) Copyright

The paper described studies of scramjet combustor behavior performed at the General Applied Science Laboratories during the time period 1966-1970, using hydrogen-fueled engines installed on thrust balances in freejet test arrangements. Particular attention is given to an analysis procedure involving fuel-injection tailoring, used to aid in the location of fuel injection sites in the scramjet combustor and to predict the static pressure rises induced by combustion at selected points throughout the combustor. The method was applied to two geometrically dissimilar scramjet engines whose performance levels were assessed in similar freejet test facilities. The investigation resulted in the development of a scramjet engine concept using fuel-injection tailoring to avoid the onset of deleterious combustor-inlet interaction. AIAA

A93-50113#
DUAL-SPRAY AIRBLAST FUEL NOZZLE FOR ADVANCED SMALL GAS TURBINE COMBUSTORS
CLIFFORD E. SMITH, ERIC J. FULLER, D. S. CROCKER (CFD Research Corp., Huntsville, AL), L. T. MEKKES, and J. C. SHELDON (Delavan, Inc., Des Moines, IA) Jun. 1993 16 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(Contract DAAJ02-92-C-0010)
(AIAA PAPER 93-2336) Copyright

A novel dual-spray airblast fuel nozzle that has the potential of improved light-off capability and higher combustor turndown fuel-air ratio is being developed for advanced military small gas turbine engines. Features of the nozzle include: 1) full integration of the combustor dome swirler and two airblast atomizers (pilot

and main) into a single functional unit; 2) minimum fuel flow passages greater than 0.018 inch; and 3) integration and optimization of the primary zone airflow and spray patterns to substantially increase combustor turndown fuel-air ratios. Nine research versions of the nozzle were designed, fabricated and tested. Measurements of ACd, spray angle, atomization quality, and air velocity were used to screen the designs. The best nozzle configurations were tested for ignition and lean blowout in a single-nozzle combustor front-end at ambient conditions. To ascertain the effect of nozzle-nozzle interaction, the best configuration was tested in a three-nozzle combustor front-end. Identical ignition and lean blowout results were obtained as compared to single-nozzle tests. The best nozzle design could be lit at a pressure drop of 1.25 inches of water and a fuel flow of 1.5 pph per nozzle.

A93-50115#
THREE-DIMENSIONAL EMISSION MODELING FOR DIFFUSION FLAME, RICH/LEAN, AND LEAN GAS TURBINE COMBUSTORS
N. K. RIZK and H. C. MONGIA (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN) Jun. 1993 14 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2338) Copyright

In a recent effort, an emission model that simulates a detailed chemical kinetic scheme has been developed to provide the rate of reactions of various species of importance. In the present investigaation, the analytical capabilities of 3-D combustor performance codes were utilized to provide the species concentrations needed to calculate the rate of formation of NO(x) in the three combustor concepts of diffusion flame, rich/lean, and lean type. By this means, the optimization of the combustor design could be achieved to minimize pollutant formation and maintain satisfactory stability and performance. The developed model satisfactorily duplicated the NO(x) emission Siren by the detailed kinetic code and agreed well with the measurements of the three combustor concepts. The developed hybrid approach identified the main regions responsible for most of the NO(x) formed in each combustor type. This illustrates the great potential of using such a unified approach to enhance the performance of current combustors as well as to develop new and novel design concepts.

A93-50152#
SIMULATION OF PROPULSION SYSTEM'S TRANSIENT RESPONSE TO PLANAR WAVE INLET DISTORTION AND THE EFFECT OF COMPRESSOR WEAR
A. HAMED, A. GAHURA, and W. TABAKOFF (Cincinnati Univ., OH) Jun. 1993 9 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2384) Copyright

This paper presents the results of a numerical study of the dynamic response of a turbojet engine to planar wave inlet distortion. The one-dimensional numerical simulation model is used to evaluate the sensitivity of the 8-stage axial-flow compressor in a complete J-85-13 turbojet. Engine dynamic response accompanying planar wave induced compressor surge is also characterized over a maximum anticipated range of simulated compressor deterioration.

A93-50153#
STALL INCEPTION IN A MULTI-STAGE HIGH SPEED AXIAL COMPRESSOR
DONALD A. HOYING (USAF, Wright Lab., Wright-Patterson AFB, OH) Jun. 1993 12 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2386)

A comprehensive study has been conducted into the inception of stall in a multi-stage high speed axial flow compressor. The compressor tested was a highly loaded, four stage axial compressor representing the state-of-the-art in current design technology. Data was taken at a variety of speeds, both with and without inlet distortion. High frequency response pressure measurements were made on three of the four stages. The data was spatially Fourier analyzed for the existence of pressure waves traveling about the annulus of the compressor pnior to stall. In addition, System Identification methods were used to estimate the frequency and stability of such waves. In this test, these waves were found at nearly all conditions tested. However, the duration of the waves prior to stall differed markedly as a function of the speed of the compressor. The System Identification results showed that the stability of these waves approached zero as the compressor was stalled.

A93-50185#
STATIC INTERNAL PERFORMANCE TESTS OF SINGLE EXPANSION RAMP NOZZLE CONCEPTS DESIGNED WITH LO CONSIDERATIONS
MALCOLM K. MACLEAN (GE Aircraft Engines, Cincinnati, OH) Jun. 1993 12 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2429) Copyright

Scale model, cold flow static testing was conducted to investigate the internal performance characteristics of several Low Observable (LO) Single Expansion Ramp Nozzle (SERN) concepts. Using an inviscid Euler code several SERN flow paths were designed. These SERN concepts were divided into two distinct categories depending on the nozzle throat location. The nozzle design philosophy for the test configurations, results of the test program, and a comparison of the test data to pretest predictions are presented.

A93-50186#
SCALE MODEL TEST RESULTS FOR SEVERAL SPHERICAL/TWO-DIMENSIONAL NOZZLE CONCEPTS
BRIAN E. MEYER and MALCOLM K. MACLEAN (GE Aircraft Engines, Cincinnati, OH) Jun. 1993 15 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993
(AIAA PAPER 93-2430) Copyright

The performance impact of different types of throat blending in spherically convergent 2D nozzles is investigated using static cold-flow internal performance test data for four nozzle concepts. These include a radial visor concept, convergent visor concept, parallel visor coplanar concept, and a parallel visor noncoplanar concept. The convergent visor concept demonstrated the best performance, with the parallel visor concepts second best because of additional surface area and supersonic turning losses. The worst performance was that of the radial visor, presumably because of shocks in the divergent section. AIAA

A93-50187*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
FLUIDIC SCALE MODEL MULTI-PLANE THRUST VECTOR CONTROL TEST RESULTS
CHARLES CHIARELLI, RAYMOND K. JOHNSEN, CHIH F. SHIEH (Rohr, Inc., Chula Vista, CA), and DAVID J. WING (NASA, Langley Research Center, Hampton, VA) Jun. 1993 21 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2433) Copyright

An experimental investigation has been conducted at the NASA Langley 16-Foot Transonic Tunnel Static Test Facility to determine the concept feasibility of using fluidics to achieve multiplane thrust vector control in a 2D convergent-divergent (2D-CD) fixed aperture nozzle. Pitch thrust vector control is achieved by injection of flow through a slot in the divergent flap into the primary nozzle flow stream. Yaw vector control results from secondary air delivered tangentially to vertical Coanda flaps. These flaps are offset laterally and aligned parallel to the primary nozzle side walls. All tests were conducted at static (no external flow) conditions. Flow visualization was conducted using a paint flow technique and Focus

Schlieren. Significant levels of pitch deflection angles (19 deg) were achieved at low pressure ratios and practical levels (14 deg) resulted at typical intermediate power settings. The ability of the Coanda surface blowing concept to produce yaw deflection was limited to NPR not greater than 4. Author (revised)

A93-50188#
DEVELOPMENT OF AN ADVANCED EXHAUST MIXER FOR A HIGH BYPASS RATIO TURBOFAN ENGINE
M. E. BOOHER, OKEY KWON, A. B. BARTA, B. R. VITTAL, and M. R. KRISHNAN (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN) Jun. 1993 7 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2435) Copyright

Efficient mixing of the hot gases from the engine core, with the relatively cooler fan bypass air, improves the thrust specific fuel consumption of the engine and tends to reduce the exhaust jet noise levels. This mixing process is generally accomplished with the help of forced mixers. Three exhaust mixers - baseline confluent, conventional forced, and advanced 3-D forced - were designed and analyzed with advanced Navier-Stokes analytic solvers. These mixers were then fabricated and experimentally tested to validate the CFD analysis and obtain improvements in performance relative to current 'state-of-the-art'. This was accomplished by optimizing lobe/flow path geometry and contour to maximize mixing by tailoring the streamline vorticity at minimal total pressure loss. The generation of streamwise vorticity and the rapid mixing of the fan and core streams downstream of the mixer yielded very high mixing effectiveness values at low total pressure losses. The test data provided excellent agreement with analytical predictions, thereby yielding a proven and viable mixer design methodology.

A93-50189*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
PERFORMANCE CHARACTERISTICS OF A VARIABLE-AREA VANE NOZZLE FOR VECTORING AN ASTOVL EXHAUST JET UP TO 45 DEG
JACK G. MCARDLE and BARBARA S. ESKER (NASA, Lewis Research Center, Cleveland, OH) Jun. 1993 33 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Previously announced in STAR as N93-27131 refs
(AIAA PAPER 93-2437) Copyright

Many conceptual designs for advanced short-takeoff, vertical landing (ASTOVL) aircraft need exhaust nozzles that can vector the jet to provide forces and moments for controlling the aircraft's movement or attitude in flight near the ground. A type of nozzle that can both vector the jet and vary the jet flow area is called a vane nozzle. Basically, the nozzle consists of parallel, spaced-apart flow passages formed by pairs of vanes (vanesets) that can be rotated on axes perpendicular to the flow. Two important features of this type of nozzle are the abilities to vector the jet rearward up to 45 degrees and to produce less harsh pressure and velocity footprints during vertical landing than does an equivalent single jet. A one-third-scale model of a generic vane nozzle was tested with unheated air at the NASA Lewis Research Center's Powered Lift Facility. The model had three parallel flow passages. Each passage was formed by a vaneset consisting of a long and a short vane. The longer vanes controlled the jet vector angle, and the shorter controlled the flow area. Nozzle performance for three nominal flow areas (basic and plus or minus 21 percent of basic area), each at nominal jet vector angles from -20 deg (forward of vertical) to +45 deg (rearward of vertical) are presented. The tests were made with the nozzle mounted on a model tailpipe with a blind flange on the end to simulate a closed cruise nozzle, at tailpipe-to-ambient pressure ratios from 1.8 to 4.0. Also included are jet wake data, single-vaneset vector performance for long/short and equal-length vane designs, and pumping capability. The pumping capability arises from the subambient pressure developed in the cavities between the vanesets, which could be used to aspirate flow from a source such as the engine compartment. Some of the performance characteristics are compared with characteristics of a single-jet nozzle previously reported.

A93-50190*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
EFFECTS OF FLOW-PATH VARIATIONS ON INTERNAL REVERSING FLOW IN A TAILPIPE OFFTAKE CONFIGURATION FOR ASTOVL AIRCRAFT
JACK G. MCARDLE and BARBARA S. ESKER (NASA, Lewis Research Center, Cleveland, OH) Jun. 1993 22 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Previously announced in STAR as N93-29065 refs
(AIAA PAPER 93-2438) Copyright

A one-third-scale model of a generic tailpipe offtake system for an advanced short takeoff, vertical landing (ASTOVL) aircraft was tested at the NASA Lewis Research Center Powered Lift Facility. The basic model consisted of a tailpipe with a center body to form an annulus simulating turbine outflow with no swirl; twin offtake ducts with elbows at the ends to turn the flow to a downward direction; flow control nozzles at the ends of the elbows; and a blind flange at the end of the tailpipe to simulate a closed cruise nozzle. The offtake duct-to-tailpipe diameter ratio was 0.74. Modifications of a generic nature were then made to this basic configuration to measure the effects of flow-path changes on the flow and pressure-loss characteristics. The modifications included adding rounded entrances at the forward edges of the offtake openings, blocking the tailpipe just aft the openings instead of at the cruise nozzle, changing the location of the openings along the tailpipe, removing the center body, and varying the Mach number (flow rate) over a wide range in the tailpipe ahead of the openings by changing the size of the flow control nozzles. The tests were made with unheated air at tailpipe-to-ambient pressure ratios from 1.4 to 5. Results are presented and compared with performance graphs, total-pressure contour plots, paint streak flow visualization photographs, and a flow-angle probe traverse at the offtake entrance.

A93-50191#
STUDY OF A CIRCULAR CROSS SECTION THRUST AUGMENTING EJECTOR
G. C. UHUAD (USAF, Electronic Systems Center, Hanscom AFB, MA) and M. E. FRANKE (USAF, Inst. of Technology, Wright-Patterson AFB, OH) Jun. 1993 8 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2439)

Thrust and mass flow augmentation of an axisymmetric ejector with eight primary nozzles around the inlet periphery is described. Primary nozzle geometry is varied during the tests. Thrust augmentation effects of a cross flow superimposed on the inlet secondary flow are presented. Exit velocity profiles for various flow conditions are given. The effects of diffuser blowing and suction on thrust augmentation are studied.

A93-50192*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
INITIAL DEVELOPMENT OF THE TWO-DIMENSIONAL EJECTOR SHEAR LAYER - EXPERIMENTAL RESULTS
M. A. BENJAMIN, M. DUFFLOCQ, and V. P. ROAN (Florida Univ., Gainesville) Jun. 1993 11 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(Contract NAG3-1187)
(AIAA PAPER 93-2440) Copyright

An experimental investigation designed to study the development of shear layers in a two-dimensional single-nozzle ejector has been completed. In this study, combinations of air/air, argon/air, helium/air, and air/helium were used as the supersonic primary and subsonic secondary, respectively. Mixing of the gases occurred in a constant-area tube 39.1 mm high by 25.4 mm wide, where the inlet static pressure was maintained at 35 kPa. The

cases studied resulted in convective Mach numbers between 0.058 and 1.64, density ratios between 0.102 and 3.49, and velocity ratios between 0.065 and 0.811. The resulting data shows the differences in the shear-layer development for the various combinations of independent variables utilized in the investigation. The normalized growth-rates in the near-field were found to be similar to two-dimensional mixing layers. These results have enhanced the ability to analyze and design ejector systems as well as providing a better understanding of the physics.

A93-50193*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
COMPARISON OF THE INITIAL DEVELOPMENT OF SHEAR LAYERS IN TWO-DIMENSIONAL AND AXISYMMETRIC EJECTOR CONFIGURATIONS
M. DUFFLOCQ, M. A. BENJAMIN, and V. P. ROAN (Florida Univ., Gainesville) Jun. 1993 10 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(Contract NAG3-1187)
(AIAA PAPER 93-2441) Copyright

A two-phase experimental investigation designed to study the development of shear layers in axisymmetric and two-dimensional single-nozzle ejectors has been completed. In this study, combinations of similar and dissimilar gases were used as the supersonic primary and subsonic secondary. Test cases included combinations of air/air, argon/air and helium/air as the supersonic primary and subsonic secondary, respectively. Similar flow conditions were studied for each ejector configuration. Mixing of the gases occurred in a constant-area tube, where the inlet pressure was maintained at 34.5 kPa. The cases studied resulted in convective Mach numbers that range between 0.06 and 1.9. The data gathered shows differences between the initial shear-layer development for the two ejector geometries, and also between the different test cases studied for each ejector configuration. The measured growth rates for the axisymmetric ejector are more than twice those measured for the two-dimensional ejector. However, in both cases the results show that compressibility has a reducing effect on the growth rate. Further, in the region immediately after the inlet to the mixing tube, compressibility seems to affect the ejector shear layers in a manner similar to that of two-stream two-dimensional mixing layers.

A93-50194#
EXPERIMENTAL INVESTIGATION OF SLOT INJECTION INTO SUPERSONIC FLOW WITH AN ADVERSE PRESSURE GRADIENT
MARK A. STAFFORD and ROY J. HARTFIELD, JR. (Auburn Univ., AL) Jun. 1993 10 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2442) Copyright

The mixing characteristics for sonic tangential slot injection into a supersonic flow with an adverse pressure gradient have been investigated. To create the pressure gradient, a shock train is established within a diverging Mach 2 test-section. Shadowgraph visualization, wall static pressure measurements and planar laser-induced iodine fluorescence visualization are used to evaluate the nonreacting flow field. Results are presented for a tunnel total pressure of 400 kPa and back pressures of 125, 200 and 225 kPa. For a back pressure of 125 kPa, the shock train is in the tunnel's diffuser and the test-section is completely supersonic. The shock train moves into the test-section and further upstream as the back pressure is increased. Injectant total pressures of 200 and 400 kPa are also examined. Shadowgraph visualization photography shows that the shear layer moves toward the primary flow and becomes less coherent as the shock train advances upstream. The movement of the shock train also produces less defined jet-induced shocks. The results indicate a possible increase in injectant spreading. This enhanced mixing will potentially lessen the cooling effectiveness of tangential slot injection in the presence of an adverse pressure gradient.

A93-50195#
DIRECT MEASUREMENTS OF SKIN FRICTION IN A SCRAMJET COMBUSTOR
J. A. SCHETZ (Virginia Polytechnic Inst. and State Univ., Blacksburg), V. A. VINOGRADOV, A. V. MARSHAKOV., and M. D. PETROV (Central Inst. of Aviation Motors, Moscow, Russia) Jun. 1993 9 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2443) Copyright

Here, we present the results of direct skin friction measurements in the boundary layer of a scramjet combustor flow. Two components of the tangential shear forces were detected using a nonintrusive floating head extended from a piezoresistive displacement transducer. This kind of sensor allows for the measurement of wall shear in both the axial and transverse directions to the flow. The tests of a hydrogen-fueled scramjet model with fuel equivalence ratios of 0-0.45 were run in the CIAM Supersonic Combustion Test Facility. The facility freestream conditions of total temperature and pressure were 1100-1800 K and 44-56 atm. At low equivalence ratios, the hydrogen fuel did not autoignite, and the flow through the combustor was supersonic. Cf values of 0.003-0.004 were obtained. For equivalence ratios above 0.3, the fuel ignited and the heat release resulted in an upstream pseudoshock train and subsonic flow in the combustor. This produced 'noisy' skin friction output and Cf = 0.005-0.008.
Author (revised)

A93-50196*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
HYPERSONIC IGNITION AND THRUST PRODUCTION IN A SCRAMJET
A. PAULL (Queensland Univ., St. Lucia, Australia) Jun. 1993 6 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Research supported by Australian Research Council and NASA refs
(AIAA PAPER 93-2444) Copyright

Experimental results are given for the specific impulse produced by a two-dimensional scramjet at flight speeds ranging between 2.5 and 5.5 km/s with a combustion chamber Mach number of 4.5. Both hydrogen and ethane fuels were used. Results show that provided sufficiently high pressures and sufficiently long combustion chambers are used specific impulses in excess of 1500 s can be obtained with hydrogen. Ethane produced specific impulses less than 600 s with the same conditions and model configuration.

A93-50197# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
EXPERIMENTAL AND NUMERICAL STUDY OF SWEPT RAMP INJECTION INTO A SUPERSONIC FLOWFIELD
JAMES M. DONOHUE, JAMES C. MCDANIEL, JR., and HOSSEIN HAJ-HARIRI (Virginia Univ., Charlottesville) Jun. 1993 18 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(Contract NAG1-795; NGT-50897)
(AIAA PAPER 93-2445) Copyright

Time-averaged measurements of pressure, temperature, velocity, and injectant mole fraction are presented using the planar laser-induced iodine fluorescence (PLIIF) techniques in the complex 3D compressible flowfield around a swept ramp fuel injector. Within the range of thermodynamic conditions present in the test case studied, the technique's accuracy is estimated to be 4 percent for pressure, 4 percent for temperature, 4 percent for velocity, and 3 percent for injectant mole fraction. Comparisons to numerical simulations using the SPARK 3D Navier-Stokes computer code with an algebraic turbulence model are made at the centerplane of the flowfield as well as on three crossflow planes downstream of the injector, and good agreement is found. A weak asymmetry in the incoming flowfield appears to be amplified by boundary layer separation occuring when the the ramp generated shock reflects off the tunnel walls. In the near field of the injector, laminar

calculations show better agreement to the measurements than turbulent calculations. Author (revised)

A93-50198#
EXPERIMENTAL STUDIES OF AERODYNAMIC PERFORMANCES OF HYPERSONIC SCRAMJET IN IMPULSE HOT-SHOT TUNNEL
V. I. ZVEGINTSEV (RAN, Inst. Teoreticheskoj i Prikladnoj Mekhaniki, Novosibirsk, Russia) Jun. 1993 6 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2446) Copyright

Based on the investigations performed at the Institute of Theoretical and Applied Mechanics, Siberian Division of the Russian Academy of Sciences, Novosibirsk, in the 70's a new scheme of scramjet was worked out which involved a convergent inlet, a combustion chamber of compact cross section, and a divergent conical nozzle. Tests of the model of a hypersonic vehicle having a hydrogen-operated engine of the mentioned scheme were carried out in the hot-shot tunnel at M = 7.9 and enabled to find total aerodynamic performances within a wide range of fuel injection rate. We obtained an excessive thrust of power plant and demonstrated the model motion against free stream under the effect of the thrust. This paper presents estimates of the summands of the total aerodynamic force and the value of combustion efficiency. Author (revised)

A93-50199#
DESIGN AND INVESTIGATION OF THE STAND AND FLYING SCRAMJET MODELS - CONCEPTIONS AND RESULTS OF EXPERIMENTS
O. N. ROMANKOV and F. I. STAROSTIN (Turaevo Machine-Building Design Bureau Soyuz, Lytkarino, Russia) Jun. 1993 12 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2447) Copyright

The results of numerical and experimental investigation of fundamental concepts of scramjet models are discussed. It is shown that echeloned pylons and uniformly cascaded injectors can be placed along a combustor section in an efficient fuel feeding scheme for Mach numbers from 4.5 to 14. For M = 4.5-7 good results are obtained for thermal choking in the combustor end in a pseudoshock model. AIAA

A93-50201#
ENGINE TESTING AT SIMULATED ALTITUDE CONDITIONS
J. H. ROBERTS, J. A. GUIDONE, B. MANCUSO (Pratt & Whitney Group, East Hartford, CT), J. BABILON (USAF, Arnold Engineering Development Center, Arnold AFB, TN), and M. MCILVEEN (Sverdrup Technology, Inc., AEDC Group, Arnold AFB, TN) Jun. 1993 10 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2452) Copyright

The development of an Arnold Engineering and Development Center's C2 test cell into an industry accepted, high bypass engine, altitude simulating test facility, performed by a Pratt & Whitney/USAF team, is described. Nozzle thrust and flow coefficients are computed using measurements of nozzle entry pressure and temperature together with the measured force and airflow taken during full-scale testing of a particular engine model. Full scale calibrations of engines from sea level and altitude environments are used to determined nozzle coefficients that cover the range from the low nozzle pressure ratios experienced at sea level static to nozzle pressure ratios well beyond the choking value as experienced in altitude cruise operation. Particular attention is given to the test design features and the measurement and instrumentation uncertainties. AIAA

A93-50215#
IMPLEMENTATION OF AN INFRARED THERMAL IMAGING SYSTEM TO MEASURE TEMPERATURE IN A GAS TURBINE ENGINE
J. D. MACLEOD and P. STECKHAN (National Research Council of Canada, Ottawa) Jun. 1993 8 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2469) Copyright

A program for the evaluation of component deterioration on gas turbine engine performance is discussed. The effort is aimed at investigating the effects of typical in-service faults on the performance characteristics of each individual engine component. An important aspect of the engine test program is the evaluation of nonintrusive sensors to measure gas turbine engine performance. This instrumentation provides an accurate measurement of temperature and does not interfere with the flow field being measured. This paper describes the project objectives, the experimental installation, and the results of the performance evaluations. A description of the infrared thermography system, and the data reduction and analysis systems used to convert infrared light into temperature profile contours is given. Recommendations on future upgrades and modifications to the hardware/software are also included. Author (revised)

A93-50217#
THREE-DIMENSIONAL PREDIFFUSER COMBUSTOR STUDIES WITH AIR-WATER MIXTURE
P. LAING, R. P. SHASTRI, C. M. EHRESMAN, and S. N. B. MURTHY (Purdue Univ., West Lafayette, IN) Jun. 1993 25 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(Contract DTFA-92-G-002)
(AIAA PAPER 93-2474) Copyright

Water ingestion into an aircraft gas turbine engine, arising during flight under conditions of rainfall, is known to have an adverse affect on the operation and handling of the engine due to modifications in the performance of the individual components, and of the engine system. An experimental investigation has been carried out with model three-dimensional gas turbine prediffuser-combustor sectors utilizing a number of mixture and flow conditions in a tunnel operating with a two-phase, air-liquid film-droplet mixture. For given entry conditions into the prediffuser (which can be related to the exit conditions of the core compressor in a bypass engine, and, therefore, also to ingestion conditions at the engine face) the two main issues are (1) the amount of water entering the primary zone of the combustor and (2) the local reduction in temperature, flame-water interactions, and the vitiation caused by the vaporizing of water. Flow visualization, and estimates of water flow and droplet size in the primary zone were undertaken under cold flow conditions. Combustion tests were carried out to establish the effects on performance, recoverability of performance, and flame-out under various conditions. Author (revised)

A93-50252*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
A COMPARISON BETWEEN NUMERICALLY MODELLED AND EXPERIMENTALLY MEASURED LOSS MECHANISMS IN WAVE ROTORS
DANIEL E. PAXSON (NASA, Lewis Research Center, Cleveland, OH) Jun. 1993 12 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2522) Copyright

A numerical model has been developed which is capable of predicting the performance of a wave rotor (pressure exchanger) of specified geometry over a wide range of operating conditions. The model can account for the major loss mechanisms of leakage from the tube ends, fluid viscosity, heat transfer to the tube wails, finite tube opening time, shock waves, and non-uniform port flows. It is a one dimensional flow model which follows a single tube as it rotates past the various stationary ports. Since the model is relatively simple (i.e., one dimensional) it uses little computer time.

This makes it suitable for design as well as analytical purposes. This paper will present a brief description of the model then discuss a comparison between the model predictions and several wave rotor experiments.

A93-50253*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
ANALYTIC METHODS FOR DESIGN OF WAVE CYCLES FOR WAVE ROTOR CORE ENGINES
EDWIN L. RESLER, JR., JEFFREY C. MOCSARI, and M. R. NALIM (Cornell Univ., Ithaca, NY) Jun. 1993 13 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Research supported by NASA refs
(AIAA PAPER 93-2523) Copyright

A procedure to design a preliminary wave rotor cycle for any application is presented. To complete a cycle with heat addition there are two separate but related design steps that must be followed. The 'wave' boundary conditions determine the allowable amount of heat added in any case and the ensuing wave pattern requires certain pressure discharge conditions to allow the process to be made cyclic. This procedure, when applied, gives a first estimate of the cycle performance and the necessary information for the next step in the design process, namely the application of a characteristic based or other appropriate detailed one dimensional wave calculation that locates the proper porting around the periphery of the wave rotor. Four examples of the design procedure are given to demonstrate its utility and generality. These examples also illustrate the large gains in performance that could be realized with the use of wave rotor enhanced propulsion cycles.

A93-50267*# National Aeronautics and Space Administration. Hugh L. Dryden Flight Research Facility, Edwards, CA.
FLIGHT-DETERMINED ENGINE EXHAUST CHARACTERISTICS OF AN F404 ENGINE IN AN F-18 AIRPLANE
KIMBERLY A. ENNIX, FRANK W. BURCHAM, JR., and LANNIE D. WEBB (NASA, Flight Research Center, Edwards, CA) Jun. 1993 13 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2543) Copyright

The exhaust characteristics of the F-18 aircraft with an F404 engine are examined with reference to the results of an acoustic flight testing program. The discussion covers an overview of the flight test planning, instrumentation, test procedures, data analysis, engine modeling codes, and results. In addition, the paper presents the exhaust velocity and Mach number data for the climb-to-cruise, Aircraft Noise Prediction Program validation, and ground tests.
AIAA

A93-50268#
F405 ENGINE IN-FLIGHT THRUST METHODOLOGY DEVELOPMENT FOR THE T-45A FLIGHT TEST PROGRAM
T. CHANDLER and J. CHISHOLM (McDonnell Douglas Corp., Saint Louis, MO) Jun. 1993 12 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2544) Copyright

A summary of the in-flight thrust methodology development undertaken by McDonnell Douglas Aerospace East for the Rolls-Royce F405-RR-401 turbofan engine in the T-45A aircraft flight test program is presented. The methods involve correlations developed from the engine altitude performance qualification test conducted from January to June 1992 at the Naval Air Warfare Center - Trenton, NJ (NAWC). They are also consistent with industry-recognized methods for in-flight thrust measurement. The flight test data system was installed along with the NAWC facility system so that output from both systems could be compared. This paper covers the correlation development and validation results leading to the release of an in-flight thrust computer deck for use in the flight test program.

A93-50277*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
NAVIER-STOKES ANALYSIS OF RADIAL TURBINE ROTOR PERFORMANCE
L. M. LAROSILIERE (Ohio Aerospace Inst., Brook Park) Jun. 1993 19 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Previously announced in STAR as N93-28609 Research sponsored by NASA refs
(AIAA PAPER 93-2555) Copyright

An analysis of flow through a radial turbine rotor using the three-dimensional, thin-layer Navier-Stokes code RVC3D is described. The rotor is a solid version of an air-cooled metallic radial turbine having thick trailing edges, shroud clearance, and scalloped-backface clearance. Results are presented at the nominal operating condition using both a zero-clearance model and a model simulating the effects of the shroud and scalloped-backface clearance flows. A comparison with the available test data is made and details of the internal flow physics are discussed, allowing a better understanding of the complex flow distribution within the rotor.

A93-50285#
AIRCRAFT CRYOGENIC FUEL SYSTEM DESIGN ISSUES
FRANK O. CHANDLER, MARTIN E. LOZANO, and SIDNEY P. GLASSER (Rockwell International Corp., Downey, CA) Jun. 1993 10 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993
(AIAA PAPER 93-2567) Copyright

The propellant system design issues and requirements for cryogenically-fueled aircraft differ from those using conventional hydrocarbon fuels. The unique thermophysical properties of cryogenic fuel pose a number of design issues relative to tank loading, tank pressure control, thermal protection system design, quantity gaging systems, e.g. control systems, ground support equipment and operations, and integration with other subsystems. This paper addresses the major design issues and presents a number of conceptual design solutions for a hypersonic aircraft using cryogenic hydrogen fuel.

A93-50287#
IHPTET EXHAUST NOZZLE TECHNOLOGY DEMONSTRATOR
TIM M. HAWKES (USAF, Wright Lab., Wright-Patterson AFB, OH) and ROGER C. OBYE (Pratt & Whitney Group, West Palm Beach, FL) Jun. 1993 9 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993
(AIAA PAPER 93-2569)

Advanced exhaust nozzle technologies will undergo full-scale engine demonstration as part of the Government/Pratt and Whitney Joint Technology Demonstrator Engine (JTDE) program in 1994 and 1995. These technologies range from aerodynamic and cooling system performance through the use of structural high temperature non-metallic materials to the validation of an entirely new afterburning nozzle concept. Internal flowpath technologies have evolved from aerodynamic performance testing evaluating geometric parameters, hot flow thermal tests evaluating cooling system characteristics, flow visualization tests and computational fluid dynamics (CFD) analysis, to design and fabrication of full-scale hardware. Cooling supply system and sealing technologies have grown from conceptual designs and rig tests to development of full-scale hardware. Materials to be demonstrated include organic and ceramic matrix composites. Other technologies include the development of a flight/propulsion control system for use in the JTDE test, and the use of advanced actuators and optics. The nozzle design itself incorporates unique structural and kinematic approaches and possesses functions including independent area control, multi-axis vectoring, flow blocking, reversing and effcient aircraft integration.

A93-50294*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
NONLINEAR DYNAMIC SIMULATION OF SINGLE- AND MULTI-SPOOL CORE ENGINES
T. SCHOBEIRI, C. LIPPKE, and M. ABOUELKHEIR (Texas A & M Univ., College Station) Jun. 1993 15 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Research supported by NASA refs
(AIAA PAPER 93-2580) Copyright

In this paper a new computational method for accurate simulation of the nonlinear dynamic behavior of single- and multi-spool core engines, turbofan engines, and power generation gas turbine engines is presented. In order to perform the simulation, a modularly structured computer code has been developed which includes individual mathematical modules representing various engine components. The generic structure of the code enables the dynamic simulation of arbitrary engine configurations ranging from single-spool thrust generation to multi-spool thrust/power generation engines under adverse dynamic operating conditions. For precise simulation of turbine and compressor components, row-by-row calculation procedures were implemented that account for the specific turbine and compressor cascade and blade geometry and characteristics. The dynamic behavior of the subject engine is calculated by solving a number of systems of partial differential equations, which describe the unsteady behavior of the individual components. In order to ensure the capability, accuracy, robustness, and reliability of the code, comprehensive critical performance assessment and validation tests were performed. As representatives, three different transient cases with single- and multi-spool thrust and power generation engines were simulated. The transient cases range from operating with a prescribed fuel schedule, to extreme load changes, to generator and turbine shut down.

A93-50306*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
NO(X) REDUCTION ADDITIVES FOR AIRCRAFT GAS TURBINE ENGINES
HENRY G. ADELMAN (Eloret Inst., Palo Alto; NASA, Ames Research Center, Moffett Field, CA), GENE P. MENEES (NASA, Ames Research Center, Moffett Field, CA), and JEAN-LUC CAMBIER (Eloret Inst., Palo Alto, CA) Jun. 1993 7 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2594) Copyright

The reduction of oxides of nitrogen (NO(x)) emissions from aircraft gas turbine engines is a vital part of the NASA High Speed Research Program. Emissions reductions are critical to the feasibility of future High Speed Civil Transports which operate at supersonic speeds in the stratosphere. It is believed that large fleets of such aircraft using conventional gas turbine engines would emit levels of NO(x) that would be harmful to the stratospheric ozone layer. Previous studies have shown that NO(x) emissions can be reduced from stationary powerplant exhausts by the addition of additives such as ammonia to the exhaust gases. Since the exhaust residence times, pressures and temperatures may be different for aircraft gas turbines, a study has been made of additive effectiveness for high speed, high altitude flight. Author (revised)

A93-50311#
THE 'ROLLS-ROYCE' WAY OF VALIDATING FAN INTEGRITY
J. HORSLEY (Rolls-Royce, PLC, Derby, United Kingdom) Jun. 1993 15 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993
(AIAA PAPER 93-2602) Copyright

Tests and techniques used by Rolls-Royce to demonstrate foreign object ingestion and containment capability on turbofan engines are briefly described. Preliminary tests are conducted on test rigs which makes it possible to manipulate test conditions and to evaluate quickly and cost effectively different designs. The design requirements are considered for three cases including bird ingestion, foreign object damage, and blade containment. AIAA

A93-50316#
COMPONENT AND ENGINE STRUCTURAL ASSESSMENT RESEARCH (CAESAR)
M. F. HUFFMAN (USAF, Aeropropulsion and Power Directorate, Wright-Patterson AFB, OH) Jun. 1993 8 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2609) Copyright

The Component and Engine Structural Assessment Research (CAESAR) initiative is a multicontractor program being conducted as part of the Integrated High Performance Turbine Engine Technology (IHPTET) initiative. The overall goal of the IHPTET initiative is to demonstrate those technologies which when applied to a wide range of military propulsion systems, would double turbopropulsion capability by the turn of the century while maintaining current levels of reliability, maintainability, and system life. One way to accomplish the IHPTET goal is to develop materials that are lighter-weight, stronger, and more temperature-tolerant than those in current systems. This paper discusses the development of the design criteria for several materials that could be applied to future turbopropulsion systems. CAESAR will verify, through Life Assessment Testing (LAT), the 'rules and tools' that were developed under two government sponsored programs: (1) Titanium Aluminide Compressor Stage Structural Assessment (TACSSA) and (2) Design, Manufacturing, and Evaluation of Titanium Aluminide Components. The testing will use the F119 core. Author (revised)

A93-50352
THE WELL MADE ENGINE
JIM KEIR (Rolls-Royce, PLC, Aerospace Group, Derby, United Kingdom) Aerospace (UK) (ISSN 0305-0831) vol. 20, no. 6 June 1993 p. 32-35.
Copyright

An account is given of high-value-adden manufacturing processes and quality management practices developed by a major turbine engine manufacturer, such as the concurrency of product design and manufacturing process development. The production facilities thus evolved are composed of 'cells' where similar components are grouped together, allowing a concentration of relevant worker and supervisor skills. AIAA

A93-51193
A TRANSFER MATRIX METHOD FOR CALCULATION OF SUPPORT STIFFNESS OF AEROENGINE STATOR
XINGMIN REN and JIALU GU (Northwestern Polytechnical Univ., Xian, China) Northwestern Polytechnical University, Journal (ISSN 1000-2758) vol. 11, no. 3 July 1993 p. 282-287. In CHINESE refs

The transfer matrix method (TMM), a method for streamlining calculation of the support stiffness of an aeroengine stator, is presented. For every stator system, all DOFs are essentially expressed implicitly by the eight parameters of state of the characteristic section of the stator. TMM yields results with the same precision as FEM. As compared with FEM, the effect of an aircraft or test platform can be more conveniently taken into account by the stiffness matrix and the transfer matrix of TMM. A specific engine stator is analyzed. It is shown that the support stiffness of the stator varies significantly with frequency. Errors will be significant if static stiffness is used to analyze the dynamic characteristics of the stator. AIAA

A93-51402#
TVC CONTROL FOR THE AIAA DESIGN CHALLENGE AIRPLANE
MICHAEL W. DIERKS and KEVIN A. WISE (McDonnell Douglas Aerospace, Saint Louis, MO) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 2 Washington American Institute of Aeronautics and Astronautics 1993 p. 995-1005. refs
(AIAA PAPER 93-3810) Copyright

The potential for improved performance is examined in an existing aircraft platform with the addition of thrust-vectoring nozzles

and an augmented flight control system. Axisymmetrical thrust-vectoring nozzles are used to augment conventional aerodynamic control effectors to expand the operational flight envelope and to provide damage control reconfiguration. Integrated flight/propulsion control paradigms are examined, and a partitioned hierarchical control law is developed for this application. The flight/propulsion control system is evaluated using high angle-of-attack maneuvers, and comparisons are made between thrust-assisted and aerodynamic-force-only responses. Results from a high-fidelity 6 degree-of- freedom simulation are examined and found to indicate a potential for significant performance improvements by a retrofit of this aircraft with thrust vector controls.

A93-51403*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
ANTIWINDUP ANALYSIS AND DESIGN APPROACHES FOR MIMO SYSTEMS
VINCENT R. MARCOPOLI and STEPHEN M. PHILLIPS (Case Western Reserve Univ., Cleveland, OH) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 2 Washington American Institute of Aeronautics and Astronautics 1993 p. 1006-1011. refs
(Contract NAG3-1232)
(AIAA PAPER 93-3811) Copyright

Performance degradation of multiple-input multiple-output (MIMO) control systems having limited actuators is often handled by augmenting the controller with an antiwindup mechanism, which attempts to maintain system performance when limits are encountered. The goals of this paper are: 1) to develop a method to analyze antiwindup systems to determine precisely what stability and performance degradation is incurred under limited conditions. It is shown that by reformulating limited actuator commands as resulting from multiplicative perturbations to the corresponding controller requests, mu-analysis tools can be utilized to obtain quantitative measures of stability and performance degradation. 2) To propose a linear, time invariant (LTI) criterion on which to base the antiwindup design. These analysis and design methods are illustrated through the evaluation of two competing antiwindup schemes augmenting the controller of a Short Take-Off and Vertical Landing (STOVL) aircraft in transition flight.

A93-51404#
A COMPARISON OF TWO MULTI-VARIABLE INTEGRATOR WINDUP PROTECTION SCHEMES
DUANE MATTERN (Sverdrup Technology, Inc., Cleveland, OH) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 2 Washington American Institute of Aeronautics and Astronautics 1993 p. 1012-1020. refs
(AIAA PAPER 93-3812) Copyright

Two methods are examined for limit and integrator wind-up protection (IWP) for multiinput, multioutput linear controllers subject to actuator constraints. The methods begin with an existing linear controller that satisfies the specifications for the nominal, small perturbation, linear model of the plant. The controllers are formulated to include an additional contribution to the state derivative calculations. The first method to be examined is the multi-variable version of the single-input, single-output, high-gain, Conventional Anti-Windup (CAW) scheme. Except for the actuator limits, the CAW scheme is linear. The second scheme, denoted the Modified Anti-Windup (MAW) scheme, uses a scalar to modify the magnitude of the controller output vector while maintaining the vector direction. The calculation of the scalar modifier is a nonlinear function of the controller outputs and the actuator limits. In both cases the constrained actuator is tracked. The two IWP methods are demonstrated on a turbofan engine control system with five measurements, four control variables, and four actuators. The closed-loop responses of the two schemes are compared and contrasted during limit operation. The issue of maintaining the direction of the controller output vector using the MAW scheme is discussed, and the advantages and disadvantages of both of the IWP methods are presented. Author (revised)

A93-51642
THE TURBULENCE AND MIXING CHARACTERISTICS OF THE COMPLEX FLOW IN A SIMULATED AUGMENTOR
Y. C. CHAO, J. H. LEU, T. H. YANG (National Cheng Kung Univ., Tainan, Taiwan), and C. K. LIN (Chung-Shan Inst. of Science and Technology, Taichung, Taiwan) *In* Aerothermodynamics in combustors; IUTAM Symposium, National Taiwan Univ., Taipei, June 3-5, 1991, Selected Papers Berlin and New York Springer-Verlag 1992 p. 279-290. refs
Copyright

The flow and the fuel-air mixing of the aircraft augmentor equipped with the pilot burner and the V-gutter are studied experimentally in a simulated augmentor. The laser Doppler velocimetry system and an aspirating concentration probe are used to measure the turbulent velocity and the mixture fraction in the augmentor flow. Due to the effect of the interaction of the swirl component and the axial velocity of the pilot burner flow, high turbulent fluctuation and intensive mixing are found in the lower portion of the pilot burner flow. This feature is further confirmed to provide a convenient path for the propagation of the pilot flame to the V-gutter to initiate the main combustion there. Also, turbulent mixing is evidently shown to be the dominant mixing mechanism in the augmentor flow.

A93-51643
SCALAR CHARACTERISTICS IN A LIQUID-FUELLED COMBUSTOR WITH CURVED EXIT NOZZLE
S. K. CHOW and J. H. WHITELAW (Imperial College of Science, Technology and Medicine, London, United Kingdom) *In* Aerothermodynamics in combustors; IUTAM Symposium, National Taiwan Univ., Taipei, June 3-5, 1991, Selected Papers Berlin and New York Springer-Verlag 1992 p. 291-299. Research supported by Ministry of Defence Procurement Executive refs
Copyright

An experimental effort has been made to deepen understanding of the performance-determining processes of a reverse-flow annular combustor typical of small gas turbine designs. Attention is given to the combustor geometry and the experimental uncertainties associated with the instrumentation used. It is found that, for the takeoff-conditions air/fuel ratio of 36:1, combustion processes continued beyond the point of entry to the curved nozzle, and led to lower CO and unburned hydrocarbons, as well as a combustion efficiency of the order of 97.8 percent. AIAA

A93-51644
MEASUREMENTS OF GAS COMPOSITION AND TEMPERATURE INSIDE A CAN TYPE MODEL COMBUSTOR
W. P. JONES and A. TOBER (Imperial College of Science, Technology and Medicine, London, United Kingdom) *In* Aerothermodynamics in combustors; IUTAM Symposium, National Taiwan Univ., Taipei, June 3-5, 1991, Selected Papers Berlin and New York Springer-Verlag 1992 p. 327-338. Research supported by Rolls-Royce, PLC refs
Copyright

Concentrations of major species and temperature have been measured at air-fuel ratios (AFR) of 57 and 91 in a model can-type gas turbine combustion chamber burning kerosene introduced via a pressure jet atomizer. Conditions within the combustor including primary and dilution jet trajectories and mixing rates are inferred from the mean mixture fraction field which is evaluated from the measured species concentrations. A comparison with earlier measurements in the same combustor burning gaseous propane suggests that the flow field and mixing rates are similar for both fuels. The maximum levels of CO are found to be effectively independent of AFR with maximum concentrations of about 6 percent arising under slightly fuel-rich conditions in both cases.
Author (revised)

A93-51645
NUMERICAL MODEL FOR PREDICTIONS OF REVERSE FLOW COMBUSTOR AEROTHERMAL CHARACTERISTICS
P. DI MARTINO, E. NARCISO, and G. CINQUE (Alfa Romeo Avio S.p.A., Pomigliano d'Arco, Italy) *In* Aerothermodynamics in

combustors; IUTAM Symposium, National Taiwan Univ., Taipei, June 3-5, 1991, Selected Papers Berlin and New York Springer-Verlag 1992 p. 339-353. refs
Copyright

A mathematical model of three-dimensional two-phase reacting flows in gas turbine combustion chambers has been developed. The governing time-averaged partial differential equations and the physical modelling for the turbulence, combustion and thermal radiation have been solved by a numerical technique based on the finite volume approach. A reverse flow type combustor was used to validate the model. The results are found to be in close agreement with available experimental data. An assessment of the adequacy of the various submodels embodied has been made in view of future improvements.

A93-51759
ACOUSTIC INTENSITY OF NONISOTHERMAL COAXIAL JETS WITH AN INVERTED VELOCITY PROFILE [AKUSTICHESKAYA MOSHCHNOST' NEIZOTERMICHESKIKH SOOSNYKH STRUJ S 'PEREVERNUTYM' PROFILEM SKOROSTEJ]
V. M. KUZNETSOV TsAGI, Trudy no. 2355 1988 p. 59-64. In RUSSIAN refs
Copyright

A parametric study is made of the noise of nonisothermal coaxial jets with different initial mean velocity profiles. It is shown that the decrease in acoustic intensity due to the conversion of the initial mean velocity profile is greater for nonisothermal jet than for isothermal jets. The use of the inverted temperature profile makes the acoustic effect due to the inverted mean velocity profile more pronounced. AIAA

A93-51760
AN APPROACH TO THE CALCULATION OF THE FAR ACOUSTIC FIELD OF A PROPELLER [OB ODNOM PODKHODE K RASCHETU DAL'NEGO AKUSTICHESKOGO POLYA VOZDUSHNOGO VINTA]
V. F. SAMOKHIN TsAGI, Trudy no. 2355 1988 p. 65-74. In RUSSIAN refs
Copyright

The possibility of using Lighthill's acoustic analogy for estimating the far acoustic field of a propeller is investigated. The principal calculation formulas are obtained from the dimensional analysis of the inhomogeneous wave equation and on the basis of the concept of pulsed acoustic emission of a propeller. Calculations of the 1/3-octave spectra of the sound pressure of the AV-72 and SV-24 propellers are compared with experimental data. AIAA

A93-51761
DETERMINATION OF FAN NOISE IN A LINED DUCT WITH FLOW USING THE GREEN FUNCTION METHOD [OPREDELENIE SHUMA VENTILYATORA V OBLITSOVANNOM KANALE S POTOKOM METODOM FUNKTSII GRINA]
A. F. SOBOLEV TsAGI, Trudy no. 2355 1988 p. 75-82. In RUSSIAN refs
Copyright

The Green function method is applied to the problem of determining the fan noise in a duct with sound-absorbing walls, with air flow within the duct being constant and uniform over the duct cross section. The analysis does not include the effect of reflection from the open end of the duct. The corresponding Green function is derived. AIAA

A93-52171
GAS TURBINE STARTER (JET FUEL STARTER) SPECIFICATION
SAE Aerospace Standard SAE AS 1606 Sept. 15, 1992 55 p. refs
(SAE AS 1606) Copyright

The requirements concerning the 'to be specified' (TBS) jet fuel starter for the gas turbine engine used in the TBS aircraft are listed in a form that they may serve as an aid in the preparation of a gas turbine starter specification. Applicable documents are presented, including military documents (specifications and standards) and other publications, and definitions and symbols; requirements, including operational, environmental, and design requirements; quality assurance provisions, including specifications concerning classification of tests, test conditions, acceptance tests, individual tests, and preproduction testing; and preparation for delivery, including directions for preservation and packaging, packing, marking, and packing list. AIAA

08

AIRCRAFT STABILITY AND CONTROL

Includes aircraft handling qualities; piloting; flight controls; and autopilots.

A93-48153#
SIDE FORCE AUGMENTATION AT HIGH ANGLE OF ATTACK FROM PNEUMATIC VORTEX FLOW CONTROL
KENNETH C. CORNELIUS and GERALD A. LUCIUS (Wright State Univ., Dayton, OH) Jul. 1993 11 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(Contract F33601-89-D-0045)
(AIAA PAPER 93-2959) Copyright

An experiment has been undertaken to measure side and lift forces with various nozzle blowing locations on an elliptic forebody. In this study a jet of small momentum excites a convective instability to produce an amplified side force at high angle of attack for a fighter forebody. This study has identified an optimized nozzle position around the circumference of the forebody and axial location using a slotted nozzle at various pressure ratio values. A forward sweep of the nozzle provided for the greatest augmentation of side force at angles of attack below 55 deg. A beveled nozzle has shown active control of side force beyond 55 deg angle of attack and has merit in extending the angle of attack range. The mass flow requirements for an equivalent yawing moment are sensitive to the angle of the jet relative to the forebody axis as well as the jet exit boundary conditions. The required mass flow is compatible with the engine bleed air to produce a side force equivalent to the vertical stabilizer at lower angles of attack.
Author (revised)

A93-48154#
ELLIPTIC CROSS SECTION TIP EFFECTS ON THE VORTEX WAKE OF AN AXISYMMETRIC BODY AT ANGLE OF ATTACK
DAVID H. BRIDGES (Mississippi State Univ., Mississippi State) and HANS G. HORNUNG (California Inst. of Technology, Pasadena) Jul. 1993 12 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-2960) Copyright

The effectiveness of a new version of an elliptic cross section tip in controlling the asymmetry of the vortex wake of an axisymmetric body at angle of attack has been studied. The elliptic cross sections were generated using two sixth-degree polynomials such that the tip radius, slope, and curvature would match that of a right circular cone at the point where the polynomial became tangent to a cone generator. The tip was found to be effective in varying the vortex wake geometry of a right circular cone at large angle of attack. The measured side force coefficient varied smoothly with tip roll angle for the two lowest angles of attack studied, and exhibited square-wave and more undesirable variations for the larger angles of attack studied. These square-wave and peak, reduction in magnitude, and change in sign variations were caused by vortex breakaway, which allowed vortex crossover to occur. Ahead of vortex breakaway, the elliptic cross section tip yielded smooth variations of vortex wake asymmetry with tip roll angle, indicating that the tip would probably be a feasible control device for high-performance fighter aircraft at high angle of attack.

A93-48301
AIAA ATMOSPHERIC FLIGHT MECHANICS CONFERENCE, MONTEREY, CA, AUG. 9-11, 1993, TECHNICAL PAPERS
Washington American Institute of Aeronautics and Astronautics 1993 647 p. For individual items see A93-48302 to A93-48360 Copyright

The present conference discusses topics in aircraft stability and control, unsteady aerodynamics, CFD and analysis of projectile/missile aerodynamics, system identification and parameter estimation methods, wind shear and atmospheric disturbances, aircraft handling qualities, experimental determination of projectile/missile aerodynamics, aircraft trajectory optimization, aircraft dynamics and performance, aeroassist technologies, and reentry technologies. Attention is given to the stability characteristics of high-performance aircraft, kinematics of the velocity vector roll, base drag prediction for missile configurations, aerodynamic coefficient estimation using neural networks, roll requirements for carrier approach, ring-wing missiles, aeroelastic effects of the B-2 maneuver response, a flying qualities criterion for flying wings, and the rarefied aerodynamics of the Magellan spacecraft during aerobraking. AIAA

A93-48302*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
EFFECT OF GEOMETRY, STATIC STABILITY, AND MASS DISTRIBUTION ON THE TUMBLING CHARACTERISTICS OF GENERIC FLYING-WING MODELS
C. M. FREMAUX, D. M. VAIRO (Lockheed Engineering & Sciences Co., Hampton, VA), and R. D. WHIPPLE (NASA, Langley Research Center, Hampton, VA) *In* AIAA Atmospheric Flight Mechanics Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers Washington American Institute of Aeronautics and Astronautics 1993 p. 1-11. refs
(AIAA PAPER 93-3615)

Results from an investigation to determine the low-speed tumbling characteristics of twelve generic flying-wing models are summarized. There is a concern that airplanes with flying-wing planforms could inadvertently enter an out-of-control tumbling motion under certain conditions. The objectives of this investigation were to: 1) identify the geometric and mass-related parameters that cause flying wings to be capable of sustained tumbling, 2) analyze some of the driving mechanisms that cause tumbling, and 3) determine the feasibility of using computer simulations to predict the tumbling characteristics of flying wings. Free-tumble and free-to-pitch tests were conducted with dynamically-scaled, generic flying wing models. The use of computer simulations as a predictive tool for tumbling was explored. Results indicated that center-of-gravity location, mass distribution, and geometric aspect ratio strongly affected the tumbling characteristics of the models tested and that positive static stability did not necessarily preclude tumbling. The magnitude of dynamic effects were found to be of the same order as static effects for the models undergoing autorotation-in-pitch. The simulations indicated that the dynamic terms in the equations of motion used to predict tumbling must be obtained using experimental methods that account for the large amplitude/high pitch-rate environment that characterizes tumbling.

A93-48303#
ANALYSIS OF STABILITY CHARACTERISTICS OF A HIGH PERFORMANCE AIRCRAFT
G. GUGLIERI (CNR, Centro di Studio per la Dinamica dei Fluidi, Turin, Italy) and F. B. QUAGLIOTTI (Torino, Politecnico, Turin, Italy) *In* AIAA Atmospheric Flight Mechanics Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers Washington American Institute of Aeronautics and Astronautics 1993 p. 12-19. refs
(AIAA PAPER 93-3616) Copyright

An investigation is conducted of the stability-related parameters of high performance aircraft configurations, on the basis of damping and cross-coupling measurements. Attention is given to the effects of angle of attack, sideslip angle, and reduced frequency and oscillation amplitude, in light of a series of pitch and roll oscillation tests. The effect of wind tunnel model support asymmetry was evaluated. AIAA

A93-48304#
CALCULATION OF TRANSONIC LONGITUDINAL AND LATERAL-DIRECTIONAL CHARACTERISTICS OF AIRCRAFT BY THE SMALL DISTURBANCE THEORY
MICHAEL D. THACKER and C. E. LAN (Kansas Univ., Lawrence) *In* AIAA Atmospheric Flight Mechanics Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers Washington American Institute of Aeronautics and Astronautics 1993 p. 20-32. refs
(AIAA PAPER 93-3617) Copyright

Finite-difference solutions based on the transonic small disturbance equation are obtained for complete airplane configurations. Embedded rectangular grids are used with each component being covered with an individual fine grid and the whole configuration being covered with a global coarse grid. The code is capable of computing pressure distribution and total forces and moments in symmetrical and asymmetrical flight conditions in subsonic through low supersonic flows. Two types of formulations for the streamwise flux are provided, one being the traditional isentropic approximation and the other being a new nonisentropic one. Extensive comparison with available pressure data in transonic flow is conducted. The results show that the code can predict the transonic pressure distribution reasonably well except near the wing tip. Examination of the computed longitudinal total forces and moments show that both lift and drag coefficients are well predicted. However, the pitching moment coefficient predictions appear to be less accurate. Calculated lateral-directional forces and moments are also compared with data in transonic and supersonic flow. The predicted results show the correct trend with the data, but the body dependent effects (such as side force and yawing moment coefficients) are underpredicted.

A93-48305#
AN ADVANCED PARALLEL ROTORCRAFT FLIGHT SIMULATION MODEL - STABILITY CHARACTERISTICS AND HANDLING QUALITIES
S. SARATHY (Georgia Inst. of Technology, Atlanta) and V. R. MURTHY (Syracuse Univ., NY) *In* AIAA Atmospheric Flight Mechanics Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers Washington American Institute of Aeronautics and Astronautics 1993 p. 33-41. refs
(AIAA PAPER 93-3618) Copyright

While blade-element models have been shown to possess the fidelity and accuracy required for advanced rotorcraft, those possessing the full measure of complexity are too slow for real-time applications. An account is presently given of a parallel computation-implemented blade element rotorcraft flight simulation model, giving attention to response- and stability-related computational tasks. Numerical results thus obtained are presented for the OH-6 helicopter. AIAA

A93-48306#
A STUDY OF THE ROTARY BALANCE TECHNIQUE FOR PREDICTING PITCH DAMPING
WILLIAM B. BLAKE (USAF, Wright Lab., Wright-Patterson AFB, OH) *In* AIAA Atmospheric Flight Mechanics Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers Washington American Institute of Aeronautics and Astronautics 1993 p. 42-52. refs
(AIAA PAPER 93-3619)

A method of extracting pitch damping from rotary balance data is studied. The method involves manipulation of results from multiple angles of sideslip. Results from the method improve as the angle of sideslip used for the analysis increases. The pitch damping data extracted compare very well with results from a vortex lattice and modified strip theory program. The method is able to discern differences between the effects of positive and negative pitch rate on the damping.

A93-48307#
ESTIMATION OF NEUTRAL AND MANEUVER POINTS OF AIRCRAFT BY DYNAMIC MANEUVERS
S. SRINATHKUMAR, PADMA MADHURANATH, and GIRIJA GOPALRATNAM (National Aerospace Lab., Bangalore, India) *In* AIAA Atmospheric Flight Mechanics Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers Washington American Institute of Aeronautics and Astronautics 1993 p. 53-59. refs
(AIAA PAPER 93-3620) Copyright

A new flight test technique, based on aircraft parameter estimation methods, is proposed to simultaneously determine the neutral and maneuver point of aircraft. The new procedure is derived by relating the neutral point and maneuver point of an aircraft to key short period parameters M sub alpha and short period natural frequency omega sub n-squared, respectively. The new flight test method results in substantial savings in flight test time compared to conventional methods. The method is more accurate since only inertial sensor data (pitch rate and normal acceleration) is used in the estimation procedure.
Author (revised)

A93-48308# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
STATUS OF THE VALIDATION OF HIGH-ANGLE-OF-ATTACK NOSE-DOWN PITCH CONTROL MARGIN DESIGN GUIDELINES
MARILYN E. OGBURN, JOHN V. FOSTER (NASA, Langley Research Center, Hampton, VA), JOSEPH W. PAHLE, R. J. WILSON (NASA, Flight Research Center, Edwards, CA), and JAMES B. LACKEY (U.S. Navy, Naval Air Warfare Center, Patuxent River, MD) *In* AIAA Atmospheric Flight Mechanics Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers Washington American Institute of Aeronautics and Astronautics 1993 p. 60-75. refs
(AIAA PAPER 93-3623) Copyright

This paper presents a summary of results obtained to date in an ongoing cooperative research program between NASA and the U.S. Navy to develop design criteria for high-angle-of-attack nose-down pitch control for combat aircraft. A fundamental design consideration for aircraft incorporating relaxed static stability in pitch is the level of stability which achieves a proper balance between high-speed performance considerations and low-speed requirements for maneuvering at high angles of attack. A comprehensive data base of piloted simulation results was generated for parametric variations of critical parameters affecting nose-down control capability. The results showed a strong correlation of pilot rating to the short-term pitch response for nose-down commands applied at high-angle-of-attack conditions. Using these data, candidate design guidelines and flight demonstration requirements were defined. Full-scale flight testing to validate the research methodology and proposed guidelines is in progress, some preliminary results of which are reviewed.

A93-48309*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
LATERAL CONTROL AT HIGH ANGLES OF ATTACK USING PNEUMATIC BLOWING THROUGH A CHINED FOREBODY
A. S. ARENA, JR. (Oklahoma State Univ., Stillwater), R. C. NELSON (Notre Dame Univ., IN), and L. B. SCHIFF (NASA, Ames Research Center, Moffett Field, CA) *In* AIAA Atmospheric Flight Mechanics Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers Washington American Institute of Aeronautics and Astronautics 1993 p. 76-85. Research supported by Univ. Notre Dame refs
(Contract NCA2-621)
(AIAA PAPER 93-3624) Copyright

Directional control through the use of pneumatic blowing was investigated on a generic subscale model with a chined forebody with blowing through a chine slot in a direction normal to the forebody surface. Comparisons are made with a vertical tail on and off, and with control through rudder deflection. Force and moment data were obtained for various blowing coefficients over a 0-75 deg alpha range, and flow visualization was also conducted in order to see qualitative effects on the flowfield. Blowing through a chined forebody generates yaw moments at large alpha where control surfaces lose their effectiveness; these moments are much larger than obtained by jet thrust alone, since the forebody flowfield is modified through the interaction of the jet with the chine vortices. Directional control increased with angle of attack for a given blowing coefficient until a maximum was reached. Further increases in angle of attack results in a rapid loss of effectiveness. For angles of attack above 60 deg, yaw moments are generated by simple jet thrust effect. The effectiveness of the pneumatic system depended on tail configuration. Author (revised)

A93-48310*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
KINEMATICS AND AERODYNAMICS OF THE VELOCITY VECTOR ROLL
WAYNE C. DURHAM, FREDERICK H. LUTZE, and W. MASON (Virginia Polytechnic Inst. and State Univ., Blacksburg) *In* AIAA Atmospheric Flight Mechanics Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers Washington American Institute of Aeronautics and Astronautics 1993 p. 86-96. refs
(Contract NCC1-158)
(AIAA PAPER 93-3625) Copyright

The velocity vector roll is an angular rotation of an aircraft about its instantaneous velocity vector, constrained to be performed at constant angle-of-attack (AOA), no sideslip, and constant velocity. Consideration of the aerodynamic force equations leads to requirements for body-axis yawing and pitching rotations that satisfy these constraints. Here, the body axis rotations, and the constraints, are used in the moment equations to determine the aerodynamic moments required to perform the velocity vector roll. For representative tactical aircraft, the conditions for maximum pitching moment are a function of orientation, occurring at about 90 deg of bank in a level trajectory. Maximum required pitching moment occurs at peak roll rate, and is achieved at AOA above 45 deg. The conditions for maximum rolling moment depend on the value of the roll mode time constant. For a small time constant (fast response) the maximum rolling moment occurs at maximum roll acceleration and zero AOA, largely independent of aircraft orientation; for a large time constant, maximum required rolling moment occurs at maximum roll rate, at maximum AOA, and at 180 deg of bank in level flight. Maximum yawing moment occurs at maximum roll acceleration, maximum AOA, and is largely independent of airplane orientation. Author (revised)

A93-48311*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
UNSTEADY AERODYNAMIC MODELS FOR MANEUVERING AIRCRAFT
CHIEN-CHUNG HU, C. E. LAN (Kansas Univ., Lawrence), and JAY BRANDON (NASA, Langley Research Center, Hampton, VA) *In* AIAA Atmospheric Flight Mechanics Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers Washington American Institute of Aeronautics and Astronautics 1993 p. 97-112. refs
(Contract NAG1-1087)
(AIAA PAPER 93-3626) Copyright

Forced oscillation tests over a large angle-of-attack range for an F-18 model are conducted in the NASA Langley 12-foot low-speed tunnel. The resulting dynamic longitudinal data are analyzed with an unsteady aerodynamic modeling method based on Fourier functional analysis and the indicial formulation. The method is extensively examined and improved to automate the calculation of model coefficients, and to evaluate more accurately the indicial integral. The results indicate that the general model equation obtained from harmonic test data in a range of reduced frequency is capable of accurately modeling the nonlinear responses with large hysteresis effect, except in the region where a delayed flow reattachment occurs at low angles of attack in down strokes. The indicial formulation is used to calculate the response to harmonic motion, harmonic ramp motion, constant-rate pitching motion and smaller-amplitude harmonic motion. The results show that more accurate results can be obtained when the motion

starts from a low angle of attack where hysteresis effect is not important.

A93-48312#
A QUALITATIVE ASSESSMENT OF CONTROL EFFECTORS ON AN ADVANCED FIGHTER CONFIGURATION
MICHAEL G. ALEXANDER (USAF, Flight Dynamics Directorate, Wright-Patterson AFB, OH) *In* AIAA Atmospheric Flight Mechanics Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers Washington American Institute of Aeronautics and Astronautics 1993 p. 113-121. refs
(AIAA PAPER 93-3627)

A wind and a water tunnel external flow visualization study was conducted on a 2.7 percent scale Fighter Lift and Control (FLAC) configuration, to qualitatively evaluate baseline vortical flows, forebody strake, and other control device effects at angles-of-attack (AOAs) ranging from +15 deg to +45 deg and at side slips of 0 deg, +5 deg, and +10 deg. Results indicated three vortical systems on the baseline FLAC configuration: forebody, leading edge extension (LEX), and wing vortices. The forebody and LEX vortex coupled and persisted throughout the AOA and side slip range. Smaller area strakes produced a vortex at high but not at low AOAs, while larger area strakes produced a vortex at low AOA that burst at high AOA. Using the strake's length to adjust strake area established the AOA range of the strake; however, adjusting the strake area using the strake's span appeared to be effective at controlling the vorticity of the strake vortex, with the smaller spans producing the smallest increase in vorticity. The LEX vortex was effectively controlled using either a 30 deg or a 60 deg deflected LEX ramp (spoiler), a 45 deg deflected LEX flap, and a LEX strake. Severe 3D surface flows on the wings were indicated by oil flows. Author (revised)

A93-48325#
PARAMETER ESTIMATES OF AN AEROELASTIC AIRCRAFT AS AFFECTED BY MODEL SIMPLIFICATIONS
A. K. GHOSH and S. C. RAISINGHANI (Indian Inst. of Technology, Kanpur, India) *In* AIAA Atmospheric Flight Mechanics Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers Washington American Institute of Aeronautics and Astronautics 1993 p. 246-250. refs
(AIAA PAPER 93-3640) Copyright

A full order model of an aeroelastic aircraft has too many parameters to yield satisfactory estimates by using any of the known parameter estimation methods. In view of this, a preliminary study has been initiated in this paper to investigate how estimation model may be simplified to reduce the number of unknown parameters, and how are the resulting parameter estimates affected by such approximate models. Special attention has been paid to the extreme case of using rigid body model in the estimation algorithm, and an analytical method is proposed to predict approximations to parameter estimates expected from use of rigid body models. Simulated flight data for an example airplane are analyzed for varying degree of flexibility to show how the parameter estimates are affected by flexibility, and how a proposed function can be used as an indicator of adequacy or otherwise of using simple rigid body models in estimation algorithms.

A93-48326#
WIND TUNNEL INVESTIGATION OF WIND SHEAR EFFECT ON TURNING FLIGHT
MOHAMMAD A. GHAZI (King Abdulaziz Univ., Jeddah, Saudi Arabia) *In* AIAA Atmospheric Flight Mechanics Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers Washington American Institute of Aeronautics and Astronautics 1993 p. 251-257. refs
(AIAA PAPER 93-3641) Copyright

An experimental investigation on the effect of the wind shear hazard on the forces and moments of an aircraft model similar to the B-747. The tests were carried out in a low-speed wind tunnel using a six-components balance. Particular emphasis was given to the aircraft performance during turning flight. The investigation demonstrated large drop in the aircraft's lifting force as a result of wind shear, particularly at low angles of attack. The drag was also reduced, with slightly higher ratios for turning flight. The side force was reduced, too, during turning flight. The aircraft gained more stability in straight flight due to wind shear, whereas constant stability was maintained during turning flight. The banking aircraft experienced an overriding negative rolling moment, which increased as wind shear intensified.

A93-48327#
A WIND SHEAR HAZARD WINDOW USEFUL IN STUDYING THE EFFECT OF WIND SHEAR ON THE AIRPLANE DURING THE LANDING APPROACH
ROLAND J. WHITE *In* AIAA Atmospheric Flight Mechanics Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers Washington American Institute of Aeronautics and Astronautics 1993 p. 268-272. refs
(AIAA PAPER 93-3643) Copyright

This paper calculates the effect of the horizontal gust velocity produced by a vortex ring on the landing approach speed of an airplane. If the approach trim speed is reduced to the airplane stall speed before the exit side of the vortex ring is reached, then a hazard is considered to occur. On this basis, hazard boundaries are developed in terms of the vortex ring height, radius, and gust intensity. Reference to the hazard window is made because low gust velocity values occur before the hazard boundary is reached. After the hazard boundary is past, a hazard stall will occur until the second hazard boundary is reached. Another interesting result was that a minimum vortex ring radius was evaluated and is referred to as a critical radius. Based on this critical radius, wind shear hazard boundaries are calculated which could be useful in designing wind shear detection instrumentation.

A93-48328#
EFFECT OF ROTARY ATMOSPHERIC GUSTS ON FIGHTER AIRPLANE
MUHAMMAD A. GHAZI (King Abdulaziz Univ., Jeddah, Saudi Arabia) *In* AIAA Atmospheric Flight Mechanics Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers Washington American Institute of Aeronautics and Astronautics 1993 p. 273-281. refs
(AIAA PAPER 93-3644) Copyright

A computer code has been developed to investigate the effect of rotating atmospheric gusts during powered landing approach at sea level, 35,000 ft subsonic cruise, and 55,000 ft supersonic cruise. Aircraft experience 'Dutch roll' and spiral modes upon encountering rolling and yawing gust disturbances. During subsonic cruise, aircraft are subject to continuously increasing incidence angle and decreasing forward velocity when a pitching gust is encountered. Stability modes are noted to markedly improve during supersonic cruise. AIAA

A93-48329#
DEVELOPMENT OF FLYING QUALITIES AND AGILITY EVALUATION MANEUVERS
DAVID J. WILSON, DAVID R. RILEY, KEVIN D. CITURS (McDonnell Douglas Corp., Saint Louis, MO), and THOMAS J. CORD (USAF, Flight Dynamics Directorate, Wright-Patterson AFB, OH) *In* AIAA Atmospheric Flight Mechanics Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers Washington American Institute of Aeronautics and Astronautics 1993 p. 282-292. refs
(Contract F33615-90-C-3600)
(AIAA PAPER 93-3645) Copyright

A process for the development and documentation of aircraft evaluation maneuvers has been defined. The process proved to be efficient and effective in developing maneuvers for the evaluation of flying qualities and agility in operationally representative scenarios. To date, twenty evaluation maneuvers have been developed and tested in piloted simulation using this process. These maneuvers comprise the initial entries into the Standard Evaluation Maneuver Set. The Standard Evaluation Maneuver Set is intended to be a 'living' document, maintained at Wright Laboratory, that includes descriptions of a wide range of evaluation

maneuvers as well as guidelines to help apply them during design and flight test.

A93-48331#
AIRCRAFT CONTROL REQUIREMENTS AND ACHIEVABLE DYNAMICS PREDICTION
JOSEPH R. BOLAND, DAVID R. RILEY, and KEVIN D. CITURS (McDonnell Douglas Corp., Saint Louis, MO) *In* AIAA Atmospheric Flight Mechanics Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers Washington American Institute of Aeronautics and Astronautics 1993 p. 304-315. refs
(AIAA PAPER 93-3648) Copyright

A proprietary control requirements and achievable dynamics prediction program has been developed which accurately predicts aircraft control effecter power, deflection, and rate requirements and optimizes control effecter usage to maximize an aircraft's dynamic response. The prediction program enables aircraft configuration synthesizers to conduct rapid configuration trade studies, thereby reducing configuration development time and reducing costly redesign resulting from inadequate control sizing early in the design process. The program also enables early incorporation of flying qualities into the aircraft design process to reduce costly control law redesign by allowing control law designers to establish realistic design goals. The prediction/optimization program methodology is described and program capabilities are illustrated. Comparison of the prediction program results with six degree-of-freedom nonlinear simulation of a high angle of attack fighter aircraft with pitch and yaw thrust vectoring validates the prediction/optimization methodology.

A93-48332#
INVESTIGATION OF ROLL REQUIREMENTS FOR CARRIER APPROACH
KEVIN D. CITURS, JAMES E. BUCKLEY, and KENNETH A. DOLL (McDonnell Douglas Corp., Saint Louis, MO) *In* AIAA Atmospheric Flight Mechanics Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers Washington American Institute of Aeronautics and Astronautics 1993 p. 316-323. refs
(AIAA PAPER 93-3649) Copyright

A simulation study of fighter aircraft roll performance requirements in Powered Approach (PA) has been conducted. While the study was initiated to review roll requirements for carrier landing, the results are applicable to all fighter/attack aircraft. A relationship between gust rejection and roll performance was identified which indicates the possibility of reducing roll performance requirements for aircraft which exhibit good gust rejection characteristics.
Author (revised)

A93-48333*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
DEVELOPMENT OF LATERAL-DIRECTIONAL DEPARTURE CRITERIA
F. H. LUTZE, W. C. DURHAM, and W. H. MASON (Virginia Polytechnic Inst. and State Univ., Blacksburg) *In* AIAA Atmospheric Flight Mechanics Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers Washington American Institute of Aeronautics and Astronautics 1993 p. 324-331. refs
(Contract NCC1-158)
(AIAA PAPER 93-3650) Copyright

Current departure prediction indicators for both open and closed loop flight are developed using the same rigorous analytical approach applied to a linear version of the aircraft model. Emphasis on the assumptions made and terms omitted indicate why the results are somewhat limited. A second approach is presented which is shown to lead to the same results as the first, but is more applicable to the nonlinear problem. Some ideas concerning the application of the linear methods to the nonlinear problem are presented.

A93-48339#
OPTIMUM POSTSTALL TURNING AND SUPERSONIC TURNING
NGUYEN X. VINH and YIH-FENG TZENG (Michigan Univ., Ann Arbor) *In* AIAA Atmospheric Flight Mechanics Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers Washington American Institute of Aeronautics and Astronautics 1993 p. 368-378. Research supported by Aeronautical Industry Development Center of China refs
(AIAA PAPER 93-3659) Copyright

In this paper we consider the optimum maneuvers for the fastest turning and the turning with the smallest radius in nearly horizontal flight. It is shown that by retaining the thrust component along the direction of the lift force, the optimum angle-of-attack for the maneuvers is beyond the usual stall angle-of-attack where the lift coefficient reaches its maximum before decreasing drastically. For very high thrust-to-weight ratio, optimum turn is performed at low speed and at the maximum angle-of-attack allowed. For fastest turn subject to prescribed end-points Mach numbers, the optimum technique in bank and thrust-control depends on the limitation on the load factor, aerodynamic and propulsive capabilities. Explicit control laws for the bank angle and for the thrust are derived and numerical examples for optimum turning are presented.

A93-48342#
A SIMPLIFIED WING ROCK PREDICTION METHOD
BRAD S. LIEBST (USAF, Inst. of Technology, Wright-Patterson AFB, OH) and ROBERT C. NOLAN (USAF, Test Pilot School, Edwards AFB, OH) *In* AIAA Atmospheric Flight Mechanics Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers Washington American Institute of Aeronautics and Astronautics 1993 p. 406-418. refs
(AIAA PAPER 93-3662)

This study is a limited investigation of the nonlinear aircraft behavior known as wing rock. An eight state F-15 model is analyzed using bifurcation theory, and equilibrium and limit cycle solutions to the nonlinear equations of motion are computed. The wing rock onset point is identified, and small perturbation analysis is used to linearize the equations of motion about this point. The eigenstructure of the model is analyzed and used to identify the stability modes involved in this motion. A procedure is developed to predict wing rock onset and frequency, and the critical stability derivatives involved in this behavior are identified. The developed procedure is applied to existing F-4J data, and a flight test involving RF-4C and T-38A aircraft is flown. The results show that wing rock is an unstable Dutch roll motion; the wing rock prediction parameter developed is accurate to within 1 deg of angle-of-attack onset. The frequency prediction parameter gives a fair estimate of wing rock motion. Author (revised)

A93-48344#
AEROELASTIC EFFECTS ON THE B-2 MANEUVER RESPONSE
B. A. WINTHER, D. A. HAGEMEYER, R. T. BRITT, and W. P. RODDEN (Northrop Corp., Pico Rivera, CA) *In* AIAA Atmospheric Flight Mechanics Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers Washington American Institute of Aeronautics and Astronautics 1993 p. 433-441. refs
(AIAA PAPER 93-3664) Copyright

Differential sensor rotations relative to the mean inertia axes usually are neglected in simulations of the quasi-steady frequency response. For control configured flying-wing aircraft, however, this aeroelastic effect may be significant as demonstrated by analyses of the USAF-Northrop B-2 aircraft. A correction for the axes rotation has been provided by Rodden and Love who formulated the unaugmented vehicle equations in terms of motion variables measured in a structurally restrained system. The present paper, while retaining the original mean axes formulation, extends the Rodden-Love concept to the sensor output equations which are required for modeling of aeroservoelastic effects. By applying the modified equations, longitudinal maneuver analyses are performed and correlated with flight test data.

A93-48346#
A NEW FLYING QUALITIES CRITERION FOR FLYING WINGS
WULF MOENNICH (DLR, Inst. fuer Flugmechanik, Braunschweig, Germany) and LOTHAR DALLDORFF (FFA Flugzeugwerke Altenrhein AG, Switzerland) *In* AIAA Atmospheric Flight

Mechanics Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers Washington American Institute of Aeronautics and Astronautics 1993 p. 448-451. refs
(AIAA PAPER 93-3668) Copyright

The paper deals with the flying qualities problems of the flying wing sailplane SB-13 in a turbulent atmosphere. By comparison with a conventional sailplane both in time and frequency domain the reason for this behavior is found. A new flying qualities criterion for flying wings is proposed.

A93-48347#
PILOTS' CONTROL BEHAVIOR INCLUDING FEEDBACK STRUCTURES IDENTIFIED BY AN IMPROVED METHOD

NORIHIRO GOTO (Kyushu Univ., Fukuoka, Japan) *In* AIAA Atmospheric Flight Mechanics Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers Washington American Institute of Aeronautics and Astronautics 1993 p. 452-460. refs
(AIAA PAPER 93-3669) Copyright

In controlling the flight path of an aircraft, the pilot has a choice of feedback structures. An improved identification method is applied in this paper to the determination of the feedback structure employed by the pilot. The improved method utilizes the autoregressive scheme and conducts a singular value analysis of the transfer function matrix from the innovations to the outputs in addition to the previously developed correlation analysis of the innovations. As a credibility study, the method is first applied to the data from a digital simulation work of an altitude tracking task in turbulence to show that it can distinguish between two hypothesized feedback structures quite clearly. The data from a fixed-base flight simulation work with the human pilots engaged in the same task are then analyzed to find that the pilots in the simulation prefer a direct altitude feedback single loop to a multiple loop with a pitch attitude feedback inner loop. Reexamination of past flight test data is finally made to discuss the control feature of an experienced pilot, suggesting that a more careful design of the experimental situation is necessary to confirm the pilot's preference for the feedback structure.

A93-48348*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
WIND-SHEAR ENDURANCE CAPABILITY FOR POWERED-LIFT AIRCRAFT

TOSHIO BANDO, KEIJI TANAKA (National Aerospace Lab., Tokyo, Japan), CHARLES S. HYNES, and GORDON H. HARDY (NASA, Ames Research Center, Moffett Field, CA) *In* AIAA Atmospheric Flight Mechanics Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers Washington American Institute of Aeronautics and Astronautics 1993 p. 461-469. refs
(AIAA PAPER 93-3670) Copyright

The present treatment of safety margin considerations for powered-lift (upper wing surface blowing) STOL aircraft emphasizes wind shear endurance, in order to establish safety margin criteria for such aircraft that are equivalent to those of conventional transport aircraft. The simulation results obtained show that a 6.6 deg climb gradient at V(app) for STOL aircraft is required for equivalent shear endurance in approaching a long STOL airport runway, if the STOL aircraft is equipped with an elaborate control/display system and is permitted a change in configuration. AIAA

A93-48349#
F/A-18 DEPARTURE RECOVERY IMPROVEMENT EVALUATION

J. LACKEY, B. MCNAMARA, and M. STEVENS (U.S. Navy, Naval Air Warfare Center, Patuxent River, MD) *In* AIAA Atmospheric Flight Mechanics Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers Washington American Institute of Aeronautics and Astronautics 1993 p. 470-480. refs
(AIAA PAPER 93-3671)

This paper discusses the results of a departure recovery improvement evaluation for the F/A-18 aircraft. The flight manual procedure required the pilot to neutralize the control stick for departure recovery. High lateral forces, such as those normally encountered during characteristic F/A-18 departures, made it difficult for pilots to maintain neutral longitudinal and lateral control stick positions. Investigations of mishaps questioned the viability of releasing the control stick as a more effective way of maintaining neutral controls thereby reducing recovery times. A flight test program was performed to study the dynamics of control stick movement during departures and its effects on departure recovery. Test results indicated that quantitatively, use of the 'controls release' recovery method did not result in adverse departure response and was qualitatively favored by pilots for it's procedural simplicity and effectiveness in improving overall situational awareness during out-of-control flight. This paper addresses the flight test program from a conduct, result, and analysis perspective. Emphasis will be given on analysis of departure mechanisms for the test maneuvers and lateral stick movement during controls released recoveries. Recommendations on minimum airspeed for affecting departure recovery will also be discussed.

A93-48350#
AIRCRAFT WITH SINGLE AXIS AERODYNAMICALLY DEPLOYED WINGS

SHLOMO DJERASSI and SHMUEL KOTZEV (Rafael Armament Development Authority, Haifa, Israel) *In* AIAA Atmospheric Flight Mechanics Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers Washington American Institute of Aeronautics and Astronautics 1993 p. 481-487. refs
(AIAA PAPER 93-3673) Copyright

The present paper deals with aircraft having two single-axis, aerodynamically deployed wings. Two issues are discussed. The first relates to the formulation of equations governing the motion of the aircraft during and after the deployment, noting that imposition of constraints occurs when the deployment of each of the wings terminates. The second issue concerns choosing between two single axis configurations, called 'up deployment' configuration and 'low deployment' configuration, as better suited to carry out a successful deployment. It is shown that to obtain meaningful predictions of the dynamical behavior of the aircraft, one has to invoke the theory of imposition of constraints, excluding alternate theories as leading to time consuming, inaccurate simulations; and that 'low deployment' configuration is less susceptible to external winds during deployment, and therefore, superior to the 'up deployment' configuration.

A93-48351*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
DYNAMIC MODEL TESTING OF THE X-31 CONFIGURATION FOR HIGH-ANGLE-OF-ATTACK FLIGHT DYNAMICS RESEARCH

MARK A. CROOM, DAVID J. FRATELLO, RAYMOND D. WHIPPLE (NASA, Langley Research Center, Hampton, VA), MATTHEW J. O'ROURKE, and TODD W. TRILLING (Lockheed Engineering & Sciences Co., Hampton, VA) *In* AIAA Atmospheric Flight Mechanics Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers Washington American Institute of Aeronautics and Astronautics 1993 p. 488-506. refs
(AIAA PAPER 93-3674) Copyright

High-angle-of-attack flight dynamics of the X-31 configuration were studied using dynamic model test techniques. These tests identified phenomena including wing rock, spins, and departures that could dominate the high-alpha behavior of the configuration and restrict its usable flight envelope. Results of these tests have been used to design flight control concepts and configuration modifications to minimize adverse effects of these phenomena. The conclusion of the high-alpha envelope expansion flight tests of the X-31 aircraft will complete the database against which the dynamic model results can be correlated.

A93-48355#
FLOW PHYSICS OF CRITICAL STATES FOR ROLLING DELTA WINGS

LARS E. ERICSSON *In* AIAA Atmospheric Flight Mechanics Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers

Washington American Institute of Aeronautics and Astronautics 1993 p. 546-554. refs
(AIAA PAPER 93-3683) Copyright

A delta wing rolling at high flow inclination has two well documented critical states. One occurs when the breakdown of the leeside leading-edge vortex moves downstream of the trailing edge, and the other when the breakdown of the windward vortex reaches the apex. The flow physics of those critical states are described for a sharp-edged 65 deg delta wing rolling around an axis inclined 30 deg to the free stream. It is shown how the measured, extremely nonlinear, unsteady aerodynamics result from the roll-rate-induced camber in conjunction with flow time lag effects.

A93-48903
DETERMINATION OF THE AERODYNAMIC BALANCE EFFICIENCY OF AIRCRAFT [K VOPROSU OPREDELENIYA BALANSIROVOCHNOGO AEHRODINAMICHESKOGO KACHESTVA SAMOLETA]
A. I. MATVEEV *In* Problems in the aerodynamics of flight vehicles and their parts Moscow Moskovskij Aviatsionnyj Institut 1991 p. 11-18. In RUSSIAN refs
Copyright

The importance of considering the effect of deflections of the longitudinal balance control surfaces on the aerodynamic characteristics of aircraft at the preliminary design stage is emphasized. Particular attention is given to a method for determining the balance resistance of aircraft with deflected longitudinal balance control surfaces. Calculation results for aircraft models of three different aerodynamic configurations are found to be in satisfactory agreement with experimental data. AIAA

A93-49519*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
INVESTIGATION OF HIGH-ALPHA LATERAL-DIRECTIONAL CONTROL POWER REQUIREMENTS FOR HIGH-PERFORMANCE AIRCRAFT
JOHN V. FOSTER, HOLLY M. ROSS (NASA, Langley Research Center, Hampton, VA), and PATRICK A. ASHLEY (Virginia Polytechnic Inst. and State Univ., Blacksburg) Aug. 1993 12 p. AIAA, Atmospheric Flight Mechanics Conference, Monterey, CA, Aug. 9-11, 1993 refs
(AIAA PAPER 93-3647) Copyright

Designers of the next-generation fighter and attack airplanes are faced with the requirements of good high angle-of-attack maneuverability as well as efficient high speed cruise capability with low radar cross section (RCS) characteristics. As a result, they are challenged with the task of making critical design trades to achieve the desired levels of maneuverability and performance. This task has highlighted the need for comprehensive, flight-validated lateral-directional control power design guidelines for high angles of attack. A joint NASA/U.S. Navy study has been initiated to address this need and to investigate the complex flight dynamics characteristics and controls requirements for high angle-of-attack lateral-directional maneuvering. A multi-year research program is underway which includes groundbased piloted simulation and flight validation. This paper will give a status update of this program that will include a program overview, description of test methodology and preliminary results.

A93-49577
LONGITUDINAL DYNAMICS OF A TOWED SAILPLANE
GUIDO DE MATTEIS (Roma I, Univ., Rome, Italy) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090) vol. 16, no. 5 Sept.-Oct. 1993 p. 822-829. AIAA, Atmospheric Flight Mechanics Conference, New Orleans, LA, Aug. 12-14, 1991, AIAA Paper 91-2862. Previously cited in issue 21, p. 3602, Accession no. A91-49818 refs
Copyright

A93-49593
USE OF NEURAL NETWORKS IN CONTROL OF HIGH-ALPHA MANEUVERS
KAMRAN ROKHSAZ and JAMES E. STECK (Wichita State Univ., KS) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090) vol. 16, no. 5 Sept.-Oct. 1993 p. 934-939. AIAA, Aerospace Sciences Meeting and Exhibit, 30th, Reno, NV, Jan. 6-9, 1992, AIAA Paper 92-0048. Previously cited in issue 07, p. 1015, Accession no. A92-22164 refs
Copyright

A93-49594
APPLICATION OF STRUCTURED SINGULAR VALUE SYNTHESIS TO A FIGHTER AIRCRAFT
ANDREW SPARKS and SIVA S. BANDA (USAF, Wright Lab., Wright-Patterson AFB, OH) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090) vol. 16, no. 5 Sept.-Oct. 1993 p. 940-947. 1992 American Control Conference, 11th, Chicago, IL, June 24-26, 1992, Proceedings. Vol. 2, p. 1301-1305. Previously cited in issue 07, p. 1087, Accession no. A93-22865 refs

A93-49595
FULL ENVELOPE MULTIVARIABLE CONTROL LAW SYNTHESIS FOR A HIGH-PERFORMANCE TEST AIRCRAFT
RICHARD J. ADAMS, ANDREW SPARKS, and SIVA S. BANDA (USAF, Wright Lab., Wright-Patterson AFB, OH) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090) vol. 16, no. 5 Sept.-Oct. 1993 p. 948-955. AIAA Guidance, Navigation and Control Conference, Hilton Head Island, SC, Aug. 10-12, 1992, Technical Papers. Pt. 1, p. 506-516. Previously cited in issue 23, p. 4064, Accession no. A92-55202 refs

A93-49598
EXACT CLOSED-FORM SOLUTION OF GENERALIZED PROPORTIONAL NAVIGATION
PIN-JAR YUAN and SHIH-CHE HSU (Chung Shan Inst. of Science and Technology, Longtan, Taiwan) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090) vol. 16, no. 5 Sept.-Oct. 1993 p. 963-966. refs
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The exact and complete closed-form solutions of generalized proportional navigation with a maneuvering target are derived. The solutions are more general and comprehensive than those obtained before. Significant characteristics such as capture capability and energy cost are investigated and discussed in the context of the effect of bias of the commanded acceleration. A special case of target maneuver is introduced to describe the effect of target maneuver. Target maneuver decreases the capture area and increases the energy cost for effective intercept of the target. AIAA

A93-50961
PREDICTION AND PLANNING OF A FLIGHT VEHICLE ROUTE IN THE PRESENCE OF MOTION INHIBITING FACTORS [PROGNOZIROVANIE I PLANIROVANIE MARSHRUTA DVIZHENIYA LETATEL'NOGO APPARATA PRI NALICHII FAKTOROV PROTIVODEJSTVIYA DVIZHENIYU]
S. V. SHEBEKO *In* Intelligent systems of flight-vehicle control Moscow Moskovskij Aviatsionnyj Institut 1991 p. 59-64. In RUSSIAN
Copyright

The paper is concerned with the problem of determining possible routes for a flight vehicle moving toward a specified point in the case where the characteristics of the terrain adjacent to this point are known. It is assumed that the terrain contains objects that may have a detrimental effect on the flight vehicle and prevent the achievement of the target. The negative effect of these objects on the flight vehicle is probabilistic. The approach proposed here is based on the simulation of human reasoning during the prediction and planning of a flight vehicle route. AIAA

A93-51329#
A HOPFIELD NEURAL NETWORK FOR ADAPTIVE CONTROL
M. J. MEARS, R. SMITH, P. R. CHANDLER, and M. PACHTER (USAF, Wright Lab., Wright-Patterson AFB, OH) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug.

9-11, 1993, Technical Papers. Pt. 1 Washington American Institute of Aeronautics and Astronautics 1993 p. 276-284. refs
(AIAA PAPER 93-3729)

The optimal plant input to track a reference (command) signal is here synthesized by means of a recurrent Hopfield neural network-based optimization, in order to achieve the speeds entailed by on-line adaptive flight control. The requisite plant parameter estimates are furnished by a constrained, least-squares identification algorithm, thereby closing the adaptive control loop. An F-16 aircraft simulation is used to illustrate the 'neuromorphic' adaptive flight control concept proposed. AIAA

A93-51357*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ROBUST CONTROL OF HYPERSONIC VEHICLES CONSIDERING PROPULSIVE AND AEROELASTIC EFFECTS
HARALD BUSCHEK and ANTHONY J. CALISE (Georgia Inst. of Technology, Atlanta) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 1 Washington American Institute of Aeronautics and Astronautics 1993 p. 550-560. refs
(Contract NAG1-1451)
(AIAA PAPER 93-3762) Copyright

The influence of propulsion system variations and elastic fuselage behavior on the flight control system of an airbreathing hypersonic vehicle is investigated. Thrust vector magnitude and direction changes due to angle of attack variations affect the pitching moment. Low structural vibration frequencies may occur close to the rigid body modes influencing the angle of attack and lead to possible cross coupling. These effects are modeled as uncertainties in the context of a robust control study of a hypersonic vehicle model accelerating through Mach 8 using H-infinity and mu synthesis techniques. Various levels of uncertainty are introduced into the system. Both individual and simultaneous appearance of uncertainty are considered. The results indicate that the chosen design technique is suitable for this kind of problem provided that a fairly good knowledge of the effects mentioned above is available. The order of the designed controller is reduced but robust performance is lost which shows the need for fixed order design techniques.

A93-51358*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
DYNAMICS OF HYPERSONIC FLIGHT VEHICLES EXHIBITING SIGNIFICANT AEROELASTIC AND AEROPROPULSIVE INTERACTIONS
FRANK R. CHAVEZ and DAVID K. SCHMIDT (Arizona State Univ., Tempe) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 1 Washington American Institute of Aeronautics and Astronautics 1993 p. 561-568. refs
(Contract NAG1-1341)
(AIAA PAPER 93-3763) Copyright

With analytic expressions previously developed for the forces and moments acting on a generic hypersonic vehicle, it is of interest to investigate the relative importance of the aerodynamic and propulsive effects on the vehicle dynamics. It is shown that the vehicle's aerodynamics and propulsive forces are both very significant in the evaluation of key stability derivatives which dictate the vehicle's dynamic characteristics. It is also shown that the vehicle model selected is unstable in pitch and exhibits strong airframe/engine/elastic coupling. With the use of literal expressions for both the systems poles and zeros, as well as the stability derivatives, key vehicle dynamic characteristics are investigated. For small errors, or uncertainties, in either the aerodynamic or propulsive forces, significant errors in the frequency and damping of the dominant modes and zero locations will arise.

A93-51361*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
APPLICATION OF CONTROLLER PARTITIONING OPTIMIZATION PROCEDURE TO INTEGRATED FLIGHT/PROPULSION CONTROL DESIGN FOR A STOVL AIRCRAFT
SANJAY GARG (NASA, Lewis Research Center, Cleveland, OH) and PHILLIP H. SCHMIDT (Akron Univ., OH) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 2 Washington American Institute of Aeronautics and Astronautics 1993 p. 610-618. refs
(AIAA PAPER 93-3766) Copyright

A parameter optimization framework has earlier been developed to solve the problem of partitioning a centralized controller into a decentralized, hierarchical structure suitable for integrated flight/propulsion control implementation. This paper presents results from the application of the controller partitioning optimization procedure to IFPC design for a Short Take-Off and Vertical Landing (STOVL) aircraft in transition flight. The controller partitioning problem and the parameter optimization algorithm are briefly described. Insight is provided into choosing various 'user' selected parameters in the optimization cost function such that the resulting optimized subcontrollers will meet the characteristics of the centralized controller that are crucial to achieving the desired closed-loop performance and robustness, while maintaining the desired subcontroller structure constraints that are crucial for IFPC implementation. The optimization procedure is shown to improve upon the initial partitioned subcontrollers and lead to performance comparable to that achieved with the centralized controller. This application also provides insight into the issues that should be addressed at the centralized control design level in order to obtain implementable partitioned subcontrollers.

A93-51369#
ROBUST, NONLINEAR, HIGH ANGLE-OF-ATTACK CONTROL DESIGN FOR A SUPERMANEUVERABLE VEHICLE
JAMES M. BUFFINGTON, RICHARD J. ADAMS, and SIVA S. BANDA (USAF, Wright Lab., Wright-Patterson AFB, OH) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 2 Washington American Institute of Aeronautics and Astronautics 1993 p. 690-700. refs
(AIAA PAPER 93-3774)

High angle-of-attack flight control laws are developed for a supermaneuverable fighter aircraft. The methods of dynamic inversion and structured singular value synthesis are combined into an approach which addresses both the nonlinearity and robustness problems of flight at extreme operating conditions. The primary purpose of the dynamic inversion control elements is to linearize the vehicle response across the flight envelope. Structured singular value synthesis is used to design a dynamic controller which provides robust tracking to pilot commands. The resulting control system achieves desired flying qualities and guarantees a large margin of robustness to uncertainties for high angle-of-attack flight conditions. High fidelity nonlinear simulation results show that the combined dynamic inversion/structured singular value synthesis control law achieves a high level of performance in a realistic environment.

A93-51370*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
CANCELLATION CONTROL LAW FOR LATERAL-DIRECTIONAL DYNAMICS OF A SUPERMANEUVERABLE AIRCRAFT
ANTONY SNELL (California Univ., Davis) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 2 Washington American Institute of Aeronautics and Astronautics 1993 p. 701-709. Research supported by Univ. of California refs
(Contract NAG1-321)
(AIAA PAPER 93-3775) Copyright

Cancellation control laws are designed which reduce the high levels of lateral acceleration encountered during aggressive rolling

maneuvers executed at high angle of attack. Two independent problem are examined. One is to reduce lateral acceleration at the mass center, while the other focuses on lateral acceleration at the pilot's station, located 7.0 m forward of the mass center. Both of these problems are challenging and somewhat different in their limitations. In each case the design is based on a linearization of the lateral-directional dynamics about a high angle of attack condition. The controllers incorporate dynamic inversion inner loops to provide control of stability-axis roll- and yaw-rates and then employ cancellation filters in both feed-forward and feed-back signal paths. The relative simplicity of the control laws should allow nonlinear generalizations to be devised. Although it is shown that lateral acceleration can be reduced substantially by such control laws, this is at the cost of slowed roll response, poor dutch-roll damping or a combination of the two.

A93-51371*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
DESIGN OF A FLIGHT CONTROL SYSTEM FOR A HIGHLY MANEUVERABLE AIRCRAFT USING MU SYNTHESIS
JACOB REINER, GARY J. BALAS, and WILLIAM L. GARRARD (Minnesota Univ., Minneapolis) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 2 Washington American Institute of Aeronautics and Astronautics 1993 p. 710-719. refs
(Contract NAG1-1380)
(AIAA PAPER 93-3776) Copyright

This paper presents a methodology for the design of longitudinal controllers for high performance aircraft operating over large ranges of angle of attack. The technique used for controller design is structured singular value or mu synthesis. The controller is designed to minimize the weighted H-infinity norm of the error between the aircraft response and the desired handling quality specifications without saturating the control actuators. The mu synthesis procedure ensures that the stability and performance of the aircraft is robust to parameter variations and modeling uncertainties included in the design model. Nonlinear simulations demonstrate that the controller satisfies handling quality requirements and provides excellent tracking of pilot inputs over a wide range of transient angles of attack and Mach number. Author (revised)

A93-51372#
NONLINEAR COMMAND AUGMENTATION SYSTEM FOR A HIGH PERFORMANCE AIRCRAFT
R. K. A. MENON (Optimal Synthesis, Palo Alto, CA) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 2 Washington American Institute of Aeronautics and Astronautics 1993 p. 720-730. Research supported by U.S. Navy refs
(AIAA PAPER 93-3777) Copyright

Development of a high performance aircraft command, augmentation system using-the feedback linearization technique is described. The pilot inputs to the system are normal acceleration and roll rate. The command augmentation system stabilizes the airframe while providing the desired handling qualities. Additionally, it tracks the pilot commands, and provides automatic turn coordination. Details of control, law design and numerical results are given.

A93-51373#
QUASI-OPTIMAL STEADY STATE AND TRANSIENT MANEUVERS WITH AND WITHOUT THRUST VECTORING
M. E. DWYER and F. H. LUTZE (Virginia Polytechnic Inst. and State Univ., Blacksburg) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 2 Washington American Institute of Aeronautics and Astronautics 1993 p. 731-748. refs
(AIAA PAPER 93-3778) Copyright

Steady state and transient maneuver problems for a high performance fighter aircraft with and without thrust vectoring are investigated. The steady state aspect of these studies determines control combinations with and without thrust vectoring which optimize selected level-flight point performance criteria including minimum speed, maximum instantaneous range, and maximum sustained turn rate. The transient maneuvers are initiated from straight and level flight and include a longitudinal pitch-up to a desired fuselage pointing angle and a lateral-directional transition (wind-up) to a desired steady level turn rate. For the transient maneuvers a full six-degree-of-freedom model of the aircraft is used with three conventional aerodynamic controls, throttle control and pitch and yaw thrust vectoring control. Each of the control time histories are parameterized so as to include both the rate and range limits of the controls. A nonlinear programming algorithm is used to determine the control parameter values which yield the minimum time to execute the prescribed maneuvers.

A93-51374#
DESIGN OF A CONTROLLER FOR A HIGH PERFORMANCE FIGHTER AIRCRAFT USING ROBUST INVERSE DYNAMICS ESTIMATION (RIDE)
E. A. M. MUIR (Defence Research Agency, Bedford, United Kingdom) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 2 Washington American Institute of Aeronautics and Astronautics 1993 p. 749-759. Research sponsored by Ministry of Defence of United Kingdom refs
(AIAA PAPER 93-3779) Copyright

A controller was designed for a high-performance fighter aircraft using Robust Inverse Dynamics Estimation (RIDE) to investigate high angle of attack maneuvering. The RIDE controller is structured so as to estimate the reverse dynamics of the open loop plant. This inverse, the motivator demand required to cancel the aerodynamic moments acting on the aircraft, is termed the equivalent control. After the plant inversion, RIDE gives the designer freedom to assign the dynamics of the controlled states. A simple mechanism to handle motivator saturations and known as the Optimal and Safe Control Algorithm (OSCA) is explained. The effects of the four tuning parameters in RIDE are demonstrated in a simple example and results from linear and nonlinear simulations of a rate demand system are shown. In addition, a simple angle of attack controller is demonstrated showing the effect of OSCA. The results demonstrate that RIDE provides a simple method of designing control laws which give specified response characteristics across the flight envelope. RIDE provides a realizable method of implementing nonlinear dynamic inversion methods and promises to produce controllers robust to plant variations as the gain matrices are based only on the control effectiveness matrix which can be determined accurately. Author (revised)

A93-51400*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
INTEGRATED FLIGHT/PROPULSION CONTROL - SUBSYSTEM SPECIFICATIONS FOR PERFORMANCE
W. K. NEIGHBORS and STEPHEN M. ROCK (Stanford Univ., CA) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 2 Washington American Institute of Aeronautics and Astronautics 1993 p. 975-983. refs
(Contract NAG3-1177)
(AIAA PAPER 93-3808) Copyright

A procedure is presented for calculating multiple subsystem specifications given a number of performance requirements on the integrated system. This procedure applies to problems where the control design must be performed in a partitioned manner. It is based on a structured singular value analysis, and generates specifications as magnitude bounds on subsystem uncertainties. The performance requirements should be provided in the form of bounds on transfer functions of the integrated system. This form allows the expression of model following, command tracking, and disturbance rejection requirements. The procedure is demonstrated on a STOVL aircraft design.

A93-51405#
A PSEUDO-LOOP DESIGN STRATEGY FOR THE LONGITUDINAL CONTROL OF HYPERSONIC AIRCRAFT
PHUONG VU and DANIEL BIEZAD (California Polytechnic State

Univ., San Luis Obispo) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 2 Washington American Institute of Aeronautics and Astronautics 1993 p. 1021-1028. refs
(AIAA PAPER 93-3814) Copyright

A longitudinal control design called the G-command, alpha follow-up is described which significantly improves the lag between pitch angle and flight path angle responses associated with hypersonic flight. The design technique relies on classical, successive loop closures and introduces the concept of 'pseudo-loops' to design dynamic compensation between input variables. This dynamic compensation constrains and 'washes out' body flap input to avoid excessive flap deflection and associated heating while providing precise angle of attack control at the engine inlet. The final design was implemented on the Generic Hypersonic Aerodynamic Model Example model at NASA Dryden and evaluated by a NASA test pilot familiar with the SR-71. The pilot flew altitude change maneuvers using the implemented control law and verified the ability to track flight path with ease and precision. Finally, evidence is presented that supports a flying qualities metric for longitudinal, hypersonic flight based on the bandwidth of the flight path angle to stick frequency response.

A93-51406#
LONGITUDINAL AND LATERAL-DIRECTIONAL FLYING QUALITIES INVESTIGATION OF HIGH-ORDER CHARACTERISTICS FOR ADVANCED-TECHNOLOGY TRANSPORTS
KEN F. ROSSITTO and JOHN HODGKINSON (McDonnell Douglas Aerospace, Long Beach, CA) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 2 Washington American Institute of Aeronautics and Astronautics 1993 p. 1029-1039. refs
(AIAA PAPER 93-3815) Copyright

The paper describes the results of a series of piloted motion-base simulation tests studying high-order effects (i.e., lags, time delays, higher-order systems) in both the longitudinal and lateral degrees of freedom. Subjective measures of flying qualities were analyzed using a combination of statistical and graphical methods. The results are compared to other ground-based as well as in-flight results on transport aircraft. Finally, recommendations are made on allowable levels of time delay in the flight control system.

A93-51407#
INITIAL RESULTS OF AN IN-FLIGHT INVESTIGATION OF LONGITUDINAL FLYING QUALITIES FOR AUGMENTED, LARGE TRANSPORTS IN APPROACH AND LANDING
KEN F. ROSSITTO, JOHN HODGKINSON, TODD M. WILLIAMS (McDonnell Douglas Aerospace, Long Beach, CA), DAVE B. LEGGETT (USAF, Wright Lab., Wright-Patterson AFB, OH), RANDALL E. BAILEY, and ERIC E. OHMIT (Arvin/Calspan Advanced Technology Center, Buffalo, NY) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 2 Washington American Institute of Aeronautics and Astronautics 1993 p. 1040-1050. refs
(AIAA PAPER 93-3816) Copyright

Initial results of a piloted, in-flight simulator experiment using the USAF Total In-Flight Simulator (TIFS) are presented. Configurations with various levels of short period frequency acceleration sensitivity and equivalent time delay were flown and evaluated by a number of pilots. The pilot ratings were used to appraise the performance of the control anticipation parameter (CAP) criterion using the equivalent system methodology. The results indicated that for large transports the Category C Level 1 CAP lower boundary could be raised slightly, and that delays up to 250 msec do not noticeably degrade pilot opinion in simulated touchdowns.

A93-51408#
ACTIVE CONTROL FOR FIN BUFFET ALLEVIATION
STEPHEN M. ROCK, HOLT ASHLEY (Stanford Univ., CA), RAMARAO DIGUMARTHI, and KENNETH CHANEY (Rann, Inc., Palo Alto, CA) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 2 Washington American Institute of Aeronautics and Astronautics 1993 p. 1051-1056. Research supported by McDonnell Aircraft Co. refs
(Contract F33615-92-C-3605)
(AIAA PAPER 93-3817) Copyright

A technique is presented and demonstrated for using active control to reduce the fin buffet response of the F/A-18 vertical tail. A model in state-variable form suitable for control design is first developed from data generated by finite element structural analysis and linearized potential aerodynamic theory. This model is then used to design a control law that uses feedback signals from an accelerometer mounted on the fin to affect the motion of the rudder. The ability of this control law to reduce the spectrum of the root bending moment is demonstrated. Using only proportional feedback, and limiting the rms rudder usage to 2 deg, it is possible to reduce the rms bending moment associated with the first modal frequency by 34 percent. Author (revised)

A93-51433#
A NEW WAY OF POLE PLACEMENT IN LQR AND ITS APPLICATION TO FLIGHT CONTROL
YOSHIMASA OCHI and KIMIO KANAI (National Defense Academy, Yokosuka, Japan) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 3 Washington American Institute of Aeronautics and Astronautics 1993 p. 1295-1303. refs
(AIAA PAPER 93-3845) Copyright

This paper presents a new way of pole placement in the linear quadratic regulator. There are three features in the proposed method. First a weighting matrix which gives desired closed-loop pole locations is obtained by solving differential equations. They are derived from the characteristic equation of a Hamilton matrix. Secondly the method can place poles arbitrarily and exactly at desired positions, though positive-definiteness of the weighting matrix is not always guaranteed depending on the assigned closed-loop eigenvalues. Thirdly a weighting matrix obtained is a diagonal one. The third feature makes output regulation with desired pole locations possible. It is applied to stabilization of lateral-directional motions of the F-4.

A93-51434#
ADAPTIVE QUADRATIC STABILIZATION CONTROL WITH APPLICATION TO FLIGHT CONTROLLER DESIGN
HIROBUMI OHTA, KOJI YAMANAKA, MIWA MATSUOKA (Nagoya Univ., Japan), and P. N. NIKIFORUK (Saskatchewan Univ., Saskatoon, Canada) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 3 Washington American Institute of Aeronautics and Astronautics 1993 p. 1304-1313. refs
(Contract NSERC-A-5625; NSERC-A-1080)
(AIAA PAPER 93-3847) Copyright

A new design method for adaptive controllers that are robust to plant noise and uncertainties and have a good transient property is presented. An algorithm to evaluate and reduce the parameter region in which the transfer function of a real plant exists is proposed. An application to a flight controller design of the F-4C aircraft is presented to illustrate the method. AIAA

A93-51435#
OPTIMAL SYMMETRIC TRAJECTORIES OVER A FIXED-TIME DOMAIN
S. MANOLESCU (Inst. of Fluid Dynamics and Flight Dynamics, Bucharest, Romania) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 3 Washington American Institute of Aeronautics and Astronautics 1993 p. 1314-1322. refs
(AIAA PAPER 93-3848) Copyright

The problem of maximizing the absolute value of altitude change for a class of two-dimensional maneuvers of a vehicle in atmospheric flight is considered. Each maneuver is characterized by a fixed initial position and final path inclination. The final values

for velocity, altitude and downrange position are free. The aim is to determine the admissible guidance program which transfers the vehicle from initial state to final state in a given time, while maximizing the pay-off function and respecting practical physical constraints on the state and control variables. The lift coefficient bounds are considered to be state dependent values. To work out the problem a point-mass model dynamics (with lift coefficient and throttle setting as controls) and Pontryagin's maximum principle are used. In order to reach the optimal solutions a nonlinear TPBVP with eight unknown parameters is resolved by means of shooting techniques. A good enough initial estimation method for the unknown adjoint variable values is advanced, in order to assure the convergence of the shooting algorithm. Some computational results are presented for zoom, dive and half-loop maneuvers to prove the effectiveness of the proposed method. The essential features of the optimal trajectories are discussed.

A93-51436#
H(INFINITY) HELICOPTER FLIGHT CONTROL LAW DESIGN WITH AND WITHOUT ROTOR STATE FEEDBACK
MARC D. TAKAHASHI (U.S. Army, Aeroflightdynamics Directorate, Moffett Field, CA) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 3 Washington American Institute of Aeronautics and Astronautics 1993 p. 1323-1335. refs
(AIAA PAPER 93-3849)

An H(infinity) formulation to design pitch-roll flight control laws for hovering helicopters is presented. The feedback performance is set by the crossover frequency, which can be directly adjusted through the sensitivity weight function. The closed-loop stability is controlled by the complementary sensitivity weight function. The relative size of the dynamic gains is adjusted through the control weight function. A framework to use the H(infinity) compensation is presented which allows systematic compliance to the quantitative low speed requirements of a modern combat rotorcraft handling qualities specification (ADS-33C). Using this H(infinity) formulation, control law designs were developed to investigate the effect of using rotor-state feedback. Two laws were developed for an articulated rotor helicopter math model in low speed flight, a compensator using rigid body measurements and one using body plus rotor-state measurements. Both laws were designed with similar crossover frequency, stability margins, and pilot-to-stick response types. The design without rotor-state feedback may pass approximately twice as much noise to the actuators near the 1/rev frequency as the design with rotor state feedback. In addition, the design with the high bandwidth rate response type and without rotor-state feedback showed more high frequency oscillation in roll. Author (revised)

A93-51437#
DESIGN OF A HELICOPTER CONTROL SYSTEM TO MEET HANDLING QUALITY SPECIFICATIONS USING H(INFINITY) TECHNIQUES
ZOHREH MIRFAKHRAIE and WILLIAM L. GARRARD (Minnesota Univ., Minneapolis) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 3 Washington American Institute of Aeronautics and Astronautics 1993 p. 1336-1341. refs
(AIAA PAPER 93-3850)

This paper describes a method for design of a flight control system for a high performance helicopter which uses H(infinity) and mu techniques to provide inner loop control laws which decouple the roll, pitch, and yaw rates and vertical velocity and provide desired bandwidth in those channels. The design is an implicit model following approach in which the weighted H(infinity) norm between the actual system outputs and outputs of desired handling quality models is minimized. Stability robustness is investigated by using nonlinear simulations. The H(infinity) controller provides excellent performance when the control inputs are small and the system is essentially linear, however performance is degraded for large inputs. The mu controller provides improved response for large inputs. Author (revised)

A93-51438*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
BENEFITS OF VARIABLE ROTOR SPEED IN INTEGRATED HELICOPTER/ENGINE CONTROL
TAKANORI IWATA and STEPHEN M. ROCK (Stanford Univ., CA) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 3 Washington American Institute of Aeronautics and Astronautics 1993 p. 1342-1348. refs
(Contract NCA2-594)
(AIAA PAPER 93-3851)

Current helicopter flight and propulsion controls are typically designed with the assumption that rotor speed will be held to a constant setpoint. A new flight and propulsion control system using a continuously variable rotor speed command is proposed to improve the maneuverability and agility of helicopter systems. In this new approach, the flight control system generates an optimal variable rotor speed command in addition to conventional control commands in a framework of integrated flight/propulsion control. The benefits (i.e. improved maneuverability and agility) of varying rotor speed during transient maneuvers are demonstrated using a bob-up maneuver as an example. In particular, two types of benefits are identified in different maneuver conditions. One comes from a thrust augmentation, while the other comes from an exchange of rotational and translational energy. In the example, a simple linear dynamic hover model is used with an optimal control design method to generate the optimal rotor speed command.

A93-51439#
AUTOMATED CONTROL OF AIRCRAFT IN FORMATION FLIGHT
L. E. BUZOGANY, M. PACHTER, and J. J. D'AZZO (USAF, Inst. of Technology, Wright-Patterson AFB, OH) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 3 Washington American Institute of Aeronautics and Astronautics 1993 p. 1349-1370. refs
(AIAA PAPER 93-3852)

The problem of automated control of a Leader/Wingman formation flight is analyzed. Based on pole-assignment arguments, a Proportional plus Integral formation-hold autopilot is synthesized. Also, the requirement of vertical separation maintenance is relaxed, and an energy-conserving three-dimensional formation control system is proposed. The modelling and analysis performed clearly indicate the necessity of integral control in the formation flight control system. The analysis also reveals the impact of the formation geometry, aircraft parameters and controller parameters on formation flight control system stability and performance. Simulations of the nonlinear formation flight control systems are performed to compare the performance of the new, analytically derived, and an existing experimentally (by simulation) obtained formation-hold autopilot.

A93-51444#
DECENTRALIZED AUTONOMOUS ATTITUDE DETERMINATION USING AN INERTIALLY STABILIZED PAYLOAD
YAAKOV OSHMAN and MICHAEL ISAKOW (Technion - Israel Inst. of Technology, Haifa) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 3 Washington American Institute of Aeronautics and Astronautics 1993 p. 1412-1422. Research supported by Ministry of Defense and Tamam - Precision Instruments Industries refs
(AIAA PAPER 93-3857)

A novel method is introduced for the autonomous determination of the attitude angles of a mini remotely piloted vehicle (RPV) with an inertially stabilized payload. The method is based on measurements of rate gyros used to inertially stabilize the payload, and other data that is normally available from conventional aircraft-mounted sensors. These measurements are used to drive a decentralized estimation algorithm, which uses the aircraft/payload mathematical models to bound the estimation errors. Exploiting modern multi-processor computer technology, the

new estimation algorithm comprises two extended Kalman filters (EKFs) working in parallel and a data fusion algorithm. Real-time simulation tests, incorporating a payload model with real rate gyros mounted on a three-axis flight table, have validated the feasibility of the concept.

A93-51456#
FAULT DETECTION, ISOLATION, AND RECONFIGURATION FOR AIRCRAFT USING NEURAL NETWORKS
HERBERT E. RAUCH, ROBERT J. KLINE-SCHODER, J. C. ADAMS, and HUSSEIN M. YOUSSEF (Lockheed Palo Alto Research Lab., CA) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 3 Washington American Institute of Aeronautics and Astronautics 1993 p. 1527-1537. Research supported by Lockheed Aeronautical Systems Co refs
(AIAA PAPER 93-3870) Copyright

This paper illustrates the application of neural networks to fault detection, isolation, and reconfiguration (FDIR) for control surfaces of high performance aircraft. The neural network approach is demonstrated using a linear, six degree-of-freedom dynamic model of the F/A-18 aircraft. Fault detection and isolation continuously monitors system response and compares the measured system response to a model representing a healthy system and models representing systems with specific failure model. When a sequence of sensor readings corresponds to a fault condition, the calculated likelihood of that fault increases. The detection and isolation algorithms use the Probabilistic Neural Network (PNN) to determine when a fault occurs and to determine the specific fault. Control reconfiguration is based on stored control laws tailored to each anticipated fault condition. Alternatively, the reconfiguration scheme can use a pseudo-inverse approach to determine a new linear control law.

A93-51465#
APPROXIMATE DECOUPLING FLIGHT CONTROL SYSTEM DESIGN WITH OUTPUT FEEDBACK FOR NONLINEAR SYSTEMS
S. PARK and M. G. NAGATI (Wichita State Univ., KS) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 3 Washington American Institute of Aeronautics and Astronautics 1993 p. 1622-1632. refs
(AIAA PAPER 93-3880) Copyright

The problem of approximate decoupling of nonlinear systems by output feedback is considered. The structure of the controller is high gain proportional plus integral (PI). Linearization of the nonlinear closed-loop equations results in the standard singular perturbation form. Based on the singular perturbation concept, a control law is found which accomplishes approximate decoupling with stability for nonlinear systems. Application of the proposed design scheme to full aircraft model (i.e., 6 DOF nonlinear aircraft equations of motion) is presented.

A93-51466#
A NEW TECHNIQUE FOR NONLINEAR CONTROL OF AIRCRAFT
M. A. KHAN and PING LU (Iowa State Univ. of Science and Technology, Ames) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 3 Washington American Institute of Aeronautics and Astronautics 1993 p. 1633-1641. refs
(AIAA PAPER 93-3881) Copyright

A newly developed methodology for design of nonlinear feedback controllers is applied to aircraft control. Using a high-performance aircraft model, we evaluate the controller performance under a variety of strenuous conditions. The controller performance is further enhanced by including a time-varying controller parameter and incorporating derivative feedback. The robustness of the controller is demonstrated by achieving satisfactory performance in the presence of large system uncertainties and external disturbance. Some additional novel applications of this control technique are presented to illustrate its potential in aircraft control.

A93-51468#
GENETIC DESIGN OF DIGITAL MODEL-FOLLOWING FLIGHT-CONTROL SYSTEMS
B. PORTER and D. L. HICKS (Salford Univ., United Kingdom) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 3 Washington American Institute of Aeronautics and Astronautics 1993 p. 1648-1657. refs
(AIAA PAPER 93-3883) Copyright

The optimal parameter settings for the PID controllers incorporated in a class of digital model-following systems are complicated, unknown functions of the underlying sampling period. In order to simplify the design process, the use of genetic algorithms for the tuning of such PID controllers is accordingly investigated. This use of genetic algorithms is illustrated by the design of digital model-following flight-control systems for the F-16 aircraft in which minimal maximum multivariable model-following error is regarded as the ultimate design requirement.

A93-51906
INTERFERENCE BETWEEN A HIGH-LIFT SWEPTFORWARD WING AND THE HORIZONTAL NOSE PLANE AT SUBSONIC VELOCITIES [INTERFERENTSIYA KRYLA OBRATNOJ STRELOVIDNOSTI S MEKHANIZATSIEJ I PEREDNEGO GORIZONTAL'NOGO OPERENIYA PRI DOZVUKOVYKH SKOROSTYAKH]
YU. V. ANDREEV, A. L. KIR'YANOV, A. N. KOLOBKOV, and G. S. SADEKOVA *In* Problems in the aerodynamics of flight vehicles and their components Moscow, Russia Moskovskij Aviatsionnyj Institut 1992 p. 29-35. In RUSSIAN
Copyright

Experimental data are presented on the interference between a high-lift sweptforward wing and the horizontal nose plane in a canard-type configuration. The wind tunnel tests were carried out at a flow velocity of 37 m/s (Re = 0.5 x 10 exp 6) and angles of attack from -4 to 40 deg. The efficiency of the high-lift devices and of the horizontal nose plane is estimated. AIAA

A93-52249
THE APPLICATION OF SCHEDULED H-INFINITY CONTROLLERS TO A VSTOL AIRCRAFT
RICHARD A. HYDE and KEITH GLOVER (Cambridge Univ., United Kingdom) IEEE Transactions on Automatic Control (ISSN 0018-9286) vol. 38, no. 7 July 1993 p. 1021-1039. Research supported by SERC and Defence Research Agency of the United Kingdom refs
Copyright

This paper applies H(infinity)-designed controllers to a generic VSTOL aircraft model (GVAM) developed by the Royal Aerospace Establishment. The design study motivates the use of H-infinity techniques and addresses some of the implementation issues which arise for multivariable and H-infinity-designed controllers. Controllers designed by the H-infinity approach can cause more of a problem than classically-designed controllers when it comes to gain scheduling. An approach for gain scheduling H-infinity controllers from the normalized coprime factor robust stabilization problem formulation used for the H-infinity design is developed. It utilizes the observer structure of this particular robustness optimization. A weighting selection procedure has been developed for the associated loop-shaping technique used to specify performance. Multivariable controllers pose additional problems in the event of actuator saturations, and a desaturation scheme which accounts for this is applied to the GVAM. A comprehensive control law is developed and evaluated using the Royal Aerospace Establishment piloted simulation facility at Bedford.

Author (revised)

A93-52437
RESPONSE OF B-2 AIRCRAFT TO NONUNIFORM SPANWISE TURBULENCE

JOHN P. CRIMALDI, ROBERT T. BRITT, and WILLIAM P. RODDEN (Northrop Corp., Pico Rivera, CA) Journal of Aircraft (ISSN 0021-8669) vol. 30, no. 5 Sept.-Oct. 1993 p. 652-659. AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference, 32nd, Baltimore, MD, Apr. 8-10, 1991, Technical Papers. Pt. 3, p. 1728-1741. Previously cited in issue 12, p. 1920, Accession no. A91-32008 refs
Copyright

A93-52444
LATERAL AERODYNAMIC INTERFERENCE BETWEEN TANKER AND RECEIVER IN AIR-TO-AIR REFUELING
A. W. BLOY, M. G. WEST, K. A. LEA, and M. JOUMA'A (Manchester, Victoria Univ., United Kingdom) Journal of Aircraft (ISSN 0021-8669) vol. 30, no. 5 Sept.-Oct. 1993 p. 705-710. Research supported by Ministry of Defence of United Kingdom and SERC refs
Copyright

Wind-tunnel data have been obtained from a tapered tanker wing and receiver aircraft model at varying vertical separation. The data are presented in derivative form and compared with theory using a flat vortex sheet model of the tanker wing wake to determine the induced angle-of-attack variation on the receiver wing, fin, and tailplane due to the tanker wing. Aerodynamic loads on the receiver are obtained by the vortex lattice method, with an allowance made for the vertical displacement of the tanker wake in the estimation of the fin side force. In the experiments, the lateral aerodynamic interference between tanker and receiver was determined by banking the tanker wing and displacing it sideways, and by yawing the receiver aircraft model. Data were obtained from open and closed test sections in order to assess the significant boundary interference effect and corrections estimated from the image vortex system of the tanker and receiver wings in the test section. In general, the theory compares favorably with the experimental data. The most significant terms are the rolling moments due to sideways and bank displacements. Significant side forces are produced due to sidewash on the fin from the tanker and receiver wings and, when displaced in yaw, the receiver experienced a loss in directional stability.

A93-52452* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
COMPUTATION OF MAXIMIZED GUST LOADS FOR NONLINEAR AIRCRAFT USING MATCHED-FILTER-BASED SCHEMES
ROBERT C. SCOTT (NASA, Langley Research Center, Hampton, VA), ANTHONY S. POTOTZKY (Lockheed Engineering and Sciences Co., Hampton, VA), and BOYD PERRY, III (NASA, Langley Research Center, Hampton, VA) Journal of Aircraft (ISSN 0021-8669) vol. 30, no. 5 Sept.-Oct. 1993 p. 763-768. AIAA Atmospheric Flight Mechanics Conference, New Orleans, LA, Aug. 12-14, 1991, Technical Papers, p. 40-48. Previously cited in issue 20, p. 3413, Accession no. A91-47155 refs
Copyright

A93-52455
ENVELOPE FUNCTION - A TOOL FOR ANALYZING FLUTTER DATA
J. E. COOPER, P. R. EMMETT, J. R. WRIGHT (Manchester, Victoria Univ., United Kingdom), and M. J. SCHOFIELD (British Aerospace /Commercial Aircraft/, Ltd., Hatfield, United Kingdom) Journal of Aircraft (ISSN 0021-8669) vol. 30, no. 5 Sept.-Oct. 1993 p. 785-790. Research supported by British Aerospace (Commercial Aircraft), Ltd refs
Copyright

In this article a new tool for flutter clearance is presented and a preliminary assessment of its capabilities undertaken. It is intended to be complementary to other approaches. The method is based on quantifying the change in the shape of the decay envelope associated with control pulse responses or impulse response functions. An indication of overall stability is obtained without curve fitting by way of a shape parameter which quickly shows whether there has been any significant change since the last test point. In addition, the envelope functions can be overlayed from different speeds. The method is illustrated with data from a simulated aeroelastic model of a multiengined transport aircraft. and the effects of turbulence are considered. Finally, the method is successfully applied to real flight test data.

A93-52458
ALTERNATIVE SOLUTION TO OPTIMUM GLIDING VELOCITY IN A STEADY HEAD WIND OR TAIL WIND
PHILIP D. BRIDGES (Mississippi State Univ., Mississippi State) Journal of Aircraft (ISSN 0021-8669) vol. 30, no. 5 Sept.-Oct. 1993 p. 795-797. refs
Copyright

The present solution to the problem of graphically ascertaining the velocity for maximum gliding distance of an aircraft assumes a parabolic drag polar for the glider, while making small angle approximations to the glide angle. The optimum glide velocity is then solved as an infinite power series involving only the windspeed and zero-wind optimum glide velocity, thereby obviating the determination of the coefficients in the previous equation. Headwind and tailwind cases are addressed; it is shown that a headwind will always require a greater velocity correction than a tail wind.
AIAA

09

RESEARCH AND SUPPORT FACILITIES (AIR)

Includes airports, hangars and runways; aircraft repair and overhaul facilities; wind tunnels; shock tube facilities; and engine test blocks.

A93-48041
ON THE COMPRESSION PROCESS IN A FREE-PISTON SHOCK-TUNNEL
L. LABRACHERIE, M. P. DUMITRESCU, Y. BURTSCHELL, and L. HOUAS (Aix-Marseille I, Univ., Marseille, France) Shock Waves (ISSN 0938-1287) vol. 3, no. 1 1993 p. 19-23. refs
Copyright

Preliminary results in the Marseille free-piston shock-tunnel facility are presented. The compression of the driver gas by the piston is studied experimentally for two different geometries of the end of the compression tube. Peak pressures obtained with the end of the compression tube closed, and with bursting of the diaphragm separating the high pressure from the low pressure chamber, are compared with calculated values in the cases of N2 and He as driver gases. A phenomenon of acoustic resonance has been uncovered, generating strong pressure oscillations which, if not properly dealt with, could impair the quality of the useful flow in such a facility.

A93-49277
USE OF FULL FLIGHT SIMULATOR TECHNOLOGY ENHANCES CLASSROOM TRAINING SESSIONS
ANTHONY DEL MAR (CAE Electronics, Ltd., Montreal, Canada) ICAO Journal (ISSN 0018-8778) vol. 48, no. 4 May 1993 p. 10, 11.
Copyright

A set of training tools based on the new generation of powerful, low-cost computers developed by CAE Electronics is described. These tools allow training organizations to bring the fidelity of full scope simulators into the classroom in both instructor-led and self-paced simulator-based training. Thus, simulator-based training organizations can meet the ever increasing stringent training requirements.
AIAA

A93-49301
SIMULATION OF HYPERSONIC FLIGHT - A CONCERTED EUROPEAN EFFORT
D. VENNEMANN (Hermes Programme Directorate, Toulouse,

France), G. EITELBERG (DLR, Goettingen, Germany), and G. FRANCOIS (ONERA, Chatillon, France) ESA Bulletin (ISSN 0376-4265) no. 74 May 1993 p. 62-69.
Copyright

The aerothermodynamic design of vehicles that will enter or reenter a planetary atmosphere relies largely on information gathered in ground-based simulation facilities. Owing to the different natures of the flow phenomena that occur along the flight path, different wind tunnels dedicated to particular phases of the flight are usually used. Ground simulation of the so-called 'hot' or hypersonic phase is particularly difficult because of the high powers required to generate the wind-tunnel flow.

A93-49617* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
HIGH-PRESSURE HYPERVELOCITY ELECTROTHERMAL WIND-TUNNEL PERFORMANCE STUDY AND SUBSCALE TESTS
OUSSAMA F. RIZKALLA, WALLACE CHINITZ (General Applied Science Labs., Ronkonkoma, NY), F. D. WITHERSPOON (GT-Devices, Inc., Alexandria, VA), and RODNEY L. BURTON (Illinois Univ., Urbana) Journal of Propulsion and Power (ISSN 0748-4658) vol. 9, no. 5 Sept.-Oct. 1993 p. 731-738. AIAA, Aerospace Sciences Meeting and Exhibit, 30th, Reno, NV, Jan. 6-9, 1992, AIAA Paper 92-0329. Previously cited in issue 09, p. 1362, Accession no. A92-25776 refs
(Contract NAS1-18450)
Copyright

A93-49726#
REAL-TIME SIMULATION OF MANEUVERABLE AIRCRAFT FLIGHT CONDITIONS ON ALTITUDE TEST CELL
D. A. OGORODNIKOV (Central Inst. of Aviation Motors, Moscow, Russia) Jun. 1993 10 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-1845) Copyright

One of the most significant factors limiting the engine stable operation range and hence the aircraft combat envelope is the nonuniformity of the gas turbine engine (GTE) inlet flowfield. This paper examines physical phenomena causing total pressure nonuniformity under various flight conditions at the GTE inlet and describes a method for real-time simulation of maneuverable aircraft flight conditions on a CIAM altitude test cell fitted with nonuniformity generators. Results are presented of the simulation and the full-scale engine tests for different types of generators. AIAA

A93-49854#
HARNESSING NITROUS OXIDE FOR ELEVATION OF TEMPERATURE AND PRESSURE IN PISTON FACILITIES
N. A. ANFIMOV, V. V. KISLYKH, and K. V. KRAPIVNOJ (Central Research Inst. of Machine Building, Kaliningrad, Russia) Jun. 1993 7 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2016) Copyright

An account is given of facilities for gasdynamic and aerothermodynamic testing of hypersonic flight vehicle models. Multicascade piston-gasdynamic units (PGUs) are used which avoid excessively high stagnation temperatures. Attention is given to a novel approach which allows the modernization of PGU technology through incorporation of a nitrogen/nitrogen oxide mixture for simulation of atmospheric air composition during gasdynamic tests. AIAA

A93-49859#
REAL GAS SIMULATION OF AIR BLOW-DOWN FACILITIES
KLAUS GEHLISCH (da Vinci Consulting, Munich, Germany) Jun. 1993 6 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2022) Copyright

Methods for testing ramjets include ground testing in connected pipe systems. In these tests, air at conditions corresponding to those leaving the intake diffuser is fed directly into the combustor. To accomplish this, air is stored in high pressure tanks at ambient temperatures and directed through a dedicated pipe- and valve system to the test stand, the Blow Down Facility. Pressure decay in the vessel during testing cannot any more be described using perfect gas law equations, because this could lead to significant errors. A method for dealing with real gas effects is presented. Results of computations using perfect gas law and real gas equations are presented.

A93-49986#
GROUND TEST SIMULATION FIDELITY OF TURBINE ENGINE AIRSTARTS
GRANT T. PATTERSON and M. A. CROSS (Sverdrup Technology, Inc., Arnold AFB, TN) Jun. 1993 11 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993
(AIAA PAPER 93-2173)

Data from spooldown airstart tests obtained in an altitude simulation test facility are compared with flight test results to determine the causes of differences in test results, and to propose improvements in ground test altitude simulation capabilities and ground/flight test procedures to eliminate those factors that influence differences in ground/flight airstart test results. Factors evaluated for their influence on test results were differences in test procedures, engine inlet conditions, power extraction, fan and compressor spooldown speed profiles, component performance and stability characteristics, fuel flow and geometry scheduling, and ground test-to-flight test engine variation. Airstarts were evaluated in two different control modes. Some special data processing was required due to the limited in-flight instrumentation and recording capabilities. Differences in test procedures for initiating the speed spooldown and differences in power extraction were determined to be the primary cause of discrepancies in ground/flight test results.

A93-49988*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
DEVELOPMENT AND USE OF HYDROGEN-AIR TORCHES IN AN ALTITUDE FACILITY
ROY A. LOTTIG (NASA, Lewis Research Center, Cleveland, OH) and GARY T. HUBER (Sverdrup Technology, Inc., Brook Park, OH) Jun. 1993 14 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Previously announced in STAR as N93-26214 refs
(AIAA PAPER 93-2176) Copyright

A hydrogen-air ignition torch concept that had been used successfully in two rocket engine test facilities to consume excess hydrogen in their exhausters at atmospheric conditions was experimentally evaluated and developed in an altitude test facility at NASA Lewis Research Center. The idea was to use several of these torches in conjunction with hydrogen detectors and dilution air to prevent excess accumulation of unburned hydrogen or mixtures of hydrogen and air exceeding the sea-level lower flammability limit in the altitude facility exhaust system during hydrogen-fueled propulsion system tests. The torches were evaluated for a range of fuel-to-air ratios from 0.09 to 0.39 and for a range of exit diameters from 19/64 to 49/64 in. From the results of these tests a torch geometry and a fuel-to-air ratio were selected that produced a reasonably sized torch exhaust flame for consumption of unburned hydrogen at altitude pressures from sea level to 4 psia.

A93-49990#
IMPROVED DATA VALIDATION AND QUALITY ASSURANCE IN TURBINE ENGINE TEST FACILITIES
DONALD J. MALLOY (Sverdrup Technology, Inc., Arnold AFB, TN) Jun. 1993 14 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2178)

In the past several years significant advances have been made

in altitude ground test facilities with respect to data validation and quality assurance. To a large measure, the advances have been the result of comprehensive data validation and quality assurance programs to improve data quality and reduce data transmittal time. This paper introduces a data validation and quality assurance methodology used in the Engine Test Facility, Arnold Engineering Development Center, to the aircraft turbine engine industry. Data quality relationships are defined from an engineering perspective and management goals, and customer objectives are established. To introduce the methodology, the reader is guided through the data validation methodology for turbine engine performance resolution. The paper concludes with a discussion of how the data validation and quality assurance methodology is implemented to improve data quality. Author (revised)

A93-49991#
SUBSCALE VALIDATION OF A FREEJET INLET-ENGINE TEST CAPABILITY
D. K. BEALE, P. G. KELLY (Sverdrup Technology, Inc., Arnold AFB, TN), and J. E. P. LACASSE (Canadian Force, Arnold AFB, TN) Jun. 1993 19 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2179)

A subscale experimental program was conducted at the Arnold Engineering Development Center to develop and validate a freejet method for evaluating inlet-engine compatibility. The validation was based on comparisons between subsonic freejet and wind tunnel test results obtained using a model of the F-15 inlet configuration. The comparisons included the flow characteristics at a reference plane in front of the inlet and total pressure distortion at an aerodynamic interface plane near the engine face station. The inlet reference plane served as the control point for the simulation. Freejet parameters were set to establish wind tunnel profiles at the inlet reference plane prior to measuring inlet distortion. The aerodynamic interface plane steady-state and time-variant distortion comparisons formed the basis for the validation. The comparisons of inlet distortion measurements were evaluated using measures of merit in an acceptance process. Results of the distortion comparisons yielded the following conclusions: (1) Free-stream inlet characteristics can be simulated using the freejet method, (2) forebody simulators can be used to simulate the presence of the complete forebody, and (3) the inlet reference plane can be used to set freejet parameters for the simulation.

A93-49992#
C-2 SUBSONIC FREEJET DEVELOPMENT AND DEMONSTRATION
P. V. MAYWALD (Sverdrup Technology, Inc., Arnold AFB, TN) Jun. 1993 16 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2180)

A subsonic freejet test capability in the C-2 test cell of the Aeropropulsion Systems Test Facility (ASTF) was demonstrated in the Arnold Engineering Development Center. The freejet provides ground determination of full-scale aircraft inlet and turbine engine compatibility in a simulated subsonic flight environment. The freejet demonstration test was aimed at determining ASTF plant capability to provide the required freejet airflow, freejet nozzle positioning, C-2 test cell and equipment response to the freejet thermal and pressure loadings, freejet simulation control effectiveness, and freejet nozzle flow quality. About 500 parameters were recorded to evaluate system performance and to monitor system operation. AIAA

A93-50200#
UNIQUE DEVELOPMENT TESTING AT ALLISON GAS TURBINE
L. F. NIGHTINGALE (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN) Jun. 1993 8 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993
(AIAA PAPER 93-2450) Copyright

This paper will include a study of unique development testing in Allison Gas Turbine's history. The text will include a narrative of AGT test facilities, and a detail description of several unique development tests and facilities - TF41 Gyroscopic Moment Test, T56-C2/E2 Dynamic Load Test, T406 Attitude Testing, ETEC (Expendable Turbine Engine Concept) Testing, and GMA 2100 Power Turbine Blade Containment. In addition, the presentation will include video tape footage of the above testing.

A93-50213#
AN UPGRADED DATA ACQUISITION AND PROCESSING SYSTEM FOR THE AEROPROPULSION SYSTEMS TEST FACILITY AT ARNOLD ENGINEERING DEVELOPMENT CENTER
W. K. MORTON and P. E. MCCARTY (Sverdrup Technology, Inc., AEDC Group, Arnold AFB, TN) Jun. 1993 12 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2466)

The upgraded capabilities and performance of the data system for the Aeropropulsion Systems Test Facility (ASTF) at the Arnold Engineering Development Center (AEDC) are presented. The system provides conditioning, recording, processing, and display of data for two simulated altitude test cells used for testing of military and commercial aircraft turbine engine propulsion systems. Data are acquired and processed for online, near-real-time analysis and archived for future offline analysis. Modifications incorporated since initial operations have greatly improved the system's reliability, performance, and overall test support capability. Descriptions of the system's hardware/software architecture, communication networks, and operating modes are included.

A93-50214#
A NEW AND WORKING AUTOMATIC CALIBRATION MACHINE FOR WIND TUNNEL INTERNAL FORCE BALANCES
L. POLANSKY (Carl Schenck AG, Darmstadt, Germany) and JOHN T. KUTNEY, SR. Jun. 1993 15 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Research supported by European Transonic Windtunnel GmbH refs
(AIAA PAPER 93-2467) Copyright

The paper describes a new automatic calibration machine for internal wind tunnel force balances, designed for the ETW cryogenic wind tunnel. Particular attention is given to the design philosophy and details, the installation and check-out specifications, and the results of testing. The tests demonstrated that the automatic calibration machine fully meets the ETW requirements. The machine makes it possible to calibrate an internal force balance on one temperature level in one working shift fully automatically, with about 900 data points being produced in this time. For the ETW, this means five working days or 40 hrs for a full calibration over the range of five temperature levels, compared with about 500 hrs needed for the same calibration with a conventional calibration ring. AIAA

A93-50216#
CALIBRATION OF A TRANSONIC 5-HOLE PROBE FOR A MULTI-ELEMENT AIRFOIL CASCADE FACILITY
M. J. FLANAGAN, JR. (Dayton Univ., OH) and D. W. HILTNER (Ohio State Univ., Columbus) Jun. 1993 8 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993
(AIAA PAPER 93-2471) Copyright

This paper presents an overview of the fabrication and calibration of a five-hole pressure probe. The probe is currently being used to measure flow angularity and flowfield Mach number in the vicinity of multiple airfoil elements in a transonic cascade facility. The probe design was the result of trade-offs between probe size, data resolution, and flowfield interference across the range of Mach numbers from 0.5 to 1.10. The probe design was calibrated at angles-of-attack from -15 to 15, yaw angles from

-150 to 15 deg, and at Mach numbers of 0.5, 0.6, 0.7, 0.8, 0.9, 0.98, and 1.08. The pitch data were acquired at 1 deg increments. The yaw data were acquired at 5 deg intervals. The numerical scheme for the data reduction is the heart of this effort and requires substantial computational power for real-time data acquisition and reduction. The calibration data exhibit trends suggesting that the probe response is highly dependent on both Mach number and yaw angle. These dependencies complicate the data reduction tasks for postcalibration use. This paper describes the probe design, the calibration and data reduction techniques, and the general data trends. Author (revised)

A93-50266#
RECENT SUCCESSES IN MODIFYING SEVERAL EXISTING JET ENGINE TEST CELLS TO ACCOMMODATE LARGE, HIGH-BYPASS TURBOFAN ENGINES
R. J. FREULER (Ohio State Univ., Columbus) Jun. 1993 15 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2542) Copyright

Several research studies on test cell aerodynamics, acoustics, and cell flow characteristics which affect engine performance have been conducted with scale model test cells using ejector-powered engine simulators. The results of the scale model studies were used to determine recommended modifications to existing airline owned and operated test cell facilities which would improve the engine test environment and permit stable, reliable, and repeatable testing capability for the GE CF6-80C2 engine. In all cases, the full-scale test cells after modification met or exceeded the aerodynamic performance goals necessary to achieve the required stable and repeatable engine testing environment. Because of the careful attention to modeling of the test cell and the engine simulator, the favorable comparison with full scale cell performance characteristics was not unexpected. These scale model investigations of engine test cell aerodynamics have helped the evolutionary process of engine test cell aerodynamic design and have provided the basis for improved engine test facilities now in use world-wide.

A93-50269#
THE DEVELOPMENT OF A LARGE ANNULAR FACILITY FOR TESTING GAS TURBINE COMBUSTOR DIFFUSER SYSTEMS
A. P. WRAY, J. F. CARROTTE (Loughborough Univ. of Technology, United Kingdom), and C. W. WILSON (Rolls-Royce, PLC, Bristol, United Kingdom) Jun. 1993 11 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Research supported by Ministry of Defence and Ministry of Trade and Industry of United Kingdom and Rolls-Royce, PLC refs
(AIAA PAPER 93-2546) Copyright

This paper describes the design, operation and instrumentation of a large, fully annular test facility which enables the detailed aerodynamic performance of combustor diffuser systems to be evaluated at representative operating conditions. The facility has been designed so that different geometries of compressor outlet guide vane, pre-diffuser and flametube can be accommodated within the test section. Realistic inlet conditions are generated using a single stage axial flow compressor and, by changing the inlet guide vanes and rotor flow coefficient, it is possible to operate over a whole range of outlet guide vane incidence values. Relatively low running costs enable large amounts of test data to be collected using automated data acquisition methods in conjunction with five hole pressure probes, a three component laser Doppler anemometry system and triple hot wire probes. Such detailed information means that, in addition to calculating overall system performance, it is also possible to determine the flow mechanisms and loss generating features within each region.

A93-51188
SOME KEY PROBLEMS IN THE DESIGN OF THE NPU OPEN-CIRCUIT LOW-TURBULENCE WIND TUNNEL
XING TU, KEMIN HE, and CUNRU BAI (Northwestern Polytechnical Univ., Xian, China) Northwestern Polytechnical University, Journal (ISSN 1000-2758) vol. 11, no. 3 July 1993 p. 254-258. In CHINESE refs

Some key problems in the design of the NPU (Northwestern Polytechnical University) open-circuit low-turbulence wind tunnel are described in this paper. The minimum turbulence level of this wind tunnel is less than 0.02 percent in the center region of the test section for the speed range V = 15-50 m/s. In addition to the well known measures used in low-turbulence wind tunnel design such as large contraction ratio and multiscreens, the authors pay special attention to the reduction of the effect of noise in the tunnel design. These key measures used in the NUP low-turbulence wind tunnel design arc: low noise fan design, flow diversion annular channel used at the outside of the fan, and a noise reduction section added forward of the fan section to prevent the upstream propagation of the fan noise. Thus, the turbulence level of the NPU low-turbulence wind tunnel is lower than the best level of *open-circuit low-turbulence wind tunnels in the world* that the authors know of and is almost the same as the best level of the closed circuit low-turbulence wind tunnels in the world.
Author (revised)

A93-51295* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
A MAGNETIC SUSPENSION SYSTEM WITH A LARGE ANGULAR RANGE
COLIN P. BRITCHER and MEHRAN GHOFRANI (Old Dominion Univ., Norfolk, VA) Review of Scientific Instruments (ISSN 0034-6748) vol. 64, no. 7 July 1993 p. 1910-1917. refs
(Contract NAG1-1056)
Copyright

The paper describes a small-scale laboratory system, called the Large-Angle Magnetic Suspension Test Fixture (LAMSTF), constructed at NASA Langley Research Center in order to explore and develop technology required for the magnetic suspension of objects over large ranges of orientation. The LAMSTF hardware comprises five electromagnets in a circular arrangement, each driven from a separate bipolar power amplifier. The suspended element is a cylindrical axially magnetized permanent magnet core, within an aluminum tube. The element, which is 'levitated' by repulsive forces, is stabilized in five degrees-of-freedom, with rotation about the cylinder axis not controlled. The controller accommodates the changes in magnetic coupling between the electromagnets and the suspended element by real-time adaptation of a decoupling matrix. The paper presents performance measurements demonstrating that the major design objective of the 360 deg rotation was accomplished. AIAA

A93-51393#
DYNAMIC ATTITUDE MEASUREMENT SYSTEM
LEONARD S. WILK and TODD A. HAMILTON (Charles Stark Draper Lab., Inc., Cambridge, MA) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 2 Washington American Institute of Aeronautics and Astronautics 1993 p. 915-923. refs
(AIAA PAPER 93-3801) Copyright

This paper describes a method for transferring the angular orientation matrix from one system or station to another, and the application of this method to a particular case. Specifically, this method has been applied to transfer the angular orientation matrix (attitude reference) near the guidance system of a missile (mounted in a canister on a Transporter-Erector-Launcher (TEL)) to an inertial/directional reference on the base of the TEL. The mechanization to do this to an accuracy of 0.1 milliradian is described in some detail. The method, and device itself, is called AXIS, which is an acronym for 'Alignment Transfer by Integrated Strain'. The sensing involves measuring the integrated strain (the total change in length) of line elements on the surface of a long thin rod. The rod is connected to the stations between which the angular orientation is being transferred. The device can have several implementations, two of which are described. One implementation is photonic; it's primary attribute being very high

sensitivity. The other is resistive wire; it's primary attribute being relatively inexpensive. The device and the development effort are described in this paper.

A93-51440#
A TEST BENCH FOR ROTORCRAFT HOVER CONTROL
MARTIN F. WEILENMANN and HANS P. GEERING (Swiss Federal Inst. of Technology, Zurich, Switzerland) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 3 Washington American Institute of Aeronautics and Astronautics 1993 p. 1371-1382. refs
(AIAA PAPER 93-3853) Copyright

This paper describes an indoor stand for a computer-controlled RC helicopter. This stand was built for practical tests of modern multivariable controller algorithms. A common RC helicopter is mounted on a mechanical structure allowing six-DOF flight conditions in a 2 m cube. The symmetrical geometry of that frame reduces its physical influence on the rotorcraft to be equivalent to a concentrated mass near the center of gravity. Respecting the dynamics of the driving motor and some unstationary aspects of the aerodynamics, an unstable 18th-order mathematical model results. In addition the radio controller causes a remarkable time delay. For this system, several control algorithms have been applied. Author (revised)

A93-51754
AN EXPERIMENTAL SYSTEM FOR STUDYING THE VIBRATIONS AND ACOUSTIC EMISSION OF CYLINDRICAL SHELLS AND PANELS IN A FIELD OF TURBULENT PRESSURE PULSATIONS [EKSPERIMENTAL'NAYA USTANOVKA DLYA ISSLEDOVANIYA KOLEBANIJ I AKUSTICHESKOGO IZLUCHENIYA TSILINDRICHESKIKH OBOLOCHEK I PANELEJ V POLE TURBULENTNYKH PUL'SATSIJ DAVLENIYA]
A. A. ANDREEV, B. M. EFIMTSOV, V. A. PANKOV, S. YU. SIDOROV, and M. K. SURZHIN TsAGI, Trudy no. 2355 1988 p. 28-33. In RUSSIAN refs
Copyright

Experimental equipment designed for the study of the vibrations and acoustic emission of cylindrical shells and panels excited by pseudoacoustic pressure pulsations in an axisymmetric channel is described. The equipment, which is relatively simple and inexpensive, can be used for validating computational relations for determining the noise in the cabin of aircraft generated by turbulent pulsations at its surface and inside the ducts of the air conditioning system. The discussion covers the general design, the principle of operation, and the main components of the system. AIAA

A93-51762
AN AEROACOUSTIC STAND FOR EVALUATING THE EFFICIENCY OF SOUND-ABSORBING STRUCTURES UNDER CONDITIONS OF ACOUSTIC WAVE PROPAGATION IN A MOVING MEDIUM [AEHROAKUSTICHESKIJ STEND DLYA ISSLEDOVANIYA EHFFEKTIVNOSTI ZVUKOPOGLOSHCHAYUSHCHIKH KONSTRUKTSIJ PRI USLOVII RASPROSTRANENIYA ZVUKOVYKH VOLN V DVIZHUSHCHEJSYA SREDE]
A. G. MUNIN, A. A. ANDREEV, Z. N. NAUMENKO, and O. A. SHEVCHENKO TsAGI, Trudy no. 2355 1988 p. 83-91. In RUSSIAN refs
Copyright

An aeroacoustic test stand is described which is designed for evaluating the acoustic efficiency of sound-absorbing structures in a channel of 150 x 150 sq mm cross section in which the flow velocity varies from 0 to 150 ms and the sound pressure level in the incident wave varies from 90 to 154 dB. The discussion covers the general design of the test stand, its technical characteristics, and details of the measuring procedure. Sample experimental results are presented. AIAA

A93-51884
CHARACTERISTICS OF THE FLAME AIR HEATER OF A HYPERSONIC WIND TUNNEL [KHARAKTERISTIKI OGNEVOGO VOZDUKHOPODOGREVATELYA GIPERZVUKOVOJ AEHRODINAMICHESKOJ TRUBY]
E. A. MESHCHERYAKOV TsAGI, Trudy no. 2491 1990 p. 3-18. In RUSSIAN refs
Copyright

The thermodynamic and gasdynamic characteristics of the combustion products of kerosene in oxygenated air in the air heater and at the nozzle exit section of a hypersonic wind tunnel are analyzed for oxidizer excess ratios of 1.4-5 in the initial mixture and pressures of 2-8 MPa inside the heater. Over a wide range of operating conditions of the heater, only four components are found to be present in the combustion products: oxygen, water vapor, carbon dioxide, and nitrogen. Water condensate in the gas flow is formed only at oxidizer excess ratios greater than 4 and pressures of 7 MPa or greater; the amount of water condensate does not exceed 2.5 percent by weight. The flow rate characteristics of the heater and component supply systems are calculated. An efficient method for calculating the mixture parameters is proposed. AIAA

A93-51934
INTERNATIONAL STANDARDS FOR THE QUALIFICATION OF AIRPLANE FLIGHT SIMULATORS; CONFERENCE, LONDON, UNITED KINGDOM, JAN. 16, 17, 1992, DOCUMENT APPROVED
London Royal Aeronautical Society 1992 79 p.
(ISBN 1-85768-040-5) Copyright

International Standards for the Evaluation of Flight Simulators developed by the Flight Simulation Group of the Royal Aeronautical Society are presented. This document is an international standard which is representative of the views of the major regulatory authorities, users, and builders of flight simulators. It is considered to be a practical and effective set of criteria by which to govern the standards to which flight simulators are built, tested, and operated. AIAA

A93-52441
GROUND FACILITY INTERFERENCE ON AIRCRAFT CONFIGURATIONS WITH SEPARATED FLOW
M. E. BEYERS (Inst. for Aerospace Research, Ottawa, Canada) and L. E. ERICSSON (Lockheed Missiles and Space Co., Inc., Sunnyvale, CA) Journal of Aircraft (ISSN 0021-8669) vol. 30, no. 5 Sept.-Oct. 1993 p. 682-688. AIAA, Aerospace Sciences Meeting and Exhibit, 30th, Reno, NV, Jan. 6-9, 1992, AIAA Paper 92-0673. Previously cited in issue 10, p. 1561, Accession no. A92-27042 refs
Copyright

A93-52645
EXPERIMENTAL EVALUATION OF FLAT PLATE BOUNDARY LAYER GROWTH OVER AN ANTI-ICING FLUID FILM
J. L. LAFORTE, P. R. LOUCHEZ, and G. BOUCHARD (Quebec Univ., Chicoutimi, Canada) Canadian Aeronautics and Space Journal (ISSN 0008-2821) vol. 39, no. 2 June 1993 p. 96-104. Research supported by Transport Canada refs

The objective of the present work is to implement an improved standard testing procedure that defines aerodynamic acceptance of deicing/antiicing fluids for large aircraft. The experimental setup consists of a rectangular duct fitted in a cold recirculated wind tunnel and instrumented to measure temperatures and boundary layer displacement thickness (BLDT) during a wind acceleration that simulates ground acceleration of a type B-737 aircraft. Previous work demonstrated that the BLDT was well-correlated to the lift loss induced by the fluid remaining on the wing at takeoff. Consequently, the BLDT that is produced by accelerating air over a 2 mm fluid layer on the bottom of the test duct can be used to identify acceptable levels of lift reduction for a given fluid. A reference fluid is used to present and validate the overall procedure, and five leading commercial fluids that exhibit acceptable behavior above -20 C are evaluated. Author (revised)

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ASTRONAUTICS

Includes astronautics (general); astrodynamics; ground support systems and facilities (space); launch vehicles and space vehicles; space transportation; spacecraft communications, command and tracking; spacecraft design, testing and performance; spacecraft instrumentation; and spacecraft propulsion and power.

A93-48835
THE REPRESENTATION OF THE AERODYNAMIC TORQUE IN SIMULATIONS OF A SPACECRAFT ROTARY MOTION [PREDSTAVLENIE AEHRODINAMICHESKOGO MOMENTA V ZADACHAKH MATEMATICHESKOGO MODELIROVANIYA VRASHCHATEL'NOGO DVIZHENIYA ISKUSSTVENNYKH SPUTNIKOV ZEMLI]
E. YU. ZUEVA, M. M. KOMAROV, and V. V. SAZONOV Kosmicheskie Issledovaniya (ISSN 0023-4206) vol. 30, no. 6 Nov.-Dec. 1992 p. 771-779. In RUSSIAN refs
Copyright

A subroutine package for calculating the main vector and torque of aerodynamic forces of an arbitrary shaped spacecraft is presented. It is considered that a collision between air molecules and spacecraft's surface is perfectly inelastic. The calculation is based on geometric modeling. The spacecraft's surface is represented by a closed piecewise-linear triangulated surface. The problem of the main vector calculation is reduced to calculating the area of the surface projection on a plane which is perpendicular to the direction of an air flow. To calculate the torque it is required to calculate the projection's geometric order-one moment. Since the calculations of the aerodynamic performance data for a complex-shape spacecraft requires much time, a number of time-saving techniques are proposed. The package is implemented in TURBOPASCAL for IBM PC. Author (revised)

A93-48838
OPTIMAL IMPULSIVE INTERORBITAL TRANSFERS WITH AERODYNAMIC MANEUVERS [OPTIMAL'NYE IMPUL'SNYE MEZHORBITAL'NYE PERELETY S AEHRODINAMICHESKIMI MANEVRAMI]
S. N. KIRPICHNIKOV and A. N. BOBKOVA Kosmicheskie Issledovaniya (ISSN 0023-4206) vol. 30, no. 6 Nov.-Dec. 1992 p. 800-809. In RUSSIAN refs
Copyright

The coplanar problem of determining the minimum-fuel impulsive interorbital transfer with aerodynamic maneuvers is investigated. The interorbital transfer is accomplished in the central gravitational field of the planet with atmosphere. The aerodynamic maneuver consists in passive impulsive decrease of velocity by means of breaking in the planet atmosphere. The size and shape of the boundary orbits are given, but their positions in the motion plane may be either fixed or arbitrary. It is shown that a significant fuel gain may be obtained by using aerodynamic maneuvers.
Author (revised)

A93-49592
TRAJECTORY CONTROL FOR A LOW-LIFT RE-ENTRY VEHICLE
AXEL J. ROENNEKE (Stuttgart Univ., Germany) and PHILLIP J. CORNWELL (Rose-Hulman Inst. of Technology, Terre Haute, IN) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090) vol. 16, no. 5 Sept.-Oct. 1993 p. 927-933. AIAA, Aerospace Design Conference, Irvine, CA, Feb. 3-6, 1992, AIAA Paper 92-1146. Previously cited in issue 13, p. 2106, Accession no. A92-33287 refs
Copyright

A93-49596* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ANALYTICAL SOLUTIONS TO CONSTRAINED HYPERSONIC FLIGHT TRAJECTORIES
PING LU (Iowa State Univ. of Science and Technology, Ames) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090) vol. 16, no. 5 Sept.-Oct. 1993 p. 956-960. Previously announced in STAR as N93-18602 refs
(Contract NAG1-1255)
Copyright

The flight trajectory of aerospace vehicles subject to a class of path constraints is considered. The constrained dynamics is shown to be a natural two-time-scale system. Asymptotic analytical solutions are obtained. Problems of trajectory optimization and guidance can be dramatically simplified with these solutions. Applications in trajectory design for an aerospace plane strongly support the theoretical development.

A93-49713*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
SUBSCALE HOT-FIRE TESTING OF A FORMED PLATELET LINER
SANDRA K. ELAM (NASA, Marshall Space Flight Center, Huntsville, AL) and WILLIAM A. HAYES (Aerojet, Propulsion Div., Sacramento, CA) Jun. 1993 10 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-1827) Copyright

To investigate low-cost options for fabricating main combustion chambers, formed platelet liners are being developed. The savings in manufacturing time and cost associated with platelet liners are accompanied by promising thermal advantages, such as lower-wall temperatures and increased cycle life. A subscale liner was tested by NASA at Marshall Space Flight Center (MSFC) to demonstrate its thermal performance. Testing to date has provided chamber pressures up to 2524 psia, while a maximum chamber pressure of 2700 psia is planned. In general, the liner has remained in good condition and performed well, with only minor areas of localized roughening. Data from this subscale test program is being used to develop a full size chamber for testing on a Space Shuttle Main Engine at MSFC in 1994. Author (revised)

A93-49829#
AN ANALYSIS OF AIR-TURBOROCKET PERFORMANCE
GIUSEPPE BUSSI, GUIDO COLASURDO, and DARIO PASTRONE (Torino, Politecnico, Turin, Italy) Jun. 1993 7 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Research supported by MURST refs
(AIAA PAPER 93-1982) Copyright

In order to assess the capabilities of the air-turborocket, an off-design analysis of a representative LOX-LH2 fed engine is carried out. Working lines on an envisageable compressor map are drawn for different flight conditions along a typical transatmospheric vehicle flight path. Characteristic aspects of the air-turborocket behavior in the spontaneous and controlled mode are highlighted. Specific thrust and propellant consumption at full throttle are computed, both in the dry and augmented mode. Performance achievable by exploiting the permissible mass flow range of the compressor map via the variation of the nozzle throat area, is shown.

A93-49833*# National Aeronautics and Space Administration, Washington, DC.
FUTURE TECHNOLOGY AIM OF THE NATIONAL AEROSPACE PLANE PROGRAM
CHARLES W. ANDERSON (National Aerospace Plane Joint Program Office, Wright-Patterson AFB, OH) Jun. 1993 5 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993
(AIAA PAPER 93-1988)

Technical areas where hypersonic technology programs outside NASP might offer assistance and participate in the NASP program are considered. These specific areas include airframe, technology opportunities for providing better performance and reduced weight, the NDV application of NASP technology, and engine propellant systems and subsystems. AIAA

A93-49954*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
DESIGN AND TEST OF A SMALL TWO STAGE COUNTER-ROTATING TURBINE FOR ROCKET ENGINE APPLICATION
F. W. HUBER, B. R. BRANSTROM, A. K. FINKE, P. D. JOHNSON, R. J. ROWEY (Pratt & Whitney Group, Government Engines and Space Propulsion Div., West Palm Beach, FL), and J. P. VERES (NASA, Lewis Research Center, Cleveland, OH) Jun. 1993 13 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2136) Copyright

The aerodynamic design and rig test evaluation of a small counter-rotating turbine system is described. The technology represented by this turbine is being developed for application in an advanced upper stage rocket engine turbopump. This engine will employ an oxygen/hydrogen expander cycle and achieve high performance through efficient combustion, high combustion pressure, and high area ratio exhaust nozzle expansion. Engine performance goals require that the turbopump drive turbines achieve high efficiency at low gas flow rates. The low flow rates result in very small airfoil diameter, height and chord. The high efficiency and small size requirements present a challenging turbine design problem. The unconventional approach employed to meet this challenge is described, along with the detailed design process and resulting airfoil configurations. The method and results of full scale aerodynamic performance evaluation testing of both one and two stage configurations, as well as operation without the secondary stage stator are presented. The overall results of this effort illustrate that advanced aerodynamic design tools and hardware fabrication techniques have provided improved capability to produce small high performance turbines for advanced rocket engines.

A93-49995*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
ANALYSIS AND DEMONSTRATION OF A SCRAMACCELERATOR SYSTEM
JOSEPH W. HUMPHREY (Advanced Projects Research, Inc., Moorpark, CA) and THOMAS H. SOBOTA (Advanced Projects Research, Inc., Hightstown, NJ) Jun. 1993 11 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993. Research supported by Advanced Projects Research, Inc., NASA, SDIO, and New Jersey Commission on Science and Technology refs
(AIAA PAPER 93-2183) Copyright

The Scramaccelerator, a novel type of supersonic-combustion, tube-based launcher has been developed that can accelerate almost any mass to velocities of 3 to over 7 km/sec. This paper describes the technology demonstration of the concept by firing 120-g projectiles into a 38 mm barrel at 2.8 to 3.2 km/sec. The results from the technology demonstration are presented along with calculated performance of the demonstration tests. Critical test issues discussed include sabot separation, venting requirements, and test performance. The results, obtained during testing indicate projectile accelerations were achieved of approximately 5000 g. Hence, these tests demonstrate successful Scramaccelerator operation and acceleration at approximately 1.95 times the Chapman Jouguet detonation velocity, far greater than the 1.15 to 1.3 times previously demonstrated. In addition, the tests demonstrate hypersonic propulsion at Mach numbers above 8, acceleration at greater than 3 km/s, and system integration technology sufficient to accomplish this success.
Author (revised)

A93-50284#
NATIONAL AEROSPACE PLANE INTEGRATED FUSELAGE/CRYOTANK RISK REDUCTION PROGRAM
K. E. DAYTON (McDonnell Douglas Aerospace, Huntington Beach, CA) Jun. 1993 11 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993
(AIAA PAPER 93-2564) Copyright

The principal objectives and results of the National Aerospace Plane (NASP) Integrated Risk Reduction program are briefly reviewed. The program demonstrated the feasibility of manufacturing lightweight advanced composite materials for single-stage-to-orbit hypersonic flight vehicle applications. A series of combined load simulation tests (thermal, mechanical, and cryogenic) demonstrated proof of concept performance for an all unlined composite cryogenic fuel tank with flat end bulkheads and a high-temperature thin-shell advanced composite fuselage. Temperatures of the fuselage were as high as 1300 F, with 100 percent bending and shear loads applied to the tank while filled with 850 gallons of cryogenic fluid hydrogen (-425 F). Leak rates measured on and around the cryotank shell and bulkheads were well below acceptable levels.
AIAA

A93-50300#
AEROELASTIC STABILITY OF SUPERSONIC NOZZLES WITH SEPARATED FLOW
L.-O. PEKKARI (Volvo Flygmotor, AB, Trollhattan, Sweden) Jun. 1993 12 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Research supported by Swedish National Space Board refs
(AIAA PAPER 93-2588) Copyright

An aeroelastic stability analysis of a rocket engine nozzle with a partially separated flow has been performed. The aeroelastic eigenfrequencies and stability of the nozzle is evaluated. It is shown that the eigenmodes of a nozzle may be strongly aeroelastically unstable for flows with partial separation if the axial pressure gradients in the flow are small. It is further shown that the characteristics of the instabilities described are consistent with the phenomena called side-load that sometimes occur in rocket engines during start-up and shut-off.

A93-50301#
NEW EXPERIMENTS IN A 120-MM RAM ACCELERATOR AT HIGH PRESSURES
D. L. KRUCZYNSKI (U.S. Army, Research Lab., Aberdeen Proving Ground, MD) Jun. 1993 9 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2589)

Initial experimental results are presented for the U.S. Army Research Laboratory's 120-mm bore ram accelerator test apparatus, which is currently the world's largest. Muzzle velocities of more than 2.6 km/sec have been experimentally demonstrated, and theoretical prospects exist for velocities above 7 km/sec. Experimental results are presented for fuel pressures as high as 102 atmospheres, and an evaluation is made of the impact of such high pressure operations on facility design and applications. Attention is given to the effects of high pressure unstarts on ram-accelerator hardware.
AIAA

A93-50318#
FUSION-ELECTRIC PROPULSION FOR HYPERSONIC FLIGHT
H. D. FRONING, JR. (Flight Unlimited, Flagstaff, AZ) and R. W. BUSSARD (Energy/Matter Conversion Corp., Manassas, VA) Jun. 1993 11 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2611) Copyright

Recent studies by Bussard (1986-1991) have shown that charged nuclei of certain light element isotopes can be electrostatically compressed to sufficient density for nuclear fusions to occur. And the resulting fusion reactions involving such nuclei emit no neutrons and induce no radioactivity at all. Such 'clean' fusion reactions can develop 4 to 8 times more engine thrust per fuel flow rate than chemical reactions with attractive engine thrust-to-weight ratios - ratios in the 3 to 6 g range. This paper shows that such propulsion could enable a 2- to 5-fold improvement in the payload delivery efficiency of earth-to-orbit aerospace planes and the accomplishment of environmentally favorable hypersonic flight.
Author (revised)

A93-51237* National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
CALIBRATION RESULTS FOR NOAA-11 AVHRR CHANNELS 1 AND 2 FROM CONGRUENT PATH AIRCRAFT OBSERVATIONS
PETER ABEL, B. GUENTHER (NASA, Goddard Space Flight Center, Greenbelt, MD), REGINALD N. GALIMORE, and JOHN W. COOPER (Hughes STX Corp., Lanham, MD) Journal of Atmospheric and Oceanic Technology (ISSN 0739-0572) vol. 10, no. 4 Aug. 1993 p. 493-508. refs

A method for using congruent atmospheric path aircraft-satellite observations to calibrate a satellite radiometer is presented. A calibrated spectroradiometer aboard a NASA ER-2 aircraft at an altitude of 19 km above White Sands (New Mexico) was oriented to view White Sands at the overpass time of the NOAA-11 AVHRR instrument along the same view vector as the satellite instrument. The data from six flights between November 1988 and October 1990 were transformed into corresponding estimates of AVHRR channel radiance at the satellite (derived from the aircraft measurements), and average counts (from the AVHRR measurements), both averaged across the footprint of the spectroradiometer. Prelaunch measurements of the AVHRR spectral response profiles are assumed, and the radiance spectrum measured by the spectroradiometer was adjusted to satellite altitude using the LOWTRAN-7 computer code. Results show reduced gains in both channel 1 (0.65 micron) and channel 2 (0.85 micron), compared to prelaunch values, with little further reduction in gain after 200 days in orbit. Results for the gain ratio (channel 1/channel 2), which is important for the calculation of the normalized vegetation index, show constant in-orbit values 5 percent above the prelaunch value. Author (revised)

A93-51331#
THE APPLICATION OF INTELLIGENT SEARCH STRATEGIES TO ROBUST FLIGHT CONTROL FOR HYPERSONIC VEHICLES
GREGORY E. CHAMITOFF (Charles Stark Draper Lab., Inc., Cambridge, MA) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 1 Washington American Institute of Aeronautics and Astronautics 1993 p. 294-304. refs
(AIAA PAPER 93-3732) Copyright

Flight control for airbreathing hypersonic vehicles is particularly difficult due the combination of strict performance requirements, nonlinear dynamics, model uncertainty, complex constraints, and bounded disturbances. These problems have motivated the development of a new approach, called Robust Intelligent Control (RIC), which is capable of real-time, short-term trajectory planning. Stable tracking of a desired trajectory is achieved by solving a constrained receding-horizon nonlinear optimal control problem via intelligent optimization methods. A viable correction trajectory is generated, followed for a short interval of time, and then recomputed. The RIC approach consists of an enhanced A* optimization technique that incorporates a Liapunov stability criterion in a highly parallelizable algorithm. The efficiency of the A* search, and the theoretical guarantees of a Liapunov method, are both achieved. The algorithm is demonstrated and evaluated using a realistic hypersonic vehicle simulation. Author (revised)

A93-51348*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
MATCHED ASYMPTOTIC EXPANSION OF THE HAMILTON-JACOBI-BELLMAN EQUATION FOR AEROASSISTED PLANE-CHANGE MANEUVERS
ANTHONY J. CALISE and NAHUM MELAMED (Georgia Inst. of Technology, Atlanta) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 1 Washington American Institute of Aeronautics and Astronautics 1993 p. 456-465. refs
(Contract NAG1-1139)
(AIAA PAPER 93-3752) Copyright

In this paper we develop a general procedure for constructing a matched asymptotic expansion of the Hamilton-Jacobi-Bellman equation based on the method of characteristics. The development is for a class of perturbation problems whose solution exhibits two-time-scale behavior. A regular expansion for problems of this type is inappropriate since it is not uniformly valid over a narrow range of the independent variable. Of particular interest here is the manner in which matching and boundary conditions are enforced when the expansion is carried out to first order. Two cases are distinguished - one where the left boundary condition coincides with or lies to the right of the singular region and one where the left boundary condition lies to the left of the singular region. A simple example is used to illustrate the procedure, and its potential application to aeroassisted plane change is described.

A93-51385#
REENTRY CONTROL TO A DRAG VS. ENERGY PROFILE
AXEL J. ROENNEKE and ABERT MARKL (Stuttgart Univ., Germany) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 2 Washington American Institute of Aeronautics and Astronautics 1993 p. 837-844. refs
(AIAA PAPER 93-3790) Copyright

We present trajectory control for a winged re-entry vehicle based on drag versus energy guidance. A linear control law is derived to track the drag reference guaranteeing satisfactory drag error dynamics. For the controller design, the vehicle's motion in the vertical plane is transformed into a drag state space, and the transformed system is linearized along the drag reference. Flight simulation results show that the control system operates effectively while subject to considerable atmospheric variations.

A93-51386#
SELF-TUNING GUIDANCE APPLIED TO AEROASSISTED PLANE CHANGE PROBLEMS
SRIGOURI KAMARSU and S. N. BALAKRISHNAN (Missouri-Rolla Univ., Rolla) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 2 Washington American Institute of Aeronautics and Astronautics 1993 p. 845-855. refs
(AIAA PAPER 93-3791) Copyright

Nonlinear self-tuning control methods are developed for use as feedback control laws for multivariable control for the atmospheric portion of aeroassisted maneuvers. A nonlinear generalized minimum variance control method and a nonlinear pole-placement method of self-tuning control are used to track the reference trajectories during this period. Flight dynamics equations are formulated in a special form for generating the self-tuned control. Numerical examples from a plane change reentry problems to illustrate the use of these methods are presented. Detailed analysis of the effects of the design parameters is given.

A93-51409#
GUIDANCE AND CONTROL LAW FOR AUTOMATIC LANDING FLIGHT EXPERIMENT OF REENTRY SPACE VEHICLE
YOSHIKAZU MIYAZAWA, KAZUTOSHI ISHIKAWA, and KENJI FUJII (National Aerospace Lab., Chofu, Japan) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 2 Washington American Institute of Aeronautics and Astronautics 1993 p. 1057-1066. refs
(AIAA PAPER 93-3818) Copyright

An automatic landing flight experiment with a sub-scale model is being prepared for a planned future reentry space vehicle by the National Aerospace Laboratory and the National Space Development Agency of Japan. The subscale model is dropped from a helicopter at a 1500-m altitude, and, controlled by an on-board navigation, guidance, and control system, it automatically lands on a 1000-m runway. This paper discusses preliminary study results obtained from numerical simulation. The guidance and control law was designed using a multiple delay model and multiple design point approach. Control system robustness against uncertain and time varying dynamics is especially considered in this approach. The control performances are evaluated with appropriately defined quadratic indices of tracking error. Simple control structures are assumed and parameters are obtained with numerical optimization.

The approach was successfully applied to the design, and feasibility of the experiment has been verified with numerical simulations.
Author (revised)

A93-51442*# National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, AL.
COMPUTATION OF OPTIMAL LOW- AND MEDIUM-THRUST ORBIT TRANSFERS
C.-H. CHUANG, TROY D. GOODSON (Georgia Inst. of Technology, Atlanta), and JOHN HANSON (NASA, Marshall Space Flight Center, Huntsville, AL) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 3 Washington American Institute of Aeronautics and Astronautics 1993 p. 1391-1402. refs
(AIAA PAPER 93-3855) Copyright

This paper presents the formulation of the optimal low- and medium-thrust orbit transfer control problem, numerical methods for solution, and numerical solutions of the problem. The problem formulation is for final mass maximization and allows for second-harmonic oblateness, atmospheric drag, and 3D noncoplanar nonaligned elliptic terminal orbits. We set up examples to demonstrate the ability of two indirect methods to solve the resulting two point boundary value problems (TPBVP). The methods demonstrated are the multiple point shooting method as formulated in Oberle's (1987) subroutine BOUNDSCO, and the minimizing boundary-condition method (MBCM). We find that although both methods can converge solutions, there are tradeoffs to using either method. We present numerical solutions of planar transfers in which both the initial orbit exit and final orbit entry points have been optimized. These solutions include two- and three-burn transfers. The methods used show an ability to handle thrust down to at least T/W(o) = O(10 exp -3). They also show similar convergence abilities with or without the oblateness and drag terms. We discuss the issue of maximizing with respect to the final time and provide evidence that implies a local optimum at a maximum final time for a given number of burns. Author (revised)

A93-51472#
GUIDANCE LAW BASED ON PIECEWISE CONSTANT CONTROL FOR HYPERSONIC GLIDERS
DAVID G. HULL (Texas Univ., Austin) and JEAN-MARIE SEGUIN (Aerospatiale, Les Mureaux, France) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 3 Washington American Institute of Aeronautics and Astronautics 1993 p. 1686-1691. refs
(AIAA PAPER 93-3888) Copyright

A midcourse guidance law is developed for the descent of a hypersonic glider to a fixed target on the ground. It is based on an optimal piecewise constant control (N intervals) obtained from an approximate physical model (flat earth, exponential atmosphere, parabolic drag polar, etc). The resulting optimal control equations can be integrated either analytically or by quadrature, and the guidance algorithm requires the solution of 2N+1 nonlinear algebraic equations. The guidance law is implemented in a realistic glider simulation, the intercept is achieved, and final velocities within 14 percent of the true values are obtained for the downrange and crossranges considered. Author (revised)

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CHEMISTRY AND MATERIALS

Includes chemistry and materials (general); composite materials; inorganic and physical chemistry; metallic materials; nonmetallic materials; and propellants and fuels.

A93-48227#
CARS STUDIES IN HYPERSONIC FLOWS
F. GRISCH, P. BOUCHARDY, and M. PEALAT (ONERA, Chatillon, France) Jul. 1993 11 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 Research supported by CNES refs
(AIAA PAPER 93-3047; ONERA, TP NO. 1993-101) Copyright

Coherent anti-Stokes Raman scattering (CARS) studies are carried out on nitrogen in a high-enthalpy wind tunnel and in a blow-down wind tunnel. The scanning CARS and the dual-line CARS techniques have been implemented in order to measure the vibrational temperature, rotational temperature and nitrogen number density in the free stream and in the vicinity of two-dimensional models. Averaged temperature and density values are compared with those predicted by theoretical solvers. The results demonstrate the usefulness of the CARS technique for measurements required by the hypersonic flow studies.

A93-49336
WHAT CAN JAPAN TEACH THE U.S. ABOUT COMPOSITES?
ALAN S. BROWN Aerospace America (ISSN 0740-722X) vol. 31, no. 7 July 1993 p. 36-40.
Copyright

Mitsubishi Heavy Industries' (MHI) F-16-based FSX will demonstrate the design and production of the greatest volume of primary airframe structure advanced composite components to date. These will include an integrally cocured wing structure. Several thousand documents concerning the critically important curing process for such large, high-performance components have already been released to General Dynamics, the originator of the F-16 design, by MHI. An evaluation is presently made of the lessons that can be derived by U.S. industry from the distinctive development and process-control practices of the Japanese in the matter of aerospace composite materials. AIAA

A93-49658#
CARBON/SILICON CARBIDE COMPOSITE MATERIALS IN ADVANCED UNMANNED GAS TURBINE ENGINE COMBUSTORS
JEFFREY ARMSTRONG, VINCENT CHUNG, MANUEL CARDENAS (AlliedSignal Propulsion Engines, Phoenix, AZ), and CARLOS ARANA (USAF, Wright Lab., Wright-Patterson AFB, OH) Jun. 1993 7 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(Contract F33615-87-C-2839)
(AIAA PAPER 93-1761) Copyright

This paper discusses the application of ceramic matrix composites (CMCs) in a limited-life combustor. A carbon-fiber-reinforced silicon carbide matrix (C/SiC) composite was selected as the material system. Three chemical vapor deposition materials were evaluated using flexural stress-rupture tests. A fiber architecture study identified manufacturing considerations with respect to component shape and material properties. A C/SiC subelement was designed and rig tested to evaluate material behavior and integrity of a ceramic/metal attachment scheme at actual combustor operating conditions. Finite-element analysis of the subelement was performed to better understand the failure mechanism of the CMC material. Posttest material analyses were performed to verify material integrity of the tested subelement.

A93-49734#
EVALUATION OF DECOMPOSITION KINETIC COEFFICIENTS FOR A FIBER-REINFORCED INTUMESCENT-EPOXY
G. W. RUSSELL (U.S. Army, Research, Development, and Engineering Center, Redstone Arsenal, AL) Jun. 1993 8 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-1856)

The kinetic coefficients for decomposition of Chartek 59 C using a modified Arrhenius relationship have been determined from thermogravimetric analyses (TGA) for a range of constant heating rates. Weight loss (decomposition) and weight loss rate (decomposition rate) were measured and recorded for four heating rates: 9 deg F/min, 18 deg F/min, 27 deg F/min, and 36 deg F/min. A computer program was developed using the Arrhenius

relationship as a curvefit for the measured TGA to determine the kinetic coefficients for decomposition. Relatively good agreement was obtained between measured and calculated decomposition as a function of temperature. Additionally, the predicted peak decomposition rates show good agreement for each of the heating rates. The differences that exist between measured and calculated decomposition rates can be reduced by increasing the number of data points used in the computer program. These coefficients, when used in the Arrhenius relationship, represent the decomposition as a function of temperature for Chartek 59C. The Arrhenius model can be used in conjunction with a charring material thermal response computer program to predict ablation and in-depth thermal effects for any given thermal boundary conditions. Author (revised)

A93-49735#
AEROTHERMAL ABLATIVE CHARACTERIZATION OF SELECTED EXTERNAL INSULATOR CANDIDATES
W. A. LUEHMANN and J. F. LYON (United Technologies, Chemical Systems Div., San Jose, CA) Jun. 1993 11 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-1857) Copyright

In March of 1992, an IR&D funded test program was initiated at United Technologies, Chemical Systems Division (CSD). The purpose of the program was to characterize the ablative performance of twenty-seven external insulator candidates when subjected to high aerodynamic heat fluxes typical of tactical missile defense (TMD) flight conditions. Between June and November of 1992, the samples were tested at CSD's ramjet engine test facility, RT-I, using a supersonic 3500 deg R vitiated air free jet to simulate flight heating conditions. The data acquired from these tests established the relative performance of the candidates in terms of effective heat of ablation and ablating surface temperature. The results of this program indicated a number of candidates that appear to have potential for high velocity TMD applications. It was also discovered that several materials either commonly used or thought to perform well as external insulators experience unacceptably high ablation when subjected to heating rates of this magnitude.

A93-49842#
HIGH TEMPERATURE CORROSION RESISTANT BEARING STEEL DEVELOPMENT
E. E. PFAFFENBERGER (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN) and PAULINE TARRANTINI (U.S. Navy, Naval Air Warfare Center, Trenton, NJ) Jun. 1993 12 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2000) Copyright

The aim towards increased power-to-weight ratios and reduced specific fuel consumption in advanced gas turbine engines demands mainshaft bearings that are able to operate under an increasingly severe environment. This environment includes higher temperatures, increased hoop stresses, and more rapid accumulation of stress cycles. In addition, corrosion currently accounts for approximately 30 percent of all bearing rejections during engine overhaul. To meet these challenges, a high-speed, high-temperature, corrosion-resistant bearing material is being developed. A production capable carburizing process for a newly developed chrome tool steel, Pyrowear 675 Alloy, was developed. Mechanical property evaluations have shown that carburized Pyrowear 675 has the required fracture toughness, rolling contact fatigue life, hot hardness, and corrosion resistance needed to operate in the rigorous environments predicted for gas turbine engines. Author (revised)

A93-49867*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
NONINTRUSIVE, MULTIPOINT VELOCITY MEASUREMENTS IN HIGH-PRESSURE COMBUSTION FLOWS
M. ALLEN, S. DAVIS, W. KESSLER, H. LEGNER, K. MCMANUS, P. MULHALL, T. PARKER, and D. SONNENFROH (Physical Sciences, Inc., Andover, MA) Jun. 1993 14 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Research sponsored by NASA and USAF refs
(AIAA PAPER 93-2032) Copyright

A combined experimental and analytical effort was conducted to demonstrate the applicability of OH Doppler-shifted fluorescence imaging of velocity distributions in supersonic combustion gases. The experiments were conducted in the underexpanded exhaust flow from a 6.8 atm, 2400 K, H2-O2-N2 burner exhausting into the atmosphere. In order to quantify the effects of in-plane variations of the gas thermodynamic properties on the measurement accuracy, a set of detailed measurements of the OH (1,0) band collisional broadening and shifting in H2-air gases was produced. The effect of pulse-to-pulse variations in the dye laser bandshape was also examined in detail and a modification was developed which increased in the single pulse bandwidth, thereby increasing the intraimage velocity dynamic range as well as reducing the sensitivity of the velocity measurement to the gas property variations. Single point and imaging measurements of the velocity field in the exhaust flowfield were compared with 2D, finite-rate kinetics simulations of the flowfield. Relative velocity accuracies of +/- 50 m/s out of 1600 m/s were achieved in time-averaged imaging measurements of the flow over an order of magnitude variation in pressure and a factor of two variation in temperature. Author (revised)

A93-50013#
IGNITION OF BORON PARTICLES COATED BY A THIN TITANIUM FILM
VALERY ROSENBAND, BENVENISTE NATAN, and ALON GANY (Technion - Israel Inst. of Technology, Haifa) Jun. 1993 12 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2201) Copyright

A theoretical model for the ignition of titanium-coated boron particles in dry air has been developed. In general, the results indicate reduction in ignition time due to high heating rate of the particle resulting from the reactions of titanium with both boron and oxygen and the deterioration of the protective properties of the coating layers due to mechanical stresses. However, ignition strongly depends on the titanium coating thickness and the ambient temperature.

A93-50014#
BORON PARTICLE IGNITION IN HIGH-SPEED FLOW
A. POVITSKY and Y. GOLDMAN (Technion - Israel Inst. of Technology, Haifa) Jun. 1993 9 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2202) Copyright

The behavior of boron particles covered with liquid oxide film was studied experimentally and by numerical simulation. Development of supersonic vehicles has brought about increased flow velocities inside the air-breathing combustor with the attendant change in approach to the ignition problem. Preheating of the solid particles makes it possible to utilize the velocity difference between gas and particle for removal of the liquid oxide with the aid of Stokes forces. The ignition limits of co-flowing boron particles were derived from a model incorporating conditions of high gas temperature, close-to-sonic initial relative particle velocity and particle preheating before ejection. It is shown, that migration of the film on the front half-surface of the particle can be derived and used in the oxide removal model. Strong interdependence, with extremal features, was demonstrated between the ignition and particle size.

A93-50107#
SOME SUPERSONIC AND HYPERSONIC RESEARCH AT GASL IN THE 1960S AND 70S
WALLACE CHINITZ (General Applied Science Labs., Inc., Ronkonkoma, NY) Jun. 1993 14 p. AIAA, SAE, ASME, and

ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2327) Copyright

Some of the work with which the author and his colleagues at GASL were involved in the 1960-73 time frame is reviewed. The following broad subject areas are discussed: (1) fundamental studies into the finite-rate (chemical kinetics) reaction of a number of fuel-oxidizer combinations, including hydrogen-air, hydrocarbon-air and Aerozine 50-N2O4; (2) experimental investigations into the conditions required to burn hydrocarbons, fuel-rich rocket exhaust products and ablating solid fuels in supersonic air; (3) computational studies of turbulent, reacting flows, including condensed phases and particle surface reactions; (4) other studies dealing with thrust vector control of hypersonic vehicles using external burning; generalized, chemically-reacting flows with vibrational relaxation; and studies of high-speed combustors for turbomachinery applications. Author (revised)

A93-50220#
ON THE STABILITY OF THE PROCESS OF FORMATION OF COMBUSTION GENERATED PARTICLES BY COAGULATION AND SIMULTANEOUS SHRINKAGE DUE TO PARTICLE OXIDATION

Y. TAMBOUR and S. KHOSID (Technion - Israel Inst. of Technology, Haifa) Jun. 1993 11 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2478) Copyright

A mathematical stability analysis is conducted to define the domain of operating conditions under which a combustion-generated particle will be formed by coagulation of incipient particles (or clusters). Two opposing concurrent mechanisms are considered, namely: (1) growth by coagulation and (2) simultaneous shrinkage due to sublimation or oxidation of the particle. These two mechanisms are incorporated in the discrete coagulation equations. Then, summations are carried out over all discrete sizes, once for the total number of incipient particles and once for the total mass. A particle is formed under conditions of growth in mass and a decrease in total number of incipient particles. The stability analysis is based on Liapunov's theorem. Various mathematical forms of collisional kernels are analyzed. Our results indicate that only enhanced collision rates will lead to an unstable rapid growth of particles. This observation is in agreement with the conclusions drawn by Harris et al. (1986) and Harris and Kennedy (1988). Author (revised)

A93-51104
MAIN DIRECTIONS OF IMPROVING THE QUALITY OF ALUMINUM-LITHIUM ALLOYS FOR WELDED AIRCRAFT STRUCTURES [OSNOVNYE NAPRAVLENIYA POVYSHENIYA KACHESTVA ALYUMINIEVO-LITIEVYKH SPLAVOV DLYA SVARNYKH AVIATSIONNYKH KONSTRUKTSIJ]

I. N. FRIDLYANDER, A. G. BRATUKHIN, and V. G. DAVYDOV (Vserossijskij Inst. Legkikh Splavov, Moscow, Russia) Fizika i Khimiya Obrabotki Materialov (ISSN 0015-3214) no. 3 May-June 1993 p. 117-122. In RUSSIAN
Copyright

The use of an aluminum-lithium alloy, 1420, combining a high density (2.47 g/cu cm) and a high elastic modulus (7.8 MPa) with high corrosion resistance and high specific strength characteristics makes it possible to achieve a 24-percent saving in the weight of welded Al-Li aircraft structures in comparison with riveted structures. The principal methods of improving the quality of 1420 alloy are discussed. In particular, it is shown that an optimum combination of mechanical properties and high resistance to stress corrosion cracking are achieved by using a hardening treatment with a controlled cooling rate. AIAA

A93-51626
AEROTHERMODYNAMICS IN COMBUSTORS; IUTAM SYMPOSIUM, NATIONAL TAIWAN UNIV., TAIPEI, JUNE 3-5, 1991, SELECTED PAPERS

RICHARD S. L. LEE, ED. (New York State Univ., Stony Brook), JAMES H. WHITELAW, ED. (Imperial College of Science, Technology and Medicine, London, United Kingdom), and T. S. WUNG, ED. (National Taiwan Univ., Taipei) Berlin and New York Springer-Verlag 1992 359 p. For individual items see A93-51627 to A93-51645
(ISBN 0-387-55404-1) Copyright

The present conference discusses advanced laser diagnostics for combustion processes, flame diagnostics by pure rotational CARS, a reaction mechanism for soot formation in nonpremixed flames, droplet vaporization laws, the control of oscillations in ducted premixed flames, and turbulence and mixing in a simulated augmentor's complex flow. Also discussed are the combustion of heavy fuel oils in a pulse combustor, gas turbine combustors for low-BTU gas, gas composition and temperature inside a can-type model combustor, a droplet vaporization law for nondilute sprays, the scalar characteristics of a liquid-fueled combustor with curved exit nozzle. AIAA

A93-51631
INVESTIGATION OF A COMBUSTION ZONE BEHIND A WEDGE

P. BRUEL, P. BLAZART, B. DESHAIES, M. CHAMPION, S. DUPLANTIER, and L. SRAMEK (Ecole Nationale Superieure de Mecanique et d'Aerotechnique, Poitiers, France) *In* Aerothermodynamics in combustors; IUTAM Symposium, National Taiwan Univ., Taipei, June 3-5, 1991, Selected Papers Berlin and New York Springer-Verlag 1992 p. 75-87. refs
Copyright

An experimental study of a turbulent combustion zone stabilized by a wedge is presented. Informations collected through temperature and velocity measurements along with CCD videocameras visualizations allow for a qualitative description of the various combustion processes involved. More precisely, it is clearly evidenced that more than one model should be used to represent numerically the whole flowfield characteristics.

A93-51634
THERMOMETRY INSIDE A SWIRLING TURBULENT FLAME - CARS ADVANTAGES AND LIMITATIONS

CLAUDE CAHEN, PASCALE BELLAICHE (Electricite de France, Direction des Etudes et Recherches, Saint-Denis), and DANIELLE GARRETON (Electricite de France, Lab. National d'Hydraulique, Chatou) *In* Aerothermodynamics in combustors; IUTAM Symposium, National Taiwan Univ., Taipei, June 3-5, 1991, Selected Papers Berlin and New York Springer-Verlag 1992 p. 119-132. refs
Copyright

A study is conducted of the detailed structure of turbulent diffusion flames using CARS spectroscopy for temperature field measurements. Attention is given to temporal and spatial resolutions. It is found that while CARS did not allow a systematic exploration of the flame, it deepened physical insight into flame behavior. A methodology for comparing experimental observations and model predictions is suggested, and the complementarity of various techniques for computational model validation is noted. AIAA

A93-51936
MICROSTRUCTURE OF YTTRIA STABILIZED ZIRCONIA-HAFNIA PLASMA SPRAYED THERMAL BARRIER COATINGS

H. IBEGAZENE, S. ALPERINE, and C. DIOT (ONERA, Chatillon, France) ONERA, TP no. 1993-54 1993 5 p. European Conference on Advanced Materials and Processes, 3rd, Paris, France, June 8-10, 1993 refs
(ONERA, TP NO. 1993-54)

Hafnia is an attractive candidate to build reliable and durable thermal barrier systems, due to its similarity to zirconia and its elevated structural transformation temperatures. We report here structural investigations of various plasma sprayed coatings composed of ZrO_2 + x mole pct HfO_2 (x = 0, 25, 50, and 100), partially stabilized by 4.53 mole pct yttria. X-ray diffraction studies and TEM investigations show that a metastable, nontransformable,

high-yttrium-content, t' phase is the only phase observed on the as-sprayed samples. Such results have not been yet related to in the literature. Author (revised)

A93-52473* National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
CHEMICAL STABILITY OF TITANIUM DIBORIDE REINFORCEMENT IN NICKEL ALUMINIDE MATRICES
J. D. RIGNEY and J. J. LEWANDOWSKI (Case Western Reserve Univ., Cleveland, OH) Journal of Materials Science (ISSN 0022-2461) vol. 28, no. 14 July 15, 1993 p. 3911-3922. Research supported by NASA and MTS Systems Corp. refs
(Contract AF-AFOSR-89-0508)
Copyright

Chemical stability of TiB2 reinforcement in NiAl (45 at percent Al) and Ni3Al (24 at percent Al) matrices has been theoretically and experimentally investigated. Calculations were made using thermodynamic properties of the systems to predict behavior at temperatures between 1173 and 1573 K. Experimental investigation of hot-press consolidated TiB2 particulate/prealloyed matrix powder blends were conducted using energy dispersive X-ray analysis, XRD, AES, and TEM. The theoretical and experimental analyses suggest that TiB2 is chemically stable in both matrices up to 1573 K; however, TiB2 was found to be less active in NiAl than in Ni3Al due to lower nickel activity in NiAl. Author (revised)

A93-52513
MEASUREMENTS OF DYNAMIC YOUNG'S MODULUS AND DAMPING IN SINGLE CRYSTALS OF A NICKEL-BASED SUPERALLOY AS A FUNCTION OF TEMPERATURE
A. WOLFENDEN, M. D. COMPERE (Texas A & M Univ., College Station), and B. DECAMPS (Paris XI, Univ., Orsay, France) Journal of Materials Science Letters (ISSN 0261-8028) vol. 12, no. 14 July 15, 1993 p. 1128-1130. refs
Copyright

The results are presented of an experimental study of the elastic and anelastic properties of two specimens of 001-line single crystals of Ni-based superalloy. The temperature of Young's modulus the Arrhenius plot of damping, and the strain amplitude dependence are reported for deformed and undeformed samples. AIAA

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ENGINEERING

Includes engineering (general); communications; electronics and electrical engineering; fluid mechanics and heat transfer; instrumentation and photography; lasers and masers; mechanical engineering; quality assurance and reliability; and structural mechanics.

A93-47650
ROBUST METHOD FOR ESTIMATING THE PARAMETERS OF A LINEAR FM WAVEFORM
C. R. GUARINO (IBM Corp., Gaithersburg, MD) *In* IGARSS '92; Proceedings of the 12th Annual International Geoscience and Remote Sensing Symposium, Houston, TX, May 26-29, 1992. Vol. 1 New York Institute of Electrical and Electronics Engineers, Inc. 1992 p. 380-383. refs
Copyright

The problem of estimating the linear and quadratic components of a chirp signal is addressed. The current methods for estimating the unknown chirp parameters from the phase history data are reviewed. The method presented relies upon unwrapping the phase history and estimating the phase parameters using a modified least squares procedure. It is shown that the proposed method leads to very accurate phase estimates. Computational complexity issues are adddressed. Comparisons are made with several recent computational phase estimation procedures. The method presented is considerably faster than recently published algorithms. A new method for estimating the parameters of a chirp waveform is presented. The new algorithms offer both accuracy and real-time performance advantages. Author

A93-48044* National Aeronautics and Space Administration, Washington, DC.
ABSOLUTE INTENSITY MEASUREMENTS OF IMPURITY EMISSIONS IN A SHOCK TUNNEL AND THEIR CONSEQUENCES FOR LASER-INDUCED FLUORESCENCE EXPERIMENTS
P. C. PALMA, A. F. P. HOUWING, and R. J. SANDEMAN (Australian National Univ., Canberra, Australia) Shock Waves (ISSN 0938-1287) vol. 3, no. 1 1993 p. 49-53. Research supported by Australian Research Council refs
(Contract NAGW-1467)
Copyright

Absolute intensity measurements of impurity emissions in a shock tunnel nozzle flow are presented. The impurity emission intensities were measured with a photomultiplier and optical multichannel analyzer and calibrated against an intensity standard. The various metallic contaminants were identified and their intensities measured in the spectral regions 290 to 330 nm and 375 to 385 nm. A comparison with calculated fluorescence intensities for predissociated laser-induced fluorescence signals is made. It is found that the emission background is negligible for most fluorescence experiments.

A93-48111#
AERODYNAMIC FLOW SIMULATION USING A PRESSURE-BASED METHOD AND A TWO-EQUATION TURBULENCE MODEL
Y. G. J. LAI, A. J. PRZEKWAS (CFD Research Corp., Huntsville, AL), and R. M. C. SO (Arizona State Univ., Tempe) Jul. 1993 13 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-2902) Copyright

In the past, most aerodynamic flow calculations were carried out with density-based numerical methods and zero-equation turbulence models. However, pressure-based methods and more advanced turbulence models have been routinely used in industry for many internal flow simulations and for incompressible flows. Unfortunately, their usefulness in calculating aerodynamic flows is still not well demonstrated and accepted. In this study, an advanced pressure-based numerical method and a recently proposed near-wall compressible two-equation turbulence model are used to calculate external aerodynamic flows. Several TVD-type schemes are extended to pressure-based method to better capture discontinuities such as shocks. Some improvements are proposed to accelerate the convergence of the numerical method. A compressible near-wall two-equation turbulence model is then implemented to calculate transonic turbulent flows over NACA 0012 and RAE 2822 airfoils with and without shocks. The calculated results are compared with wind tunnel data as well as with results obtained from the Baldwin-Lomax model. The performance of the two-equation turbulence model is evaluated and its merits or lack thereof are discussed.

A93-48117*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
COMPUTER-AIDED LIGHT SHEET FLOW VISUALIZATION
KATHRYN STACY, KURT SEVERANCE, and BROOKS A. CHILDERS (NASA, Langley Research Center, Hampton, VA) Jul. 1993 17 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-2915) Copyright

A computer-aided flow visualization process has been developed to analyze video images acquired from rotating and translating light sheet visualization systems. The computer process integrates a mathematical model for image reconstruction, advanced computer graphics concepts, and digital image processing to provide a quantitative and visual analysis capability. The image reconstruction model, based on photogrammetry, uses

knowledge of the camera and light sheet locations and orientations to project two-dimensional light sheet video images into three-dimensional space. A sophisticated computer visualization package, commonly used to analyze computational fluid dynamics (CFD) data sets, was chosen to interactively display the reconstructed light sheet images, along with the numerical surface geometry for the model or aircraft under study. A description is provided of the photogrammetric reconstruction technique, and the image processing and computer graphics techniques and equipment. Results of the computer aided process applied to both a wind tunnel translating light sheet experiment and an in-flight rotating light sheet experiment are presented. The capability to compare reconstructed experimental light sheet images and CFD solutions in the same graphics environment is also demonstrated.

A93-48120*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
SURFACE HOT-FILM METHOD FOR THE MEASUREMENT OF TRANSITION, SEPARATION AND REATTACHMENT POINTS
AKIHIKO NAKAYAMA (Kobe Univ., Japan), JOHN P. STACK, JOHN C. LIN (NASA, Langley Research Center, Hampton, VA), and WALTER O. VALAREZO (McDonnell Douglas Aerospace West Co., Long Beach, CA) Jul. 1993 9 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-2918) Copyright

A real-time method of determining positions of laminar-to-turbulent transition region, separation and reattachment points and stagnation points using an array of simultaneously operated surface-mounted hot-film sensors has been developed and applied to a wind-tunnel test of a multielement airfoil model. Determination of various types of transitions and flow directions in various regimes of flows seen on multielement airfoils are possible without precise sensor calibration or laborious post-test data analysis. The results agree with established method and theoretical methods, but determination of turbulent reattachment points are not yet satisfactory.

A93-48132*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
HIGH RESOLUTION NUMERICAL SIMULATION OF THE LINEARIZED EULER EQUATIONS IN CONSERVATION LAW FORM
KIDAMBI SREENIVAS, DAVID L. WHITFIELD (NSF, Engineering Research Center for Computational Field Simulation, Mississippi State, MS), and DENNIS L. HUFF (NASA, Lewis Research Center, Cleveland, OH) Jul. 1993 11 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(Contract NAG3-767)
(AIAA PAPER 93-2934) Copyright

A linearized Euler solver based on a high resolution numerical scheme is presented. The approach is to linearize the flux vector as opposed to carrying through the complete linearization analysis with the dependent variable vector written as a sum of the mean and the perturbed flow. This allows the linearized equations to be maintained in conservation law form. The linearized equations are used to compute unsteady flows in turbomachinery blade rows arising due to blade vibrations. Numerical solutions are compared to theoretical results (where available) and to numerical solutions of the nonlinear Euler equations.

A93-48146*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
INTAKE FLOW MODELING IN A FOUR STROKE DIESEL USING KIVA3
R. P. HESSEL and C. J. RUTLAND (Wisconsin Univ., Madison) Jul. 1993 9 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 Research supported by Caterpillar, Inc., Cray Research, Inc., and Univ. of Wisconsin refs
(Contract NAG3-1087; DAAL03-86-K-0174)
(AIAA PAPER 93-2952) Copyright

Intake flow for a dual intake valved diesel engine is modeled using moving valves and realistic geometries. The objectives are to obtain accurate initial conditions for combustion calculations and to provide a tool for studying intake processes. Global simulation parameters are compared with experimental results and show good agreement. The intake process shows a 30 percent difference in mass flows and average swirl in opposite directions across the two intake valves. The effect of the intake process on the flow field at the end of compression is examined. Modeling the intake flow results in swirl and turbulence characteristics that are quite different from those obtained by conventional methods in which compression stroke initial conditions are assumed.
Author (revised)

A93-48159*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
MULTI-ZONAL NAVIER-STOKES CODE WITH THE LU-SGS SCHEME
G. H. KLOPFER and S. YOON (NASA, Ames Research Center, Moffett Field; MCAT Inst., San Jose, CA) Jul. 1993 9 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(Contract NCC2-616; NCC2-505)
(AIAA PAPER 93-2965) Copyright

The LU-SGS (lower upper symmetric Gauss Seidel) algorithm has been implemented into the Compressible Navier-Stokes, Finite Volume (CNSFV) code and validated with a multizonal Navier-Stokes simulation of a transonic turbulent flow around an Onera M6 transport wing. The convergence rate and robustness of the code have been improved and the computational cost has been reduced by at least a factor of 2 over the diagonal Beam-Warming scheme.

A93-48204*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
A SOLUTION-ADAPTIVE HYBRID-GRID METHOD FOR THE UNSTEADY ANALYSIS OF TURBOMACHINERY
SANJAY R. MATHUR (Iowa State Univ. of Science and Technology, Ames), NATERI K. MADAVAN (MCAT Inst.; NASA, Ames Research Center, Moffett Field, CA), and R. G. RAJAGOPALAN (Iowa State Univ. of Science and Technology, Ames) Jul. 1993 14 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(Contract NCA2-541)
(AIAA PAPER 93-3015) Copyright

A solution-adaptive method for the time-accurate analysis of two-dimensional flows in turbomachinery is described. The method employs a hybrid structured-unstructured zonal grid topology in conjunction with appropriate modeling equations and solution techniques in each zone. The viscous flow region in the immediate vicinity of the airfoils is resolved on structured O-type grids while the rest of the domain is discretized using an unstructured mesh of triangular cells. Implicit, third-order accurate, upwind solutions of the Navier-Stokes equations are obtained in the inner regions. In the outer regions, the Euler equations are solved using an explicit upwind scheme that incorporates a second-order reconstruction procedure. An efficient and robust grid adaptation strategy, including both grid refinement and coarsening capabilities, is developed for the unstructured grid regions. Grid adaptation is also employed to facilitate information transfer at the interfaces between unstructured grids in relative motion. Results for grid adaptation to various features pertinent to turbomachinery flows are presented. Good comparisons between the present results and experimental measurements and earlier structured-grid results are obtained.

A93-48247# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
LASER INTERFEROMETER SKIN-FRICTION MEASUREMENTS *OF CROSSING-SHOCK WAVE/TURBULENT* BOUNDARY-LAYER INTERACTIONS
T. J. GARRISON and G. S. SETTLES (Pennsylvania State Univ., University Park) Jul. 1993 14 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 Research supported by NASA refs

(Contract AF-AFOSR-89-0315; NGT-50952)
(AIAA PAPER 93-3072) Copyright

Wall shear stress measurements beneath crossingshock wave/turbulent boundary-layer interactions have been made for three interactions of different strengths. The interactions are generated by two sharp fins at symmetric angles of attack mounted on a flat plate. The shear stress measurements were made for fin angles of 7 and 11 degrees at Mach 3 and 15 degrees at Mach 4. The measurements were made using a Laser Interferometer Skin Friction (LISF) meter; a device which determines the wall shear by optically measuring the time rate of thinning of an oil film placed on the test model surface. Results of the measurements reveal high skin friction coefficients in the vicinity of the fin/plate junction and the presence of quasi-two-dimensional flow separation on the interaction centerline. Additionally, two Navier-Stokes computations, one using a Baldwin-Lomax turbulence model and one using a k-° model, are compared to the experimental results for the Mach 4, 15 degree interaction case. While the k-° model did a reasonable job of predicting the overall trend in portions of the skin friction distribution, neither computation fully captured the physics of the near surface flow in this complex interaction.
Author (revised)

A93-48277#
MODELLING THREE-DIMENSIONAL GAS-TURBINE-COMBUSTOR MODEL FLOW USING SECOND-MOMENT CLOSURE
C. A. LIN and C. M. LU (National Tsing Hua Univ., Hsinchu, Taiwan) Jul. 1993 9 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(Contract NSC-81-0401-E007-537)
(AIAA PAPER 93-3104) Copyright

Numerical predictions were applied to a gas-turbine combustor model flow where dilutions jets were injected radially inwards into a swirling flow, leading to a very strong interaction between the two streams. Effects of different inlet swirl level to the interior flow field were investigated numerically and the predicted mean and turbulence results were also contrasted with measurements. The present study demonstrates that the characteristics of the combustor flow are closely linked to the representation of the interaction between the swirl field and the jets. Diffusive transport was found to be highly influential, and this also increases the importance of turbulence representation. Comparisons with experimental measurements indicated that the stress model with an anisotropy modified e-source combined with quadratic approximation of convection fluxes represents the flow field reasonably well, in contrast to the k-epsilon model whose diffusive nature leads to an intense vortex core near the centerline region. Reduction of strength of the centerline recirculation zone due to the elevated level of swirl momentum transport from the swirler, was also well reproduced by the stress model variant.
Author (revised)

A93-48514
DYNAMIC ANALYSIS OF A GEAR DRIVE SYSTEM IN AEROENGINE
XIANGDONG YUAN and CHUANRONG ZHOU (Nanjing Aeronautical Inst., China) Journal of Aerospace Power (ISSN 1000-8055) vol. 8, no. 2 April 1993 p. 151-154. In CHINESE refs

A new technique of structural dynamic analysis especially for analysis of a gear drive system has been developed, which combines the principle of substructure analysis with the idea of structure modification. A gear stiffness model of the degrees of the freedom of the structure node in which the gear relation exists has also been developed. It has the advantages of both the method of substructure analysis and vibration reanalysis of modified structure. The natural frequencies and modes calculated by the present program are in quite good agreement with the results calculated by FEM. Author (revised)

A93-48518
EXPERIMENTAL STUDY ON HEAT TRANSFER OF SEPARATED IMPINGEMENT JETS IN SHORT DISTANCE
YING KANG, XUGUANG QIU, and WEI ZHOU (Beijing Univ. of Aeronautics and Astronautics, China) Journal of Aerospace Power (ISSN 1000-8055) vol. 8, no. 2 April 1993 p. 165-168. In CHINESE

In actual cooling construction of turbine blade the relative distance between circular jets c(n)/d(n) is less than 3 and the relative distance of nozzle exit to target surface is also less than 3. But the available empirical formulas were achieved on the basis of a very large range of these geometric parameters. Obviously, these formulas may be inaccurate in the practical narrow range of these parameters, in particular when the temperature of the turbine is very high, and on the surface of the blade exist many rows of film-cooling holes. So an experimental research on the heat transfer of impingement jets has been carried out in the actual range of the geometric parameters, and new empirical formulas which can be applied to the turbine blade of the advanced aeroengine have been derived. Author (revised)

A93-48601* National Aeronautics and Space Administration. Goddard Space Flight Center, Greenbelt, MD.
MAGNETIC BEARINGS FOR CRYOGENIC TURBOMACHINES
VICTOR IANNELLO and HERBERT SIXSMITH (Creare, Inc., Hanover, NH) *In* Advances in cryogenic engineering. Vol. 37B - Proceedings of the 1991 Cryogenic Engineering Conference, Univ. of Alabama, Huntsville, June 11-14, 1991 New York Plenum Press 1991 p. 809-816. refs
(Contract NAS5-30854; DE-AC01-87ER-80477)
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Magnetic bearings offer a number of advantages over gas bearings for the support of rotors in cryogenic turboexpanders and compressors. Their performance is relatively independent of the temperature or pressure of the process gas for a large range of conditions. Active magnetic bearing systems that use capacitive sensors have been developed for high speed compressors for use in cryogenic refrigerators. Here, the development of a magnetic bearing system for a miniature ultra high speed compressor is discussed. The magnetic bearing has demonstrated stability at rotational speeds exceeding 250,000 rpm. This paper describes the important features of the magnetic bearing and presents test results demonstrating its performance characteristics.

A93-48612
TEST RESULTS OF AN ORIFICE PULSE TUBE REFRIGERATOR
STEPHEN F. KRAL, DALLAS HILL, JON RESTIVO, JOSEPH JOHNSON (Astronautics Corp. of America, Astronautics Technology Center, Madison, WI), PETER CURWEN, WARREN WALDRON, and HOWARD JONES (Mechanical Technology, Inc., Latham, NY) *In* Advances in cryogenic engineering. Vol. 37B - Proceedings of the 1991 Cryogenic Engineering Conference, Univ. of Alabama, Huntsville, June 11-14, 1991 New York Plenum Press 1991 p. 931-937. refs
Copyright

An orifice pulse tube refrigerator has been designed, fabricated and tested. A hydraulically actuated diaphragm compressor, which allows direct determination of compressor PV work, dynamic pressure amplitudes and phase shifts, is used to drive the refrigerator. Test results are presented and compared to analytic predictions and design specifications. Sources of potential performance improvement are identified and future testing goals are discussed.

A93-48616
APPLICATION OF VANADIUM HYDRIDE COMPRESSORS FOR JOULE-THOMSON CRYOCOOLERS
R. C. BOWMAN, JR., B. D. FREEMAN (Aerojet, Electronic Systems Div., Azusa, CA), and J. R. PHILLIPS (Harvey Mudd College, Claremont, CA) *In* Advances in cryogenic engineering. Vol. 37B - Proceedings of the 1991 Cryogenic Engineering Conference, Univ.

of Alabama, Huntsville, June 11-14, 1991 New York Plenum Press 1991 p. 973-980. refs
Copyright

The Joule-Thomson expansion of hydrogen gas offers efficient and reliable cryocoolers to produce temperatures between 10 and 50 K. A critical component to the development of these devices is the metal hydride storage bed that provides a nonmechanical method to compress hydrogen gas via the reversible absorption by appropriate metals or alloys. A thermodynamic model has been used to calculate the impact of operational parameters such as input/output pressure ratios and bed temperature on energy balance and system efficiency. Detailed comparisons are reported for a compressor which utilizes vanadium metal as the sorbent for either hydrogen or deuterium where the unusually large isotope differences between the phase diagrams and thermal properties for VH(x) and VD(x) have been considered. The sensitivity of heat input requirements to the uncertainties in primary variables are described. Author (revised)

A93-48635
SLUSH HYDROGEN QUANTITY GAGING AND MIXING FOR THE NATIONAL AEROSPACE PLANE
R. S. RUDLAND, I. M. KROENKE, and A. R. URBACH (Ball Electro-Optics/Cryogenics Div., Boulder, CO) *In* Advances in cryogenic engineering. Vol. 37B - Proceedings of the 1991 Cryogenic Engineering Conference, Univ. of Alabama, Huntsville, June 11-14, 1991 New York Plenum Press 1991 p. 1157-1164. Research supported by Rockwell International Corp refs
Copyright

The National Aerospace Plane (NASP) design team has selected slush hydrogen as the fuel needed to power the high-speed ramjet-scramjet engines. Use of slush hydrogen rather than normal hydrogen provides significant improvements in density and cooling capacity for the aircraft. The loading of slush hydrogen in the NASP tank must be determined accurately to allow the vehicle size and weight to be kept to a minimum. A unique sensor developed at Ball to measure the slush density will be used in each region of the hydrogen tank to accurately determine the total mass of fuel loaded in the vehicle. The design, analysis, and test configuration for the mixing system is described in this paper. The mixing system is used to eliminate large-scale disturbances in the fluid produced by the large heat flux through the wall. The mixer also provides off-bottom suspension of the solids to create a more uniform slush mixture. The mixer design uses a pump to supply flow to an array of jets that produce mixing throughout the tank. Density sensors will be used in the test configuration to evaluate the mixing effectiveness. Author (revised)

A93-48806
AERODYNAMIC PHENOMENA IN HIGH PULSE REPETITION RATE XECL LASER
M. L. SENTIS, J. P. TRUONG, O. UTEZA, B. M. FORESTIER, B. L. FONTAINE, and PH. C. DELAPORTE (Inst. de Mecanique des Fluides, Marseille, France) *In* Lasers '91; Proceedings of the 14th International Conference on Lasers and Applications, San Diego, CA, Dec. 9-13, 1991 McLean, VA STS Press 1992 p. 748-755. refs
Copyright

The acoustic perturbations induced in the laser head by electrical excitation play a leading role in the limitation of high average power excimer laser development. The poor discharge quality due to a too high perturbation level between the electrodes limits the pulse rate frequency of that kind of lasers. The use of acoustic dampers allows to reduce the perturbation level and improve the laser performances. Nickel foam dampers have to be set closer as possible to the discharge zone. A 250 W XeCl laser has been demonstrated at a pulse repetition rate of 700 Hz without shot to shot energy fluctuation by using acoustic dampers.

A93-48825
RELIABILITY AND DURABILITY PROBLEMS [PROBLEMY NADEZHNOSTI I DOLGOVECHNOSTI]
B. V. BOJTSOV, ED. and V. Z. KONDRASHOV, ED. (Moskovskij Aviatsionnyj Inst., Moscow, Russia) Moscow Moskovskij Aviatsionnyj Institut 1992 72 p. In RUSSIAN No individual items are abstracted in this volume
Copyright

The papers presented in this volume focus on methods for determining the stress-strain state of structures and machines and evaluating their reliability and service life. Specific topics discussed include a method for estimating the service life of thin-sheet automotive structures, stressed state at the tip of small cracks in anisotropic plates under biaxial tension, evaluation of the elastic-dissipative characteristics of joints by vibrational diagnostics methods, and calculation of the reliability of ceramic structures for arbitrary long-term loading programs. Papers are also presented on the effect of prior plastic deformation on fatigue damage kinetics, axisymmetric and local deformation of cylindrical parts during finishing-hardening treatments, and adhesion of polymers to diffusion coatings on steels. AIAA

A93-48850
A STUDY OF THE INTERACTION OF A NONSTATIONARY SHOCK WAVE WITH A BOUNDARY LAYER ON A PLATE IN THE TRANSITION REGIME [ISSLEDOVANIE VZAIMODEJSTVIYA NESTATSIONARNOGO SKACHKA UPLOTNENIYA S POGRANICHNYM SLOEM NA PLASTINE NA PEREKHODNOM REZHIME]
S. V. KUIMOV and V. S. KHLEBNIKOV Rossijskaya Akademiya Nauk, Izvestiya, Mekhanika Zhidkosti i Gaza (ISSN 0568-5281) no. 6 Nov.-Dec. 1992 p. 174-180. In RUSSIAN refs
Copyright

The characteristics of supersonic flow in the region of interaction of a fluctuating shock wave with a boundary layer on a plate in the transition regime were investigated experimentally in a wind tunnel with an axisymmetric test section and flow heating at Mach 3. New three-dimensional periodic structures in the interaction region are identified. The structures are very similar to Taylor-Goertler vortices formed in the separation and reattachment regions in the turbulent regime. AIAA

A93-48909
EFFECT OF THE WING PLANFORM ON THE OPTIMAL DEFORMATION OF THE MIDDLE SURFACE [VLIYANIE FORMY KRYLA V PLANE NA OPTIMAL'NUYU DEFORMATSIYU SREDINNOJ POVERKHNOSTI]
M. I. NIKOLAEV *In* Problems in the aerodynamics of flight vehicles and their parts Moscow Moskovskij Aviatsionnyj Institut 1991 p. 47-52. In RUSSIAN refs
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The effect of the wing planform and its geometrical parameters, such as aspect ratio, taper, and sweep angle, on the optimal deformations and wing twist are calculated for wings of rectangular planform and delta wings of aspect ratios 3, 4, 6, and 8. It is found that the wing planform and its geometrical parameters do not affect the deformation mode of the middle surface. The determining factor is thought to be the position of the pressure center line over the wing span. AIAA

A93-48911
EFFECT OF FLEXURAL AND ROTATIONAL WING OSCILLATIONS ON THE PREVENTION OF FLOW SEPARATION [VLIYANIE IZGIBNYKH I VRASHCHATEL'NYKH KOLEBANIJ KRYLA NA LIKVIDATSIYU OTRYVA POTOKA]
A. YA. VASIL'EV *In* Problems in the aerodynamics of flight vehicles and their parts Moscow Moskovskij Aviatsionnyj Institut 1991 p. 57-63. In RUSSIAN refs
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An approximate method is developed for calculating the regimes of wing oscillations that eliminate flow separation. The method is based on the assumption that suction generated during the downward motion of the trailing edge of a wing and eliminating flow separation will be also sufficient to eliminate flow separation during the upward motion due to the inertial properties of the medium. The validity of the approach is demonstrated. AIAA

A93-49000
AUTOMATED DESIGN AND FABRICATION OF RADIO-ELECTRONIC CIRCUITS [AVTOMATIZATSIYA KONSTRUIROVANIYA I TEKHNOLOGICHESKOJ PODGOTOVKI REHS]
V. A. SOROKOPUD, ED. Moscow Moskovskij Aviatsionnyj Institut 1992 88 p. In RUSSIAN No individual items are abstracted in this volume
Copyright

The papers presented in this volume summarize recent developments in the computer-aided design of radio-electronic circuits and implementation of CAD systems for circuit design using microcomputers. In particular, attention is given to the automation of the design of specialized products at the early stages of design, a method for solving the radio-electronic circuit layout problem using a parametric reliability criterion, and models for nonorthogonal tracing. Papers are also included on a concept for the design of flexible microprocessor systems for the control of aircraft equipment, new heat-dissipating substrates for integrated circuits, and optimization of a process for producing cermet tuning resistors. AIAA

A93-49007
FLOW AND HEAT TRANSFER IN A TURBULENT BOUNDARY LAYER THROUGH SKEWED AND PITCHED JETS
XIN ZHANG and MICHAEL W. COLLINS (City Univ., London, United Kingdom) AIAA Journal (ISSN 0001-1452) vol. 31, no. 9 Sept. 1993 p. 1590-1599. refs
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A study was carried out of longitudinal vortices in a low speed turbulent boundary layer due to small jets. The jet was pitched at 45 deg and skewed between 0 and 120 deg. The effects of jet velocity ratio from 0 to 3.0 and skew angle from 0 to 120 deg were addressed. Mass-averaged Navier-Stokes equations were solved using computational fluid dynamics and heat transfer. Turbulence closure was achieved using k-epsilon model. Three types of vortex production were noted at various jet velocity ratios. When a longitudinal vortex is positioned at the edge or in the outer region of the boundary layer, optimal effects of the flow and heat transfer control were achieved. When the vortex lay deeply in the boundary layer, the effects on heat transfer control could be detrimental. When the jet penetrated the boundary layer, the favorable effects of the vortex on control were reduced due to the larger distance away from the surface. Significant improvements of vortex strength and heat transfer were seen between skew angle 0 and 45 deg, although in 45-120 deg the improvements were marginal. Author (revised)

A93-49017
STABILITY OF FLUTTERED PANELS SUBJECTED TO IN-PLANE HARMONIC FORCES
T. H. YOUNG and F. Y. CHEN (National Taiwan Inst. of Technology, Taipei) AIAA Journal (ISSN 0001-1452) vol. 31, no. 9 Sept. 1993 p. 1667-1673. refs
(Contract NSC-80-0401-E011-07)
Copyright

This paper presents an investigation into the stability of a fluttered panel acted on by an in-plane harmonic force. The in-plane force is assumed to be slow varying and small in magnitude compared to the aerodynamic force. Because of this small harmonic force, the system may become stable although the aerodynamic force exceeds its critical value. In this work, the finite element formulation is applied to obtain the discretized system equations. The autonomous terms in the system equations are then uncoupled by transforming these terms into Jordan canonical forms. Finally, the method of multiple scales is used to solve for analytical solutions of the system. The effects of system parameters on the changes of stability boundaries are studied numerically.

A93-49026
EFFECTS OF A REAR STAGNATION JET ON THE WAKE BEHIND A CYLINDER
R. DUKE, B. SHRADER, and J. MO (Memphis State Univ., TN) AIAA Journal (ISSN 0001-1452) vol. 31, no. 9 Sept. 1993 p. 1727-1729. Research supported by Memphis State Univ refs
Copyright

A visualization of the flow past a cylinder with and without a rear stagnation jet has been performed. Results show that the massively separated wake behind the cylinder can be completely eliminated and the flow around the cylinder behaved as inviscid flow by a rear stagnation jet with a minimum dimensionless parameter. AIAA

A93-49240
DRAG CHARACTERISTICS OF EXTRA-THIN-FIN-RIBLETS IN AN AIR FLOW CONDUIT
Z. Y. WANG (Xian Jiaotong Univ., China) and J. JOVANOVIC (Erlangen-Nuernberg, Univ., Erlangen, Germany) ASME, Transactions, Journal of Fluids Engineering (ISSN 0098-2202) vol. 115, no. 2 June 1993 p. 222-226. refs
Copyright

An experimental study of riblets with extra thin fins (5 microns thick) is presented. A drag reduction of 2-3 percent per quarter conduit wall is indicated when h(+) is around 3-15 in a square section of air flow conduit lined with the extra-thin-fin-riblets (ETFR) on one side wall. The pressure distributions along the conduit indicate the influence of the riblet front step on the drag reduction performance in the conduit flow. The measurement methods and the detailed structure of the ETFR are also discussed.
Author (revised)

A93-49346
HIGH SPEED DATABUS EVALUATION - FURTHER WORK
ANDREW J. LEE (ERA Technology, Ltd., Leatherhead, United Kingdom) *In* 1993 Aerospace Avionic Systems Division Conference, 3rd, Denver, CO, Apr. 22, 1993, Proceedings Warrendale, PA Society of Automotive Engineers, Inc. 1993 p. 49-52. refs
(SAE PAPER 931597) Copyright

Communication elements of avionic architectures and tools for assessing their capabilities are discussed with emphasis placed on the most recent study aimed at understanding and using of high speed databuses. The latter include Linear Token Passing Bus, High Speed Ring Bus, and Fiber Distributed Data Interface. Simulation techniques for evaluating the performance of communication system elements provide a cost-effective and time efficient method of assessment. Further work is aimed at providing a unique capability capable of simulating the hardware and software functionality as well as communication elements. This tool will be used to assess complete avionic architectures. AIAA

A93-49396
A SURVEY OF POSITION TRACKERS
KENNETH MEYER, HUGH L. APPLEWHITE (Piltdown, Inc., Beaverton, OR), and FRANK A. BIOCCA (North Carolina Univ., Chapel Hill) Presence: Teleoperators and Virtual Environments (ISSN 1054-7460) vol. 1, no. 2 Spring 1992 p. 173-200. refs
Copyright

This paper is a survey of position-tracking technologies and their use in virtual reality (VR) applications. A framework is established to evaluate the suitability of a position-tracking implementation for virtual reality use. Mechanical, optical, magnetic, and acoustic implementations are discussed with examples of each. Also, the effect of position tracking on a virtual reality user is discussed, especially with regard to the position tracker's role as a cause of simulation sickness. A catalog of implementations and uses is included in an appendix.

A93-49455
SOURCES AND DETECTORS FOR FIBER COMMUNICATIONS; PROCEEDINGS OF THE MEETING, BOSTON, MA, SEPT. 8, 9, 1992
STEPHEN D. HERSEE, ED. (New Mexico Univ., Albuquerque) Bellingham, WA Society of Photo-Optical Instrumentation

Engineers (SPIE Proceedings. Vol. 1788) 1993 194 p. No individual items are abstracted in this volume
(SPIE-1788; ISBN 0-8194-0967-7) Copyright

Various papers on sources and detectors of fiber communications are presented. Individual topics addressed include: Development of GaInAsP/GaAs strained-layer quantum-well diode lasers, InGaAs/AlGaAs strained quantum-well die lasers, AlGaInP materials grown by elemental-source molecular beam epitaxy, low-threshold visible laser diodes for high-power applications, temperature-engineered growth of low-threshold lasers on nonplanar substrates, shadow-masked growth and its applications, modeling of transport and film growth over patterned substrates, integration of InP grating-based DEMUX with pin array for monolithic WDM detection. Also discussed are: InGaAs/GaAs strained quantum-well lasers, application of multichip modules to advanced avionics systems, dual pin photodetector with very low parasitic series interconnection, high-performance four-wavelength laser transmitter, characterization of noise in semiconductor lasers an its influence in a practical FSK link, theoretical limitations of broadband matching networks in PIN-FET receivers. AIAA

A93-49470
COMPACT HIGH RELIABILITY FIBER COUPLED LASER DIODES FOR AVIONICS AND RELATED APPLICATIONS

DAVID R. DANIEL, GORDON S. RICHARDS, ADRIAN P. JANSSEN, STEPHEN E. H. TURLEY (Northern Telecom Optoelectronics, Paignton, United Kingdom), and THOMAS E. STOCKTON (Northern Telecom Optoelectronics, Thousand Oaks, CA) *In* Specialty fiber optic systems for mobile platforms and plastic optical fibers; Proceedings of the Meeting, Boston, MA, Sept. 9-11, 1992 Bellingham, WA Society of Photo-Optical Instrumentation Engineers 1993 p. 142-148.
Copyright

This paper describes a newly developed compact high reliability fiber coupled laser diode which is capable of providing enhanced performance under extreme environmental conditions including a very wide operating temperature range. Careful choice of package materials to minimize thermal and mechanical stress, used with proven manufacturing methods, has resulted in highly stable coupling of the optical fiber pigtail to a high performance MOCVD-grown Multi-Quantum Well laser chip. Electro-optical characteristics over temperature are described together with a demonstration of device stability over a range of environmental conditions. Real time device lifetime data is also presented.

A93-49505
HEAT TRANSFER AND FLUID MECHANICS INSTITUTE, 33RD, CALIFORNIA STATE UNIV., SACRAMENTO, JUNE 3, 4, 1993, PROCEEDINGS

FREDERICK H. REARDON, ED. (California State Univ., Sacrameno) Sacramento, CA California State University (ISSN 0097-059X) 1993 303 p. For individual items see A93-49506 to A93-49514
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The present volume on heat transfer and fluid mechanics discusses vortex shedding and pressure oscillations in rockets and ramjets, chemically reactive turbulent flow mixing mechanisms, a computational study of atomization in a high-speed gas flow, and the development and verification of a computer model of cross-flow atomization. Attention is given to viscous liquid flow heating, a method of local corrections for high-speed viscous flows, an experimental study of the transient temperature distributions in concrete, and the thermal stability of two horizontal fluid layers with radiative heating from above. Topics addressed include the effect of molecular diffusion on the scalar field injet mixing, the effect of scattering on the total emittance from an isothermal gas-particle mixture, heat transfer to a bubble suspended in a liquid layer near a solid plate, and a finite analytic solution of Burger's equation using a node moving algorithm. AIAA

A93-49523
COMPUTATIONAL METHODS FOR VISCOUS HYPERSONIC FLOWS

D. HAENEL (Univ. Duisburg Gesamthochschule, Germany) *In* Computational methods in hypersonic aerodynamics Southampton, United Kingdom/Dordrecht, Netherlands Computational Mechanics Publications/Kluwer Academic Publishers 1992 p. 29-79. refs
Copyright

This paper is concerned with computational methods for the solution of the Navier-Stokes equations for hypersonic flows. The governing equations and relations for equilibrium flow are described in the first part. Their numerical formulation is outlined including a brief consideration of the conservative discretization, the evolution of the numerical fluxes and of typical methods of solution. As a further topic the influence of the numerical damping on the solution is discussed demonstrated for steady-state solutions of the Navier-Stokes equations. The special properties of hypersonic, viscous flows and the resulting numerical problems are considered finally.

A93-49527
EFFICIENT MULTIGRID COMPUTATION OF STEADY HYPERSONIC FLOWS

B. KOREN and P. W. HEMKER (Center for Mathematics and Computer Science, Amsterdam, Netherlands) *In* Computational methods in hypersonic aerodynamics Southampton, United Kingdom/Dordrecht, Netherlands Computational Mechanics Publications/Kluwer Academic Publishers 1992 p. 203-231. Research supported by ESA refs
Copyright

Remedies are presented for overcoming problems wherein Newton iteration as a local relaxation procedure and nonlinear multigrid iteration as an acceleration procedure may both easily fail in steady hypersonic flow computations. The equations considered are the steady, 2D Navier-Stokes equations; they are discretized by an upwind finite volume method. Collective point Gauss-Seidel relaxation is applied as the standard smoothing technique. Collective point Gauss-Seidel relaxation is reconsidered and improved; a divergence monitor is introduced and in case of divergence a switch is made to a local explicit time-stepping technique. Satisfactory single-grid convergence results are shown for the computation of a hypersonic reentry flow around a blunt forebody with canopy. For the test cases considered, the most significant improvement comes from the upwind prolongation rather than from the upwind restriction and the defect damping. AIAA

A93-49663#
CORRELATION OF DROPLET BEHAVIOR WITH GAS-PHASE STRUCTURES IN A GAS TURBINE COMBUSTOR

H. Y. WANG, V. G. MCDONNELL, and G. S. SAMUELSEN (California Univ., Irvine) Jun. 1993 12 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Research supported by GE Aircraft Engines refs
(AIAA PAPER 93-1767) Copyright

The droplet-air interaction is studied downstream of the fuel injector-air swirler ('swirl cup') assembly of a CFM56 gas turbine combustor via phase Doppler interferometry and flow visualization. Droplet behavior is represented semi-quantitatively via a new approach using droplet velocity probability density functions and droplet size-velocity correlations. This information adds insight to the local behavior of droplets which has been disregarded because of a lack of appropriate diagnostics and the time required for post-data processing. In addition to the time-averaged droplet mean and rms velocities, droplet behavior including droplet spatial evolution and its correlation with the structures of the aerodynamic flow field, are identified. This study reveals that (1) droplet dispersion is dominated by the gas-phase flow field characteristics, (2) the droplet behavior and its evolution can be correlated with the large structures of the gas-phase flow field, and (3) intense interaction exists between the gas and dispersed phases.
Author (revised)

A93-49707#
SYNCHRONOUS X-RAY SINOGRAPHY FOR NONDESTRUCTIVE IMAGING OF TURBINE ENGINES UNDER LOAD
T. KIRCHNER (Foster-Miller, Inc., Waltham, MA), P. BURSTEIN (Skiametrics, Inc., Winchester, MA), J. YOUNGBERG (Perceptics Corp., Salt Lake City, UT), and D. WATERS (Bio-Imaging Research, Inc., Lincolnshire, IL) Jun. 1993 7 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993
(Contract DTRS57-92-C-00012)
(AIAA PAPER 93-1819) Copyright

The Spin Synchronous X-ray Sinography (SXS) System presents the first true imaging device that can see inside an operating aircraft turbine engine and remove the overlying mechanical complexity that impedes normal X-ray imaging techniques. The SXS presents a crisp cross-sectional image of the interior of a spinning turbine with spatial and contrast resolution fine enough to find small cracks. A demonstration of the technique has been conducted and preliminary images of the center of a spinning turbine are presented.

A93-49714#
NUMERICAL ANALYSIS OF HIGH ASPECT RATIO COOLING PASSAGE FLOW AND HEAT TRANSFER
F. LEBAIL and M. POPP (Deutsche Aerospace AG, Munich, Germany) Jun. 1993 14 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-1829) Copyright

A program for three-dimensional flow and heat transfer analysis in a rocket engine cooling channel of high aspect ratio is described. The program, which is based on the parabolized Navier-Stokes equations, was validated by comparing flow and heat transfer calculations with measurement data as found in the literature. Calculations were performed for cooling channel flow of an actual 100 bar engine. Calculated bulk temperature rise and pressure drop data agree well with data obtained from test results. A parameter study shows the effects of turbulence intensity, wall surface roughness, heat transfer boundary condition, and near-wall flow model. It is shown that the program can be successfully used for three-dimensional analysis of flow and heat transfer in rocket engine cooling channels. It is sufficiently CPU-time efficient and easy to handle to be employed in support of the design process of present and future rocket engine combustion chambers.

A93-49826# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
UNSTEADY, THREE-DIMENSIONAL, NAVIER-STOKES SIMULATIONS OF MULTISTAGE TURBOMACHINERY FLOWS
KAREN L. GUNDY-BURLET (NASA, Ames Research Center, Moffett Field, CA), MAN M. RAI (NASA, Langley Research Center, Hampton, VA), and NATERI K. MADAVAN (NASA, Ames Research Center, Moffett Field, CA) Jun. 1993 12 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-1979) Copyright

Hub corner stall regions, endwall boundary layers, tip leakage flows and airfoil wakes combine to form the 3D flowfields found in axial turbomachines. Turbomachinery flow fields are also inherently unsteady because of the relative motion between rotor and stator airfoils. This relative motion causes complex time-varying aerodynamic interactions to occur between the different aerodynamic structures and the rotor and stator airfoils. It is necessary to understand the 3D unsteady aerodynamics associated with these interactions in order to design turbomachines that are both lightweight and compact as well as reliable and efficient. The current study uses a time-accurate 3D thin-layer Navier-Stokes zonal approach to investigate the unsteady aerodynamics of multistage turbines and compressors. Relative motion between rotor and stator airfoils is accounted for by the use of systems of patched and overlaid grids. Time-averaged surface pressures, surface flow visualizations, and time-averaged flow field contours have been computed for a 1 1/2-stage turbine and are in good agreement with experimental data. This favorable comparison represents an initial validation of the current method for unsteady computations of multistage turbomachinery flows.

Author (revised)

A93-49839#
HYSTERESIS AND BRISTLE STIFFENING EFFECTS OF CONVENTIONAL BRUSH SEALS
P. BASU, A. DATTA, R. JOHNSON, R. LOEWENTHAL, and J. SHORT (EG&G Fluid Components Technology Group, Cranston, RI) Jun. 1993 9 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(Contract F33615-90-C-2001)
(AIAA PAPER 93-1996)

Extensive testing of conventional brush seals has identified the phenomena of bristle 'hysteresis' and 'stiffening' with pressure as their two major drawbacks. Subsequent to any differential movement of the runner into the bristle pack due to its radial excursions or centrifugal/thermal growths, the displaced bristles do not recover against the frictional forces between them and the backing plate. As a result, a significant leakage increase is observed following any runner movement. Furthermore, the bristle pack exhibits a considerable stiffening effect with the application of pressure. This phenomenon adversely affects the life of the seal and the runner due to a highly increased mechanical contact pressure at the sliding interface. In comparison with these conventional design seals, the characteristics of an improved design, known as the 'low hysteresis' design, are presented here. This design shows a substantially lower degree of the detrimental effects mentioned above. This type of seal can maintain its reduced leakage characteristics throughout the running cycle with runner excursions and growths. The bristles also do not show any stiffening, up to a certain pressure threshold. Therefore, this seal also has a potential for a longer life than a brush seal of conventional design.

A93-49840#
TESTING OF A HIGH PERFORMANCE COMPRESSOR DISCHARGE SEAL
JOHN H. MUNSON (General Motors Corp., Allison Gas Turbine Div., Indianapolis, IN) Jun. 1993 10 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Research supported by U.S. Navy refs
(AIAA PAPER 93-1997) Copyright

A gas lubricated film riding face seal (FRFS) is being developed for use in an advanced subsonic demonstrator engine. This seal will replace the multiple sets of labyrinth seals currently used to seal the compressor discharge air from the engine secondary flow system. The described program consisted of a design, fabrication, and test evaluation phase. This paper deals with testing and results of the rig evaluation of the seals. Several alternative hydrostatic and hydrodynamic FRFS designs were considered in the design phase. Film stiffness, leakage, and heat generation were selected to be the most important design criteria. Using these criteria, hydrodynamic seals proved superior to the hydrostatic designs. Spiral groove design and Rayleigh step pad type seals were selected for detail design and fabrication. Testing was performed in an advanced seal test rig. Both seals were successfully demonstrated. Testing included operation to approximately 700 ft/sec relative velocity, 500 psi pressure differential, and temperatures of at least 1200 F. Noncontacting operation and low leakage rates were demonstrated by both seals.

Author (revised)

A93-49901*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
COMPUTATIONS OF SPRAY, FUEL-AIR MIXING, AND COMBUSTION IN A LEAN-PREMIXED-PREVAPORIZED COMBUSTOR

A. DASGUPTA, Z. LI, T. I.-P. SHIH (Carnegie Mellon Univ., Pittsburgh, PA), K. KUNDU (NASA, Lewis Research Center, Cleveland, OH), and J. M. DEUR (Sverdrup Technology, Inc., Brook Park, OH) Jun. 1993 13 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(Contract NAG3-1009)
(AIAA PAPER 93-2069) Copyright

A code was developed for computing the multidimensional flow, spray, combustion, and pollutant formation inside gas turbine combustors. The code developed is based on a Lagrangian-Eulerian formulation and utilizes an implicit finite-volume method. The focus of this paper is on the spray part of the code (both formulation and algorithm), and a number of issues related to the computation of sprays and fuel-air mixing in a lean-premixed-prevaporized combustor. The issues addressed include: (1) how grid spacings affect the diffusion of evaporated fuel, and (2) how spurious modes can arise through modelling of the spray in the Lagrangian computations. An upwind interpolation scheme is proposed to account for some effects of grid spacing on the artificial diffusion of the evaporated fuel. Also, some guidelines are presented to minimize errors associated with the spurious modes.

A93-49906*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
ADVANCED INSTRUMENTATION FOR NEXT-GENERATION AEROSPACE PROPULSION CONTROL SYSTEMS
S. BARKHOUDARIAN, G. S. CROSS (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA), and CARL F. LORENZO (NASA, Lewis Research Center, Cleveland, OH) Jun. 1993 13 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2079) Copyright

New control concepts for the next generation of advanced air-breathing and rocket engines and hypersonic combined-cycle propulsion systems are analyzed. The analysis provides a database on the instrumentation technologies for advanced control systems and cross matches the available technologies for each type of engine to the control needs and applications of the other two types of engines. Measurement technologies that are considered to be ready for implementation include optical surface temperature sensors, an isotope wear detector, a brushless torquemeter, a fiberoptic deflectometer, an optical absorption leak detector, the nonintrusive speed sensor, and an ultrasonic triducer. It is concluded that all 30 advanced instrumentation technologies considered can be recommended for further development to meet need of the next generation of jet-, rocket-, and hypersonic-engine control systems. AIAA

A93-49963#
INITIAL TEST RESULTS OF 40,000 HORSEPOWER FAN DRIVE GEAR SYSTEM FOR ADVANCED DUCTED PROPULSION SYSTEMS
M. E. MCCUNE (Pratt & Whitney Group, East Hartford, CT) Jun. 1993 10 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2146) Copyright

Analytical and model testing during the past several years by industry and NASA have shown projections for further improvements in the next generation of turbofan engines: the advanced ducted propulsion (ADP) system. The ADP offers the fundamental propulsive benefit of high bypass ratio resulting in significant reduction in fuel consumption and noise. One of the key enabling technologies for the ADP is the fan drive gear system (FDGS). After describing the FDGS configuration, the specific technical goals for a back-to-back rig test program are identified and results are presented from the 40,000 horsepower FDGS test program, which demonstrated operation with over 41,000 horsepower, efficiency in excess of the 99.3 percent goal, and successful completion of endurance testing. Author (revised)

A93-49966*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
LOW-NOISE, HIGH-STRENGTH, SPIRAL-BEVEL GEARS FOR HELICOPTER TRANSMISSIONS
DAVID G. LEWICKI, ROBERT F. HANDSCHUH (U.S. Army, Research Lab.; NASA, Lewis Research Center, Cleveland, OH), ZACHARY S. HENRY (Bell Helicopter Textron, Inc., Fort Worth, TX), and FAYDOR L. LITVIN (Illinois Univ., Chicago) Jun. 1993 14 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Previously announced in STAR as N93-23019 refs
(AIAA PAPER 93-2149)

Improvements in spiral-bevel gear design were investigated to support the Army/NASA Advanced Rotorcraft Transmission program. Program objectives were to reduce weight by 25 percent, reduce noise by 10 dB, and increase life to 5000 hr mean-time-between-removal. To help meet these goals, advanced-design spiral-bevel gears were tested in an OH-58D helicopter transmission using the NASA 500-hp Helicopter Transmission Test Stand. Three different gear designs tested included: (1) the current design of the OH-58D transmission except gear material X-53 instead of AISI 9310; (2) a higher-strength design the same as the current but with a full fillet radius to reduce gear tooth bending stress (and thus, weight); and (3) a lower-noise design the same as the high-strength but with modified tooth geometry to reduce transmission error and noise. Noise, vibration, and tooth strain tests were performed and significant gear stress and noise reductions were achieved.

A93-49968#
HIGH SPEED, HEAVILY LOADED AND PRECISION AIRCRAFT TYPE EPICYCLIC GEAR SYSTEM DYNAMIC ANALYSIS OVERVIEW AND SPECIAL CONSIDERATIONS
K. BUYUKATAMAN (Pratt & Whitney Group, East Hartford, CT) and K. KAZEROUNIAN (Connecticut Univ., Storrs) Jun. 1993 9 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2151) Copyright

Dynamic analysis of reliable, lightweight, high speed and high power density epicyclic gears requires special effort to predict their maximum power transmitting capacity. This paper focuses on single-stage epicyclic gears of this category. The true definition of gear system power transmitting capacity requires understanding and proper evaluation of its dynamic capacity, as well as a state-of-the-art elasto-dynamic simulation which responds to input data as a fully instrumented test cell would. This paper presents an overview of key considerations, a background of dynamic system simulation, and emphasizes what needs to be done to make an epicyclic gear system successful in responding to tomorrow's challenging propulsion needs.

A93-50009# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
A K-OMEGA MULTIVARIATE BETA PDF FOR SUPERSONIC TURBULENT COMBUSTION
G. A. ALEXOPOULOS, R. A. BAURLE, and H. A. HASSAN (North Carolina State Univ., Raleigh) Jun. 1993 12 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(Contract NAG1-244; NAGW-1331)
(AIAA PAPER 93-2197) Copyright

In a recent attempt by the authors at predicting measurements in coaxial supersonic turbulent reacting mixing layers involving H2 and air, a number of discrepancies involving the concentrations and their variances were noted. The turbulence model employed was a one-equation model based on the turbulent kinetic energy. This required the specification of a length scale. In an attempt at detecting the cause of the discrepancy, a coupled k-omega joint probability density function (PDF) is employed in conjunction with a Navier-Stokes solver. The results show that improvements resulting from a k-omega model are quite modest.
Author (revised)

A93-50010# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
MODELING OF TURBULENT SUPERSONIC H2-AIR COMBUSTION WITH A MULTIVARIATE BETA PDF
R. A. BAURLE and H. A. HASSAN (North Carolina State Univ., Raleigh) Jun. 1993 13 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(Contract NAG1-244; NAGW-1331)
(AIAA PAPER 93-2198) Copyright

Recent calculations of turbulent supersonic reacting shear flows using an assumed multivariate beta PDF (probability density function) resulted in reduced production rates and a delay in the onset of combustion. This result is not consistent with available measurements. The present research explores two possible reasons for this behavior: use of PDF's that do not yield Favre averaged quantities, and the gradient diffusion assumption. A new multivariate beta PDF involving species densities is introduced which makes it possible to compute Favre averaged mass fractions. However, using this PDF did not improve comparisons with experiment. A countergradient diffusion model is then introduced. Preliminary calculations suggest this to be the cause of the discrepancy. Author (revised)

A93-50015#
EXPERIMENTAL DETERMINATION OF THE BULK SWIRL ATTENUATION BETWEEN TWO AXIAL STATIONS IN THE LM2500 INLET BELLMOUTH
T. M. HIGGINS and R. J. FREULER (Ohio State Univ., Columbus) Jun. 1993 11 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2203) Copyright

The LM2500 gas turbine engine is used for propulsion in a variety of marine vessels. When a gas turbine engine is placed within a confined environment, such as in an enclosure in the hull of a marine vessel, it is unreasonable to expect to achieve a perfectly uniform airflow environment entering the engine inlet, and thus, limits are placed on the swirl angle of the incoming flow. Swirl limits are set at 5-deg preswirl and 12-deg counterswirl at the 'compressor face plane' for the LM2500. In full-scale tests performed in the field (shipboard during sea trials), a 'bellmouth measurement plane' was defined somewhat forward of the compressor face plane. The relationship of the swirl angles between the bellmouth measurement plane and the compressor face plane has been under some debate for the past several years. Historically, an attenuation factor of 0.5 has been used, but a more recent analytical study suggested an attenuation factor of 0.76 was more appropriate. A one-fifth scale model of the LM2500 bellmouth was constructed along with a swirl generator system capable of producing either a uniform straight or a uniformly swirling flow and delivering it to the LM2500 bellmouth inlet. Based on the results of this study, the use of an attenuation factor of 0.5 is justified. Author (revised)

A93-50042#
FLOW INVESTIGATION OF A LOW-SPEED-OPERATED CENTRIFUGAL COMPRESSOR OVER A FLOW RANGE INCLUDING ZERO FLOW
A. ENGEDA and N. K. AMINENI (Michigan State Univ., East Lansing) Jun. 1993 6 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2240) Copyright

A centrifugal impeller with back-sweep-blades, followed by a vaneless diffuser, r/r(2) = 2.5, was tested at one-fifth of its design speed. As expected, its overall performance curve consisting of negative and positive slopes had great similarity to the performance of centrifugal pumps. It showed no sign of significant instability as it was run up to shut-off-condition. A centrifugal compressor inducer is known to be very sensitive to incidence change. In this investigation, it was expected that significant incidence losses and eventually incidence stall due to the high incidence, resulting from the wider range of operation, could be generated. In addition, the diffuser was also expected to be a source of instability. However, both the inducer and the diffuser were relatively stable; the flow mechanism responsible for this is examined. Author (revised)

A93-50047#
ADVANCED COMPOSITE FIBER/METAL PRESSURE VESSELS FOR AIRCRAFT APPLICATIONS
ALECK PAPANICOLOPOULOS (Harsco Corp., Plant City Steel Div., Pomona, CA) Jun. 1993 10 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2246) Copyright

Structural Composites Industries has developed, qualified, and delivered a number of high performance carbon epoxy overwrapped/seamless aluminum liner pressure vessels for use in military aircraft where low weight, low cost, high operating pressure and short lead time are the primary considerations. This paper describes product design, development, and qualification for a typical program. The vessel requirements included a munitions insensitivity criterion as evidenced by no fragmentation following impact by a .50 cal tumbling bullet. This was met by the development of a carbon-Spectra hybrid composite overwrap on a thin-walled seamless aluminum liner. The same manufacturing, inspection, and test processes that are used to produce lightweight, thin walled seamless aluminum lined carbon/epoxy overwrapped pressure vessels for satellite and other space applications were used to fabricate this vessel. This report focuses on the results of performance in the qualification testing. Author (revised)

A93-50050*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
HIGH REYNOLDS NUMBER AND TURBULENCE EFFECTS ON AERODYNAMICS AND HEAT TRANSFER IN A TURBINE CASCADE
FREDERICK C. YEH, STEVEN A. HIPPENSTEELE, and G. J. VANFOSSEN (NASA, Lewis Research Center, Cleveland, OH) Jun. 1993 16 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Previously announced in STAR as N93-29157 refs
(AIAA PAPER 93-2252) Copyright

Experimental data on pressure distribution and heat transfer on a turbine airfoil were obtained over a range of Reynolds numbers from 0.75 to 7.5 million and a range of turbulence intensities from 1.8 to about 15 percent. Fundamental heat transfer and pressure distribution data are obtained over a wide range of high Reynolds numbers and to extend the heat transfer data base to include the range of Reynolds numbers encountered in the SSME turbopump turbines. The results obtained indicated that Reynolds number and turbulence intensity have a large effect on both the transition from laminar to turbulent flow and the resulting heat transfer. For a given turbulence intensity, heat transfer for all Reynolds numbers at the leading edge can be correlated with the Frossling number developed for lower Reynolds numbers. For a given turbulence intensity, heat transfer for the airfoil surfaces downstream of the leading edge can be approximately correlated with a dimensionless parameter. Comparison of the experimental results were also made with a numerical solution from a 2D Navier-Stokes code.
Author (revised)

A93-50084*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
ENGINEERING SCIENCE RESEARCH ISSUES IN HIGH POWER DENSITY TRANSMISSION DYNAMICS FOR AEROSPACE APPLICATIONS
RAJENDRA SINGH and DONALD R. HOUSER (Ohio State Univ., Columbus) Jun. 1993 12 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Research supported by Gear Dynamics and Gear Noise Research Lab. Industrial Consortium refs
(Contract DAAL03-92-G-0120; NAG3-773)
(AIAA PAPER 93-2299) Copyright

This paper discusses analytical and experimental approaches

that will be needed to understand dynamic, vibro-acoustic and design characteristics of high power density rotorcraft transmissions. Complexities associated with mathematical modeling of such systems will be discussed. An overview of research work planned during the next several years will be presented, with emphasis on engineering science issues such as gear contact mechanics, multi-mesh drive dynamics, parameter uncertainties, vibration transmission through bearings, and vibro-acoustic characteristics of geared rotor systems and housing-mount structures. A few examples of work in progress are cited.

A93-50118#
PARTICULATES AND AEROSOLS CHARACTERIZED IN REAL TIME FOR HARSH ENVIRONMENTS USING THE UMR MOBILE AEROSOL SAMPLING SYSTEM (MASS)
DONALD E. HAGEN, PHILIP D. WHITEFIELD, MAX B. TRUEBLOOD (Missouri-Rolla Univ., Rolla), and HARVEY V. LILENFELD (McDonnell Douglas Corp., Saint Louis, MO) Jun. 1993 7 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Research supported by USAF refs
(Contract NSF ATM-88-20708)
(AIAA PAPER 93-2344) Copyright

Over the past 10 years a compact mobile aerosol sampling and characterization facility has been developed and operated by the Cloud and Aerosol Sciences Laboratory at UMR. In this presentation its measurement capabilities which include: total number density, size distribution and hydration property determination in real time for aerosols/particles greater than 0.007 micron, and operational methodology will be described. Its application in harsh environments will be evidenced with data from recent measurement campaigns where the system was used to (1) sample and characterize particulates from the supersonic reacting flow of a high energy chemical laser, (2) detect the presence of an invisible jet engine exhaust plume minutes after the aircraft had passed and discriminate the recently generated jet engine aerosol from ambient background carbonaceous aerosol, and (3) characterize engine and fuel specific aerosol sampled during jet engine testing.

A93-50143#
PYROMETER FOR TURBINE APPLICATIONS IN THE PRESENCE OF REFLECTION AND COMBUSTION
E. SUAREZ (Pratt & Whitney Group, West Palm Beach, FL) Jun. 1993 8 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2374) Copyright

The critical dependence of jet engine turbine blade life on operating metal temperatures and the limitations of conventional methods to perform this measurement have driven the development of techniques to make the pyrometer a useful tool in this radiative environment. This paper discusses the use of multi-band pyrometry and data sorting techniques to correct for the presence of flame in the field of view, and reflection from hotter sources such as the combustor. Results of application of these techniques in a jet engine are presented.

A93-50167*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
GRAVITY SENSITIVITY OF A RESISTOJET WATER VAPORIZER
W. E. MORREN (NASA, Lewis Research Center, Cleveland, OH) Jun. 1993 23 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Previously announced in STAR as N93-29194 refs
(AIAA PAPER 93-2402) Copyright

A laboratory model of a water vaporizer for resistojet applications was designed, fabricated, and steady and transient characteristics were measured. Vaporizer operation was not impacted by rotation about a horizontal axis normal to its own. The vaporizer was operated under low and high accelerations aboard a jet aircraft for periods up to 25 s at flow rates ranging from 159(10)(exp -6) to 230(10)(exp -6) kg/s. Slight changes in inlet and outlet pressures and some heat exchanger temperatures were observed during the low-gravity tests. However, the results of these tests indicated probable compatibility of the vaporizer design tested with a low-gravity environment.

A93-50254*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
THREE-DIMENSIONAL NUMERICAL SIMULATION OF GRADUAL OPENING IN A WAVE ROTOR PASSAGE
LOUIS M. LAROSILIERE (Ohio Aerospace Inst., Brook Park) Jun. 1993 32 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Previously announced in STAR as N93-29072 Research sponsored by NASA refs
(AIAA PAPER 93-2526) Copyright

The evolution of the contact interface and the propagation of compression waves inside a single wave rotor passage gradually opening to and traversing an inlet port is studied numerically using an inviscid formulation of the governing equations. Insights into the response of the interface and kinematics of the flow field to various opening times are given. Since the opening time is inversely proportional to the rotational speed of the rotor, the effects of passage rotation such as centripetal and Coriolis accelerations are intrinsically coupled to the gradual opening process. Certain three-dimensional features associated with the gradual opening process as a result of centripetal and Coriolis accelerations are illustrated. For the range of opening times or rotational speeds considered, a portion of the interface behaves like a vortex sheet that can degenerate into a complex interfacial structure. The vortices produced along the interface can serve as a stirring mechanism to promote local mixing. Coriolis and centripetal accelerations can introduce three dimensional effects such as interfacial distortions in meridional planes and spanwise migration of fluid elements.

A93-50261*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
BRUSH SEAL LOW SURFACE SPEED HARD-RUB CHARACTERISTICS
ROBERT C. HENDRICKS, JULIE A. CARLILE, and ANITA D. LIANG (NASA, Lewis Research Center, Cleveland, OH) Jun. 1993 13 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Previously announced in STAR as N93-27132 refs
(AIAA PAPER 93-2534) Copyright

The bristles of a 38.1-mm (1.5-in.) diameter brush seal were flexed by a tapered, 40-tooth rotor operating at 2600 rpm that provided sharp leading-edge impact of the bristles with hard rubbing of the rotor lands. Three separate tests were run with the same brush accumulating over 1.3 x 10(exp 9) flexure cycles while deteriorating 0.2 mm (0.008 in.) radially. In each, the test bristle incursion depth varied from 0.130 to 0.025 mm (0.005 to 0.001 in.) or less (start to stop), and in the third test the rotor was set 0.25 mm (0.010 in.) eccentric. Runout varied from 0.025 to 0.076 mm (0.001 to 0.003 in.) radially. The bristles wore but did not pull out, fracture, or fragment. Bristle and rotor wear debris were deposited as very fine, nearly amorphous, highly porous materials at the rotor groove leading edges and within the rotor grooves. The land leading edges showed irregular wear and the beginning of a convergent groove that exhibited sharp, detailed wear at the land trailing edges. Surface grooving, burnishing, 'whipping,' and hot spots and streaks were found. With a smooth-plug rotor, post-test leakage increased 30 percent over pretest leakage.

A93-50264# National Aeronautics and Space Administration. John C. Stennis Space Center, Bay Saint Louis, MS.
LIQUID HYDROGEN FOIL-BEARING TURBOPUMP
RICHARD J. GILBRECH (NASA, Stennis Space Center, Bay Saint Louis, MS), ALSTON GU, TOM RIGNEY, MARSHALL SAVILLE (AlliedSignal Aerospace Systems & Equipment, Torrance, CA), and MIKE ROSSONI (McDonnell Douglas Aerospace, Huntington Beach, CA) Jun. 1993 10 p. AIAA, SAE, ASME, and ASEE,

Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Research supported by McDonnell Douglas Aerospace, NASA, USAF, and U.S. Navy refs
(AIAA PAPER 93-2537) Copyright

The testing and performance evaluation of a liquid hydrogen turbopump with the rotor supported by foil bearings is discussed. The objectives of the program were to demonstrate the long-life feature of a foil-bearing turbopump and to evaluate its operational characteristics. The demonstration has successfully shown the reliability, long life, and robust nature of foil-bearing turbopumps by operating for long periods of time, with many start and stop cycles and a wide speed range. It has also proven that foil-bearing turbopumps can start without total chilldown of the foil bearing, offering operational simplicity.

A93-50280*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
CHIMERA GRIDS IN THE SIMULATION OF THREE-DIMENSIONAL FLOWFIELDS IN TURBINE-BLADE-COOLANT PASSAGES
M. A. STEPHENS, M. J. RIMLINGER, T. I.-P. SHIH (Carnegie Mellon Univ., Pittsburgh, PA), and K. C. CIVINSKAS (NASA, Lewis Research Center, Cleveland, OH) Jun. 1993 14 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(Contract NAG3-929)
(AIAA PAPER 93-2559)

When computing flows inside geometrically complex turbine-blade coolant passages, the structure of the grid system used can affect significantly the overall time and cost required to obtain solutions. This paper addresses this issue while evaluating and developing computational tools for the design and analysis of coolant-passages, and is divided into two parts. In the first part, the various types of structured and unstructured grids are compared in relation to their ability to provide solutions in a timely and cost-effective manner. This comparison shows that the overlapping structured grids, known as Chimera grids, can rival and in some instances exceed the cost-effectiveness of unstructured grids in terms of both the man hours needed to generate grids and the amount of computer memory and CPU time needed to obtain solutions. In the second part, a computational tool utilizing Chimera grids was used to compute the flow and heat transfer in two different turbine-blade coolant passages that contain baffles and numerous pin fins. These computations showed the versatility and flexibility offered by Chimera grids. Author (revised)

A93-50295#
DEVELOPMENTS IN SILICON CARBIDE FOR AIRCRAFT PROPULSION SYSTEM APPLICATIONS
STEPHEN J. PRZYBYLKO (USAF, Wright Lab., Wright-Patterson AFB, OH) Jun. 1993 10 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 Research supported by USAF refs
(AIAA PAPER 93-2581)

The physical and electrical properties of silicon carbide make it the foremost semiconductor material for high-temperature, radiation-resistant, and high-power electronic devices. These attributes make SiC particularly suitable for application to aircraft engines. Recent proof-of-concept efforts have verified SiC's potential. Field-effect transistors have shown high-temperature operating capability from 350 C to 650 C. JFETs, MOSFETs, and MESFETs have been fabricated. Ultraviolet photodiodes with high quantum efficiencies and extremely low dark currents have been fabricated and tested. Blue light-emitting diodes are for sale in production quantities as are one-inch diameter wafers. These developments have established a sufficient level of confidence to pursue the development of devices for aircraft-engine applications.

A93-50369 National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
THE AIRBORNE OCEAN COLOR IMAGER - SYSTEM DESCRIPTION AND IMAGE PROCESSING
ROBERT C. WRIGLEY, ROBERT E. SLYE (NASA, Ames Research Center, Moffett Field, CA), STEVEN A. KLOOSTER (TGS Technology, Inc.; NASA, Ames Research Center, Moffett Field, CA), RICHARD S. FREEDMAN (Sterling Federal Systems, Inc.; NASA, Ames Research Center, Moffett Field, CA), MARK CARLE (Spectro Scan, Inc., Coral Gables, FL), and LLOYD F. MCGREGOR (Lockheed Engineering & Sciences Co.; NASA, Stennis Space Center, Bay Saint Louis, MS) Journal of Imaging Science and Technology (ISSN 8750-9237) vol. 36, no. 5 Sept.-Oct. 1992 p. 423-430. refs
Copyright

The Airborne Ocean Color Imager was developed as an aircraft instrument to simulate the spectral and radiometric characteristics of the next generation of satellite ocean color instrumentation. Data processing programs have been developed as extensions of the Coastal Zone Color Scanner algorithms for atmospheric correction and bio-optical output products. The latter include several bio-optical algorithms for estimating phytoplankton pigment concentration, as well as one for the diffuse attenuation coefficient of the water. Additional programs have been developed to geolocate these products and remap them into a georeferenced data base, using data from the aircraft's inertial navigation system. Examples illustrate the sequential data products generated by the processing system, using data from flightlines near the mouth of the Mississippi River: from raw data to atmospherically corrected data, to bio-optical data, to geolocated data, and, finally, to georeferenced data.

A93-50405
A TWO-DIMENSIONAL ANALYSIS OF MULTIPLE MATRIX CRACKING IN A LAMINATED COMPOSITE CLOSE TO ITS CHARACTERISTIC DAMAGE STATE
D. CAMBY and J. L. REBIERE (Ecole Nationale Superieure de Mecanique et d'Aerotechnique, Poitiers, France) Composite Structures (ISSN 0263-8223) vol. 25, no. 1-4 1993 p. 325-337. Composite structures; Proceedings of the 7th International Conference, Univ. of Paisley, United Kingdom, July 5-7, 1993. A93-50376 21-24 refs
Copyright

The proposed approach incorporates all the stress components of interest in each layer of a cracked cross-ply laminate. Its starting point is a very general distribution of the shearing stress in both types of layer, represented by a series, each term of which is the product of a trigonometric function in the axial coordinate, a hyperbolic function in the thickness coordinate and an undetermined coefficient a(q); all the other stress components in each layer are deduced from the above by using the equilibrium equations, interface continuity conditions and traction boundary conditions. Minimizing the complementary energy of the whole laminate yields an algebraic system whose unknowns (a(q)) are the above coefficients. The validity of the proposed model is assessed by comparing the stress values it gives with those estimated through other semianalytical models or an FEM. Moreover, the series convergence is all the faster since the crack density is large, thus enabling careful investigation of the stress field when transverse cracking attains its saturation spacing.
Author (revised)

A93-50420
BUCKLING OF OPEN-SECTION BEAD-STIFFENED COMPOSITE PANELS
D. H. LAANANEN and S. P. RENZE (Arizona State Univ., Tempe) Composite Structures (ISSN 0263-8223) vol. 25, no. 1-4 1993 p. 469-476. Composite structures; Proceedings of the 7th International Conference, Univ. of Paisley, United Kingdom, July 5-7, 1993. A93-50376 21-24 Research supported by ICI Composite Structures refs
Copyright

Stiffened panels are structures that can be designed to efficiently support inplane compression, bending, and shear loads. Although the stiffeners are usually discrete elements which are fastened or bonded to a flat or continuously curved plate, manufacturing methods such as thermoforming allow integral

formation of the stiffeners in a panel. Such a configuration offers potential advantages in terms of a reduced number of parts and manufacturing operations. For thermoplastic composite panels stiffened by integrally formed open-section beads, the effects of bead spacing and bend cross-section geometry on the initiation of buckling under uniaxial compression and uniform shear loading were investigated. Finite elements results for a range of stiffened panel sizes and bead geometries are presented and compared with approximate closed-form solutions based on an effective flat plate size. Experimental verification of analytical predictions for one of the shear panels and one of the compression panels is described. Compensation of the forming tool to reduce the degree of initial curvature of the panels was found to be necessary.

A93-50430
ON DESIGN METHODS FOR BOLTED JOINTS IN COMPOSITE AIRCRAFT STRUCTURES
TOMAS IREMAN, TONNY NYMAN, and KURT HELLBOM (Saab Military Aircraft, Linkoping, Sweden) Composite Structures (ISSN 0263-8223) vol. 25, no. 1-4 1993 p. 567-578. Composite structures; Proceedings of the 7th International Conference, Univ. of Paisley, United Kingdom, July 5-7, 1993. A93-50376 21-24 refs
Copyright

The problems related to the determination of the load distribution in a multirow fastener joint using the finite element method are discussed. Both simple and more advanced design methods used at Saab Military Aircraft are presented. The stress distributions obtained with an analytically based method and an FE-based method are compared. Results from failure predictions with a simple analytically based method and the more advanced FE-based method of multi-fastener tension and shear loaded test specimens are compared with experiments. Finally, complicating factors such as three-dimensional effects caused by secondary bending and fastener bending are discussed and suggestions for future research are given.

A93-50524
A STUDY OF A DIRECT-INJECTION STRATIFIED-CHARGE ROTARY ENGINE FOR MOTOR VEHICLE APPLICATION
RYOJI KAGAWA, SYUNKI OKAZAKI, NOBUHIRO SOMYO, and YUJI AKAGI (Mazda Motor Corp., Hiroshima, Japan) (ISSN 0148-7191) Mar. 1993 11 p. SAE, International Congress and Exposition, Detroit, MI, Mar. 1-5, 1993 refs
(SAE PAPER 930677) Copyright

A study of a direct-injection stratified-charge system (DISC), as applied to a rotary engine (RE) for motor vehicle usage, was undertaken. The goals of this study were improved fuel consumption and reduced exhaust emissions. These goals were thought feasible due to the high thermal efficiency associated with the DISC-RE. This was the first application of this technology to a motor vehicle engine. Stable ignition and ideal stratification systems were developed by means of numerical calculations, air-fuel mixture measurements, and actual engine tests. The use of DISC resulted in significantly improved fuel consumption and reduced exhaust emissions. The use of an exhaust gas recirculating system was studied and found to be beneficial in NOx reduction.

A93-50543
RECEIVING AND SCATTERING CHARACTERISTICS OF AN IMAGED MONOPOLE BENEATH A LOSSY SHEET
WANG-JIE GESANG, E. ROTHWELL, K. M. CHEN (Michigan State Univ., East Lansing), KEVIN BURKET, WILLIAM P. HANSEN, JR., and JUANG-LU LIN (Boeing Defense & Space Group, Seattle, WA) IEEE Transactions on Antennas and Propagation (ISSN 0018-926X) vol. 41, no. 3 March 1993 p. 287-294. refs
Copyright

An analytical treatment of the radiation, scattering, and receiving properties of an imaged monopole in trilayered media with a perfectly conducting ground plane, a dielectric substrate, an electrically or magnetically lossy sheet as superstrate, and a homogeneous cover region is carried out. It is shown that while the power received by the monopole antenna is reduced by the presence of the lossy sheet, the scattered field is more greatly reduced, in agreement with observed behavior. Comparison with experimental and previously published numerical results validates the analysis.

A93-50561
NEUTRON-INDUCED SINGLE EVENT UPSETS IN STATIC RAMS OBSERVED AT 10 KM FLIGHT ALTITUDE
J. OLSEN, P. E. BECHER, P. B. FYNBO (Riso National Lab., Roskilde, Denmark), P. RAABY, and J. SCHULTZ (DataFlight Europe A/S, Birkerod, Denmark) IEEE Transactions on Nuclear Science (ISSN 0018-9499) vol. 40, no. 2 April 1993 p. 74-77. refs
Copyright

Neutron induced single event upsets (SEUs) in static memory devices (SRAMs) have so far been seen only in laboratory environments. We report observations of 14 neutron induced SEUs at commercial aircraft flight altitudes. The observed SEU rate at 10 km flight altitude based on exposure of 160 standard 256 Kbit CMOS SRAMs is 4.8 x 10 exp -8 upsets/bit/day. In the laboratory 117 SRAMs of two different brands were irradiated with fast neutrons from a Pu-Be source. A total of 176 SEUs have been observed, among these are two SEU pairs. The upset rates from the laboratory tests are compared to those found in the airborne SRAMs. Author (revised)

A93-50566
SINGLE EVENT UPSET IN AVIONICS
A. TABER (IBM Federal Systems Co., Owego, NY) and E. NORMAND (Boeing Defense and Space Group, Seattle, WA) IEEE Transactions on Nuclear Science (ISSN 0018-9499) vol. 40, no. 2 April 1993 p. 120-126. Research supported by DNA refs
(Contract N00014-91-C-2177)
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Data from military/experimental flights and laboratory testing indicate that typical non radiation-hardened 64K and 256K static random access memories (SRAMs) can experience a significant soft upset rate at aircraft altitudes due to energetic neutrons created by cosmic ray interactions in the atmosphere. It is suggested that error detection and correction (EDAC) circuitry be considered for all avionics designs containing large amounts of semi-conductor memory.

A93-51243
A TECHNIQUE FOR THE MEASUREMENT OF CLOUD STRUCTURE ON CENTIMETER SCALES
DARREL BAUMGARDNER, BRADLEY BAKER, and KIM WEAVER (NCAR, Boulder, CO) Journal of Atmospheric and Oceanic Technology (ISSN 0739-0572) vol. 10, no. 4 Aug. 1993 p. 557-565. refs
Copyright

A system was developed for measuring the distance between cloud droplets along the flight path with an airborne optical particle counter. This technique resolves separation distances as small as 0.2 mm at a typical flight speed of 100 m/s, a measure of cloud structure at scales much smaller than previously possible. This technique also provides an important alternative measure of droplet concentration that is negligibly affected by coincidence and dead-time losses. This new measurement technique may lead to a better understanding of cloud processes by providing the means of examining clouds at scales that are important in determining rates of droplet growth and evaporation. The capability of measuring droplet concentrations that are unbiased by coincidence and dead-time losses is a major offshoot of this technique and removes much of the uncertainty that has hampered previous measurements with optical particle probes. Author (revised)

A93-51250
INTEGRATED OPTOELECTRONICS FOR COMMUNICATION AND PROCESSING; PROCEEDINGS OF THE MEETING, BOSTON, MA, SEPT. 3, 4, 1991
C.-S. HONG, ED. (Boeing Aerospace & Electronics High Technology Center, Seattle, WA) Bellingham, WA Society of

Photo-Optical Instrumentation Engineers (SPIE Proceedings. Vol. 1582) 1992 309 p. No individual items are abstracted in this volume
(SPIE-1582; ISBN 0-8194-0713-5) Copyright

The present volume on integrated optoelectronics and processing discusses backplane interconnects, transmitters, array technology, receivers, modulators, and lasers. Attention is given to fiber-optic technologies for aircraft applications, packet switch networks, hybrid packaging of surface-emitting microlaser arrays on planar optical systems, and techniques for the implementation of high-speed free-space optical interconnections. Topics addressed include the development of efficient monolithic surface-emitting laser diode arrays, hybrid optoelectronic integration of transmitter arrays on a silicon waferboard, a four-channel hybrid receiver using a silicon substrate for packaging, and novel processing techniques for optoelectronic devices and their integration. Also discussed are processing issues and technologies for optoelectronic integrated circuits and devices, a wideband impedance-matched integrated optoelectronic transmitter, laser packaging for single-mode fiber systems, and an integrated active optical bistable circuit. AIAA

A93-51388#
ORDER REDUCTION OF AEROELASTIC MODELS THROUGH LK TRANSFORMATION AND RICCATI ITERATION
LEONARD R. ANDERSON (Boeing Commercial Airplane Group, Seattle, WA) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 2 Washington American Institute of Aeronautics and Astronautics 1993 p. 865-870. refs
(AIAA PAPER 93-3795) Copyright

This paper presents application of the LK transformation taken from singular perturbations to the order reduction of aeroelastic models of flight vehicles. Order reduction methodology is described which has been found to accurately reduce the order of large time-domain aeroelastic models for the design of aircraft active flight control systems. The LK transformation, and Riccati iteration when needed, can greatly reduced the model order, yet accurately represent the vehicle time-domain and frequency-domain characteristics up to a specified bandwidth. Numerical examples are provided.

A93-51528* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
AN AIRCRAFT INSTRUMENT DESIGN FOR IN SITU TROPOSPHERIC OH MEASUREMENTS BY LASER INDUCED FLUORESCENCE AT LOW PRESSURES
WILLIAM H. BRUNE, PHILIP S. STEVENS, and JAMES H. MATHER (Pennsylvania State Univ., University Park) *In* Optical methods in atmospheric chemistry; Proceedings of the Meeting, Berlin, Germany, June 22-24, 1992 Bellingham, WA Society of Photo-Optical Instrumentation Engineers 1993 p. 413-424. refs
(Contract NSF ATM-89-09155; NAG1-1057)
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The hydroxyl radical (OH) is important for many processes involved in tropospheric chemistry. For instance, it initiates the photochemical degradation of gases that cause global climate change, such as methane and the chlorofluorocarbon substitutes (HCFCs). Because of its reactivity, its abundances are less than 0.1 pptv. Thus, OH has been very difficult to measure accurately, despite its importance. Techniques have evolved, however, so that good measurements of tropospheric OH abundances are now possible. One of these techniques that is adaptable to aircraft measurements is the laser induced fluorescence detection of the OH radical in a detection chamber at low pressures. The current ground-based instrument, which can be readily adapted to aircraft, can detect OH abundances of 1.4 x 10 exp 5 OH molecules/cu cm with S/N = 2 in 30 sec, and 5 x 10 exp 4/cu cm in 5 min. Author (revised)

A93-51632
THE INFLUENCE OF SWIRL GENERATOR CHARACTERISTICS ON FLOW AND COMBUSTION IN TURBULENT DIFFUSION FLAMES
B. MUNDUS (Gaswaerme -Inst., Essen, Germany) and H. KREMER (Bochum, Ruhr-Univ., Germany) *In* Aerothermodynamics in combustors; IUTAM Symposium, National Taiwan Univ., Taipei, June 3-5, 1991, Selected Papers Berlin and New York Springer-Verlag 1992 p. 89-103. refs
Copyright

The present paper discusses experimental work to investigate the influence of swirl generator characteristics on the aerodynamic properties of unconfined turbulent swirl jets and the combustion behavior of unconfined swirl flames. The distribution of the tangential velocity component at the burner exit characterizes different types of vortices typical of each swirl generator. These different vortices may be described by a modified solid body vortex approach. Swirl generators producing similar vortices generate swirl jets and swirl flames with similar properties. Swirl intensity is described by means of a swirl number. The paper discusses the prediction of swirl numbers from swirl generator design data and the validation of these numbers by measurement.

A93-51728
THERMOPLASTIC COMPOSITE PARTS MANUFACTURE AT DU PONT
STEVEN J. MEDWIN and EDWARD J. COYLE (Du Pont de Nemours & Co., Wilmington, DE) Jan. 1993 19 p. In RUSSIAN Society of Manufacturing Engineers, Conference on Composites in Manufacturing '93, Pasadena, CA, Jan. 19, 20, 1993 refs
(SME PAPER EM93-106) Copyright

Low-cost routes to the manufacture of complex shaped composite parts have been defined using metal forming techniques and Du Pont's long discontinuous fiber (LDF) Technology. These manufacturing techniques include roll forming, stretch forming, and press forming. Near equivalence between the static, dynamic, and damage tolerance properties of LDF and continuous fiber composites have been demonstrated. Several examples are cited which demonstrate the potential for this technology to significantly reduce the cost of aerospace components. Author (revised)

A93-51729
ADVANTAGES OF A ONE-PART RESIN SYSTEM FOR PROCESSING AEROSPACE PARTS BY RESIN TRANSFER MOLDING (RTM)
GERALD J. SUNDSRUD (3M Co., Aerospace Materials Dept., Saint Paul, MN) Jan. 1993 12 p. In RUSSIAN Society of Manufacturing Engineers, Conference on Composites in Manufacturing '93, Pasadena, CA, Jan. 19, 20, 1993 refs
(SME PAPER EM93-112) Copyright

One-part resin systems for RTM are being recognized as having several significant advantages over the more common two-part systems in use today. The advantages in processing include elimination of mix ratio concerns, reduction of in-process QC testing and reduction of worker exposure to chemicals. 3M Aerospace Materials Department offers a unique one-part resin system for RTM that provides additional advantages. The 3M PR 500 is derated during manufacture thereby eliminating the degassing step and pumping directly from the shipping container is possible. The excellent stability of this one-part resin dramatically reduces waste and cleanup. Equipment for handling one-part systems will be discussed as well as a brief review of the unique characteristics and properties of 3M PR 500.

A93-51733
DESIGN FOR MANUFACTURE BY RESIN TRANSFER MOLDING OF COMPOSITE PARTS FOR ROTORCRAFT
J. C. KORNGOLD, D. E. LARSON, A. F. LUSCHER, and W. R. DEVRIES (Rensselaer Polytechnic Inst., Troy, NY) Jan. 1993 16 p. In RUSSIAN Society of Manufacturing Engineers, Conference on Composites in Manufacturing '93, Pasadena, CA,

Jan. 19, 20, 1993 Research supported by Sikorsky Aircraft refs
(SME PAPER EM93-103) Copyright
The paper examines the features of resing transfer molding (RTM) that should be considered by a designed for insuring high performance and productivity. A case study is presented which illustrates the need for design for manufacture (DFM) guidelines in RTM, and a scenario describing the features of a prototype computer-aided DFM tool that supports a designer in following the guidelines is discussed. The design of rotorcraft transmission housings provides an example of the application of the DFM concept. AIAA

A93-51893
EFFECT OF ROUNDING SIDE CORNERS ON VORTICES SHEDDING AND DOWNWASH FROM SQUARE CYLINDER OF FINITE LENGTH PLACED ON A GROUND PLANE
SHIKI OKAMOTO, MASATO INOUE, SATOSHI MURAKAMI, and KAZUAKI MUROTA Japan Society of Mechanical Engineers, Transactions B (ISSN 0387-5016) vol. 59, no. 558 Feb. 1993 p. 334-341. In JAPANESE refs
Copyright
This paper describes the effect of rounding side corners on vortices shedding and downwash from a square cylinder of finite length placed on a ground plane. The experiment was carried out in an N.P.L blowdown-type wind tunnel with a working section of 500 mm x 500 mm x 2000 mm in size, at the Reynolds number 1.25 x 10 exp 4 and 2.5 x 10 exp 4. The power spectrum, autocorrelation, and velocity were measured, and the Strouhal number was determined. The two types of vortices shed from a square cylinder with rounded side corners were also observed. As a result, it was found that (1) the vortices shed from a cylinder are arch vortices for H/D = 2, which change into Karman vortices at H/D = 4 to about 7; (2) the decay of shedding vortices and turbulent eddies becomes fast and the average scale of turbulent eddies decreases as rounding of the side corners increases; and (3) the downwash from the free end weakens as rounding of the side corners increases. Author (revised)

A93-52152* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
DEVELOPMENT OF A MICROCOMPUTER-BASED MAGNETIC HEADING SENSOR
H. D. GARNER (NASA, Langley Research Center, Hampton, VA) Sep. 1987 11 p. Sensors Expo Conference, Detroit, MI, Sept. 15-17, 1987, Paper refs
This paper explores the development of a flux-gate magnetic heading reference using a single-chip microcomputer to process heading information and to present it to the pilot in appropriate form. This instrument is intended to replace the conventional combination of mechanical compass and directional gyroscope currently in use in general aviation aircraft, at appreciable savings in cost and reduction in maintenance. Design of the sensing element, the signal processing electronics, and the computer algorithms which calculate the magnetic heading of the aircraft from the magnetometer data have been integrated in such a way as to minimize hardware requirements and simplify calibration procedures. Damping and deviation errors are avoided by the inherent design of the device, and a technique for compensating for northerly-turning-error is described. Author (revised)

A93-52167
EDDY CURRENT INSPECTION OF OPEN FASTENER HOLES IN ALUMINUM AIRCRAFT STRUCTURE
SAE Aerospace Recommended Practice SAE ARP 4402 April 1, 1992 16 p. refs
(SAE ARP 4402) Copyright
Eddy current NDE is used in maintenance and overhaul operations to detect service-induced cracks in Al-alloy aircraft structures. Attention is presently given to the eddy-current apparatus inspection of open fastener holes, including hole preparation for inspection, instrument calibration, and instrument operation. AIAA

A93-52170
DOCUMENT FOR 270 VOLTAGE DIRECT CURRENT (270 V DC) SYSTEM
SAE Aerospace Recommended Practice SAE ARP 4729 Sept. 18, 1992 35 p. refs
(SAE ARP 4729) Copyright
The paper presents the technical design and application information established by the SAE Aerospace Recommended Practice concerning the generation, distribution, control, and utilization of aircraft 270 V dc electrical power systems and support equipment. Also presented are references and definitions making it possible to compare various electrical systems and components. A diagram of the generic 270 V Direct Current High-Voltage Direct System is included. AIAA

A93-52419
AUREOLE LIDAR - INSTRUMENT DESIGN, DATA ANALYSIS, *AND COMPARISON WITH AIRCRAFT SPECTROMETER* MEASUREMENTS
WILLIAM P. HOOPER (U.S. Navy, Naval Research Lab., Washington) Applied Optics (ISSN 0003-6935) vol. 32, no. 21 July 20, 1993 p. 4019-4027. Research supported by U.S. Navy refs
Copyright
A lidar system is developed to map extinction under the flight path of a P-3 aircraft. With a modified Cassegrainian telescope, signals from both wide and narrow fields of view are detected. The wide field-of-view detector senses the aureole signal generated by sea surface reflection and aerosol forward scattering. The narrow field-of-view detector senses the backscattering profile and the direct reflection off the sea surface. Optical depth and extinction profiles are derived from these signals. In comparisons made between in situ aerosol-size spectrometer and lidar measurements, lidar profiles are smaller in magnitude but similar in shape to the spectrometer profiles.

A93-52449* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
VECTOR UNSYMMETRIC EIGENEQUATION SOLVER FOR NONLINEAR FLUTTER ANALYSIS ON HIGH-PERFORMANCE COMPUTERS
JIANGNING QIN (Old Dominion Univ., Norfolk, VA), CARL E. GRAY, JR. (NASA, Langley Research Center, Hampton, VA), and CHUH MEI (Old Dominion Univ., Norfolk, VA) Journal of Aircraft (ISSN 0021-8669) vol. 30, no. 5 Sept.-Oct. 1993 p. 744-750. AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference, 32nd, Baltimore, MD, Apr. 8-10, 1991, Technical Papers. Pt. 3, p. 1971-1980. Previously cited in issue 12, p. 1997, Accession no. A91-32027 Research supported by Old Dominion Univ. refs
(Contract NAS1-18584; NAG1-858)
Copyright

A93-52453
STRINGER PEELING EFFECTS AT STIFFENED COMPOSITE PANELS IN THE POSTBUCKLING RANGE
D. HACHENBERG (Deutsche Airbus GmbH, Hamburg, Germany) and H. KOSSIRA (Braunschweig Technical Univ., Germany) Journal of Aircraft (ISSN 0021-8669) vol. 30, no. 5 Sept.-Oct. 1993 p. 769-776. ICAS, Congress, 17th, Stockholm, Sweden, Sept. 9-14, 1990, Proceedings. Vol. 1, p. 511-521. Previously cited in issue 09, p. 1407, Accession no. A91-24356 refs
Copyright

A93-52517* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
STREAMING VORTICITY FLUX FROM OSCILLATING WALLS WITH FINITE AMPLITUDE
J. Z. WU, X. H. WU, and J. M. WU (Tennessee Univ., Tullahoma) Physics of Fluids A (ISSN 0899-8213) vol. 5, no. 8 Aug. 1993 p. 1933-1938. Research supported by National Cheng Kung Univ. refs

(Contract NAG1-844)
Copyright

How to describe vorticity creation from a moving wall is a long standing problem. This paper discusses relevant issues at the fundamental level. First, it is shown that the concept of 'vorticity flux due to wall acceleration' can be best understood by following fluid particles on the wall rather than observing the flow at fixed spatial points. This is of crucial importance when the time-averaged flux is to be considered. The averaged flux has to be estimated in a wall-fixed frame of reference (in which there is no flux due to wall acceleration at all); or, if an inertial frame of reference is used, the generalized Lagrangian mean (GLM) also gives the same result. Then, for some simple but typical configurations, the time-averaged vorticity flux from a harmonically oscillating wall with finite amplitude is analyzed, without appealing to small perturbation. The main conclusion is that the wall oscillation will produce an additional mean vorticity flux (a fully nonlinear streaming effect), which is partially responsible for the mechanism of vortex flow control by waves. The results provide qualitative explanation for some experimentally and/or computationally observed phenomena.

A93-52560
AN ACOUSTIC EMISSION PRE-FAILURE WARNING SYSTEM FOR COMPOSITE STRUCTURAL TESTS
B. C. DYKES, W. T. HARDRATH, and D. S. ULM (Boeing Commercial Airplane Group, Seattle, WA) *In* AECM-4, International Symposium on Acoustic Emission from Composite Materials, 4th, Seattle, WA, July 27-31, 1992, Proceedings Columbus, OH American Society for Nondestructive Testing, Inc. 1992 p. 175-181.
Copyright

An Acoustic Emission Prefailure Warning System (AEPWS) has been designed and built to provide warning of impending failure in objects made of composite materials. The application for which the AEPWS is most suited is the monitoring of large-scale composite structural tests; it has particular applications to aircraft safety. The testing of the AEPWS is described and future plans for its use are briefly addressed. An AEPWS display is shown.
AIAA

A93-52601
THE EFFECTS OF FIXED ROTOR TILT ON THE ROTORDYNAMIC COEFFICIENTS OF INCOMPRESSIBLE FLOW ANNULAR SEALS
J. K. SCHARRER, N. RUBIN (Rockwell International Corp., Rocketdyne Div., Canoga Park, CA), and C. C. NELSON (Texas A & M Univ., College Station) ASME, Transactions, Journal of Tribology (ISSN 0742-4787) vol. 115, no. 3 July 1993 p. 336-340; Discussion, p. 340, 341. STLE and ASME, Tribology Conference, Saint Louis, MO, Oct. 13-16, 1991 refs
Copyright

The basic equations are derived for incompressible flow in an annular seal with large rotor tilt. The flow is assumed to be completely turbulent in the axial and circumferential directions with no separation, and is modeled by Moody's friction factor equation. Linearized zeroth and first-order perturbation equations are developed for small motion about an arbitrary position by an expansion in the eccentricity ratio. The zeroth-order continuity and momentum equations are solved using a Fast Fourier technique, yielding the axial and circumferential velocity components and the pressure distribution. The first-order equations are integrated to satisfy the boundary conditions and yield the perturbation pressure distribution. This resultant pressure distribution is integrated along and around the seal to yield the force developed by the seal and the corresponding dynamic coefficients. Results of a parametric study show that the detrimental effects of a tilted rotor are small.

A93-52606
MULTILEVEL SOLUTION OF THE ELASTOHYDRODYNAMIC LUBRICATION OF CONCENTRATED CONTACTS IN SPIROID GEARS
CHANGHUA HUANG, SHIZHU WEN, and PING HUANG (Tsinghua Univ., Beijing, China) ASME, Transactions, Journal of Tribology (ISSN 0742-4787) vol. 115, no. 3 July 1993 p. 481-486. ASME and STLE, Tribology Conference, San Diego, CA, Oct. 18-21, 1992 Research supported by China Postdoctoral Science Foundation refs
Copyright

This paper presents a new method for analyzing the lubrication performance of spiroid gears, which combines the elastohydrodynamic lubrication analysis with LTCA. The LTCA provides the geometry of teeth surfaces at the vicinity of contact point, normal load, and lubricant entrainment velocity. Multilevel techniques are used to solve the elastohydrodynamic lubrication of concentrated contacts with high ellipticity ratio under heavy load in spiroid gears. Finally, a pair of spiroid gears used in aircraft is analyzed. Some interesting new conclusions are presented.
Author (revised)

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GEOSCIENCES

Includes geosciences (general); earth resources; energy production and conversion; environment pollution; geophysics; meteorology and climatology; and oceanography.

A93-47553
PRELIMINARY RESULTS OF THE ISM CAMPAIGN - THE LANDES, SOUTH WEST FRANCE
F. ZAGOLSKI, J. P. GASTELLU-ETCHEGORRY, G. MARTY, G. GIORDANO, E. MOUGIN, D. ALCAYDE, J. FONTANARI, J. ROUZAUD, J. COUTERET, P. FRABEL (Centre d'Etude Spatiale des Rayonnements, Toulouse, France) et al. *In* IGARSS '92; Proceedings of the 12th Annual International Geoscience and Remote Sensing Symposium, Houston, TX, May 26-29, 1992. Vol. 1 New York Institute of Electrical and Electronics Engineers, Inc. 1992 p. 6-8. refs
Copyright

The ISM instrument, an airborne spectrometer that operates in the near infrared and middle infrared part of the electromagnetic spectrum, is described. It has a 20 deg off-nadir capability with 12 min instantaneous field of view. An ISM survey that tested the capability of this instrument for studying biophysical parameters of local vegetation with special emphasis on the middle infrared region for water content analyses is described. In-situ reflectance data are derived from the various airborne data, whereas vegetation samples are collected for further laboratory analysis of biophysical parameters, such as water content, nitrogen and cellulose content, vegetation structure, etc. Geometrically corrected reflectance data are computed and coregistered with locally available vegetation database. Preliminary results are presented and discussed.

A93-47583
INFLIGHT ANTENNA DIAGRAM DETERMINATION OF SPACEBORNE AND AIRBORNE SAR-SYSTEMS
P. SEIFERT and M. ZINK (DLR, Inst. fuer Hochfrequenztechnik, Oberpfaffenhofen, Germany) *In* IGARSS '92; Proceedings of the 12th Annual International Geoscience and Remote Sensing Symposium, Houston, TX, May 26-29, 1992. Vol. 1 New York Institute of Electrical and Electronics Engineers, Inc. 1992 p. 117-119. refs
Copyright

Quantitative analyses of SAR signatures require an absolute radiometric calibration of the complete SAR system. The authors describe the use of a number of high-precision calibration receivers, arranged in cross-track direction, to record azimuth slices of the antenna pattern. The actual inflight elevation pattern is then obtained by time-correlating these cuts. This method also allows for measurement of azimuth cuts in both polarizations; registration of the actual pulse shapes; measurement of antenna squint angles;

measurement of the alignment of different beams (different polarizations or different frequencies); and synthesis of the antenna pattern main cut in the elevation direction.

A93-47657
A REFINED PROCEDURE TO GENERATE CALIBRATED IMAGERY FROM AIRBORNE SYNTHETIC APERTURE RADAR DATA
RALF HORN, JOAO MOREIRA (DLR, Inst. fuer Hochfrequenztechnik, Oberpfaffenhofen, Germany), and ERICH MEIER (Zurich Univ., Switzerland) *In* IGARSS '92; Proceedings of the 12th Annual International Geoscience and Remote Sensing Symposium, Houston, TX, May 26-29, 1992. Vol. 1 New York Institute of Electrical and Electronics Engineers, Inc. 1992 p. 406-408. refs
Copyright

A procedure to generate calibrated imagery from synthetic aperture radar (SAR) systems installed on board small aircraft is described. It has been developed for an experimental radar system E-SAR, which uses antennas fixed directly to the body of a DO 228 aircraft. A receiver gain control system, specifically, sensitivity time control (STC), is implemented. The correction of the STC variable receiver gain, the compensation of the translational and rotational motion errors of the aircraft, and the calibration of the radar data in the SAR processor are described. Results obtained from a recent experiment are shown. I.E.

A93-47658
THE REALIZATION PHASE OF THE PHARUS PROJECT
PAUL SNOEIJ (Delft Univ. of Technology, Netherlands), PETER J. KOOMEN, PETER HOOGEBOOM (TNO, The Hague, Netherlands), and HENK POUWELS (National Aerospace Lab., Amsterdam, Netherlands) *In* IGARSS '92; Proceedings of the 12th Annual International Geoscience and Remote Sensing Symposium, Houston, TX, May 26-29, 1992. Vol. 1 New York Institute of Electrical and Electronics Engineers, Inc. 1992 p. 409-411.
Copyright

The design of the PHARUS (phased array universal SAR, or synthetic aperture radar) polarimetric SAR has been finalized. The system uses a dual polarized microstrip patch antenna with 48 radiators (expandable to 96). Each radiator has its own T/R module with a total transmitted power of 600 W. The values for resolution in both azimuth and range are user-selectable. The system will offer the possibility of selecting the number of polarizations. The maximum range and the swath width depend on the selected mode and vary between 7 and 26 km for the range and between 2 and 18 km for the swath width. The number of looks is also dependent on the mode and varies between 3 and 20. The system has an active phased array antenna, which can be steered in one axis to compensate aircraft yaw and drift. I.E.

A93-47676
PBMR OBSERVATIONS OF SURFACE SOIL MOISTURE IN MONSOON 90
T. SCHMUGGE, T. J. JACKSON (USDA, Hydrology Lab., Beltsville, MD), D. GOODRICH, and S. AMER (USDA, Southwest Watershed Research Center, Tucson, AZ) *In* IGARSS '92; Proceedings of the 12th Annual International Geoscience and Remote Sensing Symposium, Houston, TX, May 26-29, 1992. Vol. 1 New York Institute of Electrical and Electronics Engineers, Inc. 1992 p. 480-482. refs
Copyright

The 21-cm Push Broom Microwave Radiometer (PBMR) was flown to map the surface soil moisture over the USDA Agricultural Research Service (ARS) Walnut Gulch experimental watershed. Microwave brightness and soil moisture were mapped over a large area. With the PBMR it is possible to observe the spatial variations of the rain amounts and the temporal variation of the moisture content as the soil dries. The brightness temperatures are registered to a UTM grid so that they can be compared to the rain gauge readings and to the ground measurements of soil moisture in the 0 to 5-cm layer. The decreases in brightness temperature are well correlated with the rainfall amounts up to a threshold level of 25 or 30 mm, and the comparison of the brightness temperatures with soil moisture is good. I.E.

A93-47865* Jet Propulsion Lab., California Inst. of Tech., Pasadena.
JPL AIRSAR PROCESSING ACTIVITIES AND DEVELOPMENTS
R. CARANDE, B. CHAPMAN, Y. LOU, and V. TAYLOR (JPL, Pasadena, CA) *In* IGARSS '92; Proceedings of the 12th Annual International Geoscience and Remote Sensing Symposium, Houston, TX, May 26-29, 1992. Vol. 2 New York Institute of Electrical and Electronics Engineers, Inc. 1992 p. 1152-1154. Research supported by DARPA and DOD refs
Copyright

Significant progress has been made in processing the Jet Propulsion Laboratory airborne synthetic aperture radar (JPL AIRSAR) data. These advances include increased swath width, increased number of looks; increased processor throughput, and decreased processor turnaround time (including photo product). These advances are made possible by new processing algorithms, software, and hardware. In addition to these processor improvements, a more mature understanding of the AIRSAR system in general has made it possible for the processor to routinely produce calibrated data based on internal calibration tests. Starting with the processing of 1991 acquired data, this new processor has become operational for the routine processing of AIRSAR data.

A93-48141*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
COMPUTATION OF WAKE/EXHAUST MIXING DOWNSTREAM OF ADVANCED TRANSPORT AIRCRAFT
TODD R. QUACKENBUSH, MILTON E. TESKE, and ALAN J. BILANIN (Continuum Dynamics, Inc., Princeton, NJ) Jul. 1993 16 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 Research supported by NASA refs
(AIAA PAPER 93-2944) Copyright

The mixing of engine exhaust with the vortical wake of high speed aircraft operating in the stratosphere can play an important role in the formation of chemical products that deplete atmospheric ozone. An accurate analysis of this type of interaction is therefore necessary as a part of the assessment of the impact of proposed High Speed Civil Transport (HSCT) designs on atmospheric chemistry. This paper describes modifications to the parabolic Navier-Stokes flow field analysis in the UNIWAKE unified aircraft wake model to accommodate the computation of wake/exhaust mixing and the simulation of reacting flow. The present implementation uses a passive chemistry model in which the reacting species are convected and diffused by the fluid dynamic solution but in which the evolution of the species does not affect the flow field. The resulting analysis, UNIWAKE/PCHEM (Passive CHEMistry) has been applied to the analysis of wake/exhaust flows downstream of representative HSCT configurations. The major elements of the flow field model are described, as are the results of sample calculations illustrating the behavior of the thermal exhaust plume and the production of species important to the modeling of condensation in the wake. Appropriate steps for further development of the UNIWAKE/PCHEM model are also outlined.

A93-48846
ATMOSPHERIC AEROSOLS DUE TO AIRCRAFT AND ECOLOGICAL PROBLEMS [ATMOSFERNYE AEHROZOLI AVIATSIONNOGO PROISKHOZHDENIYA I EHKOLOGICHESKIE PROBLEMY]
A. B. VATAZHIN and A. A. SOROKIN Rossijskaya Akademiya Nauk, Izvestiya, Mekhanika Zhidkosti i Gaza (ISSN 0568-5281) no. 6 Nov.-Dec. 1992 p. 57-72. In RUSSIAN refs
Copyright

Problems related to the formation and evolution of atmospheric aerosol produced by the jets of subsonic aircraft are examined. Analysis is made of the hydrodynamic and physicochemical processes occurring in the combustion chamber, exhaust system, wake jet, and ambient atmosphere that lead to the heterogeneous

and homogeneous condensation and formation of disperse phases of different compositions in the upper troposphere and lower stratosphere. The amount of aircraft-related aerosol at these altitudes is predicted on the basis of the available data. AIAA

A93-49069
SURFACE DRAG INSTABILITIES IN THE ATMOSPHERIC BOUNDARY LAYER
GEORGE CHIMONAS (Georgia Inst. of Technology, Atlanta) Journal of the Atmospheric Sciences (ISSN 0022-4928) vol. 50, no. 13 July 1, 1993 p. 1914-1924. refs
(Contract NSF ATM-90-19969)
Copyright

Jeffreys' analysis of wavelike instabilities observed in turbulent water running down an incline is extended to wavelike instabilities in the wind over level ground. In the lowest part of the atmosphere the wind experiences an aerodynamic surface drag that balances part of the horizontal pressure gradient, and this balance is shown to be unstable against wave-associated modulation of the drag, the mechanism presented by Jeffreys. Model computations for the statistically stable atmospheric boundary layer evaluate this instability for several classes of ducted waves. Linearized theory predicts very small growth rates for the fundamental modes (those with the simplest vertical structure) and much larger growth rates for the higher modes. The drag mechanism allows synoptic conditions to maintain turbulence in the stably stratified boundary layer: waves grow until overturning cascades energy into the small-scale turbulence, and in this way the waves process available potential energy from the larger scales into boundary-layer mixing. Field experiments are needed to verify the mechanism and provide better parameterizations of the turbulent Reynolds stresses associated with wave activity.

A93-49130
THE ONSET OF DISINTEGRATION AND CORONA IN WATER DROPS FALLING AT TERMINAL VELOCITY IN HORIZONTAL ELECTRIC FIELDS
A. K. KAMRA, ROHINI V. BHALWANKAR, and A. B. SATHE (Indian Inst. of Tropical Meteorology, Pune, India) Journal of Geophysical Research (ISSN 0148-0227) vol. 98, no. D7 July 20, 1993 p. 12,901-12,912. refs
Copyright

Results are presented of an investigation of the onset of disintegration and a corona in water drops falling at their terminal velocity in a vertical wind tunnel and exposed to horizontal electric fields. Contrary to previous observations, the drops elongate in a horizontal direction and distort into the shape of a concave-convex lens with a convex bottom and a sharp-edged rim facing upward. Most of the drops produce a corona just before their breakup. Among various drops that are freely suspended in the wind tunnel, one by one, the number of drops that produce a corona and/or breakup increases with increase in the electric field and/or drop size. The drops become unstable and produce a corona when the drops' oscillation amplitude overshoots their equilibrium value and the plane of the drop oscillation coincides with the direction of the electric field. It is concluded that the horizontal electric fields at the bases of thunderclouds may cause the disintegration of large raindrops, and the occurrence of a corona from their surfaces may trigger a lightning discharge. AIAA

A93-49551
INCREASE IN MORTALITY RATES DUE TO AIRCRAFT NOISE
W. C. MEECHAM and N. A. SHAW Verein fuer Wasser-, Boden- und Lufthygiene, Schriftenreihe (ISSN 0300-8665) vol. 88 1993 p. 428-441.
Copyright

In a study using data from the 1970-1980 decade, we find that people near Los Angeles International Airport (LAX) suffer a 5 percent increase in mortality rates due to increases in a number of fatal diseases. There is an 18 percent increase in cardiovascular deaths, for people over 75 in areas around the airport. Approximately 200,000 people are involved in the study, split into two groups, test and control, near LAX. The two areas were adjusted to be alike in race, age, and economic level. The number of suicides in the age bracket 45-54 was increased by the jet noise by over 100 percent at a 99 percent confidence level. Total accidental deaths increased by over 60 percent in the age group above 75 at a 96 percent confidence level. If we add together all increases there are an average of 24 extra deaths due to aircraft, primarily jet, noise in the high noise area. If we included all people living within the extended high noise contour, there is reason to believe that there is an increase of over 60 deaths in the LAX area per year. Author (revised)

A93-49552
A COMPARISON BETWEEN THE IMPACT OF NOISE FROM AIRCRAFT, ROAD TRAFFIC AND TRAINS ON LONG-TERM RECALL AND RECOGNITION OF A TEXT IN CHILDREN AGED 12-14 YEARS
S. HYYGE Verein fuer Wasser-, Boden- und Lufthygiene, Schriftenreihe (ISSN 0300-8665) vol. 88 1993 p. 416-427.
Copyright

A total of 417 students, 12-14 old, took part in three 15-min learning sessions in their ordinary class-rooms. Their task was to read a text, and they were tested one week later with difficult recall questions and less difficult recognition items on the text. The first session was a pretest for their learning abilities. This session was run in ambient noise conditions and all the students read the very same text. The scores from a pretest session run in ambient noise were used to divide the pupils along the median into two groups of learning ability. Three subgroups of the pupils were exposed to aircraft noise, train noise, and road-traffic noise. It was found that noise impaired long-term recall of the more difficult items. The degree of impairment on the recall items did not correlate with noise source or learning ability. The average impairment due to aircraft and road-traffic noise was around 23 percent of the scores. Train noise had no effect. For the easy recognition items, there was no effects of noise exposure. The results are discussed in terms of arousal and cognitive overload. Author (revised)

A93-49554
THE INFLUENCE OF NOCTURNAL AIRCRAFT NOISE ON SLEEP AND ON CATECHOLAMINE SECRETION
C. MASCHKE, S. BREINL, R. GRIMM, and H. ISING Verein fuer Wasser-, Boden- und Lufthygiene, Schriftenreihe (ISSN 0300-8665) vol. 88 1993 p. 395-407.
Copyright

The influence of noise from night flying on electro-biological reactions and on the secretion of catecholamines (adrenaline and noradrenaline) was studied in eight healthy adults whose place of residence exposes them to daytime aircraft noise. The interrelationships were then analyzed, with daytime noise exposure, personality traits, and general day-to-day condition reflected in control variables. The subjects were each observed during five nights without noise exposure (L(eq) less than 32 dB(A)) and five nights with noise exposure (L(eq) of 36 to 56 dB(A)), when the following factors were varied: number of flights (16, 32, and 64 overflights with a constant maximum indoor sound level of 75 dB(A)); and sound level (64 overflights at a maximum indoor sound level of 55, 65, and 75 dB(A)). When the various daytime exposures are taken into account, significant mean value differences between noisy and peaceful nights are demonstrated in 8-h urine for both catecholamines. In the case of adrenaline, the original data already showed a significant increase with noise exposure. Furthermore, catecholamine concentration increases with sound level. The analysis confirms a close link between the volume of adrenaline in the urine collected and electro-biological reactions, with consideration given to personality traits and day-time alcohol consumption. Author (revised)

A93-49557
RESULTS OF A LOW-ALTITUDE FLIGHT NOISE STUDY IN GERMANY - ACUTE EXTRAAURAL EFFECTS
I. CURIO and R. MICHALAK Verein fuer Wasser-, Boden- und

Lufthygiene, Schriftenreihe (ISSN 0300-8665) vol. 88 1993 p. 307-321.
Copyright

This study on the acute effects of low-altitude flight noise gave attention to the relationship between noise parameters (maximum sound level and sound level rise rate) and specific reactions by the individuals affected. The subjects, healthy volunteers, were exposed via earphones to digitally recorded military low altitude flight (MLAF) noise, using sophisticated recording technology. It emerged that a high sound level rise rate is a physical parameter which leads not only to more physical symptoms being cited by the subjects, but also to more pronounced myokinetic effects of an objectively measurable nature. Studies of circulation physiology were also conducted to throw light on the haemodynamic mechanism of the startle reaction. The findings suggest that increases in cardiac output per minute in a startled subject with a healthy circulation need not necessarily lead to protracted increases in blood pressure. A sensitization is observed after repeated exposure, with the startle reaction intensifying or else being triggered off by lower sound levels. This phenomenon of sensitization enables us to establish the hypothetical link between specific acute reactions to MLAF noise and long-term health effects. Author (revised)

A93-49558
SPECIFIC FEATURES OF MILITARY LOW-ALTITUDE FLIGHT NOISE - CRITERIA FOR RISK OF DAMAGE AND PHYSIOLOGICAL EFFECTS
M. SPRENG Verein fuer Wasser-, Boden- und Lufthygiene, Schriftenreihe (ISSN 0300-8665) vol. 88 1993 p. 271-287.
Copyright

The impact of sound from military low-altitude flying (75 m) is characterized by high maximum levels of up to 125 dB, a rapid rise in sound pressure level (steepest 10-dB slope up to 111 dB/s, mean value 36 dB/s), and occasional (30 percent) follow-up oscillations of up to around 100 dB. The energy within this broadband sound is often concentrated in the 0.8 to 4 kHz range. A criterion for the risk of damage can be applied using constant-frequency spectral dose analysis in order to establish how many overflight events are tolerable. Animal experiments reveal damage to the extremely sensitive stereocilia of the hair cells in the inner; slight impairment to hearing is possible in low-altitude flight zones, given either the recorded mean frequency of 17 direct overflights a day (with maximum levels over 100 dB) or else a few extreme isolated events. In laboratory experiments involving exposure to this type of highly dynamic low-altitude flight noise, short-term increases in heart rate (up to 21 beats/min) were found to be much greater than those provoked by other forms of environmental noise with comparable maximum levels (pile driving, gunfire). Author (revised)

A93-49559
REVIEW - EXTRAAURAL HEALTH EFFECTS OF AIRCRAFT NOISE
R. G. DE JONG Verein fuer Wasser-, Boden- und Lufthygiene, Schriftenreihe (ISSN 0300-8665) vol. 88 1993 p. 250-270.
Copyright

One solution to 'rush hours' in the airspace around airports is to spread the number of flights more evenly over time. This leads to more flights in the sensitive parts of the day: evening and night, and places the potential health effects of noise at the focus of societal attention. Effects of noise become detectable at a relatively low noise level, about 30 dB(A); whether noise levels become threatening to health above this figure is still largely unknown. This holds true for cardiovascular effects, mental health, mortality rates, medicine consumption, pregnancy, and physical development. Nighttime noise that disturbs or prevents sleep can be detrimental to health. Reading ability is also hampered by noise. For vegetative aspects, no clear and stable exposure-response relations are known at this moment. Author (revised)

A93-50117#
NO(X) SCAVENGING ON CARBONACEOUS AEROSOL SURFACES IN AIRCRAFT EXHAUST PLUMES. I
PHILIP D. WHITEFIELD, DONALD E. HAGEN, W. M. BARNETT, and HARVEY V. LILENFELD (Missouri-Rolla Univ., Rolla) Jun. 1993 5 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2343) Copyright

This paper describes results from the first part of a multi-year research program to investigate the effectiveness of jet exhaust aerosols as scavengers of NO(x) species, both within the exhaust plume and in the ambient atmosphere. A method is described for the measurement of the accommodation coefficients for NO2 and N2O on monodisperse jet engine aerosol simulants of known surface area, age and chemical composition as a function of atmospheric composition and temperature in the range 230-300 K. The validity of the aerosol simulation technique is addressed by comparison with actual jet exhaust aerosol characteristics determined in both engine ground tests and in flight.

A93-50373* National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
THREE-DIMENSIONAL SIMULATION OF THE DENVER 11 JULY 1988 MICROBURST-PRODUCING STORM
F. H. PROCTOR and R. L. BOWLES (NASA, Langley Research Center, Hampton, VA) Meteorology and Atmospheric Physics (ISSN 0177-7971) vol. 49 1992 p. 107-124. refs
Copyright

A simulation of the July 11, 1988 thunderstorm near Denver, which produced a microburst of unusual intensity during the test operation of the Terminal Doppler Weather Radar system is carried out using the Terminal Area Simulation System also known as the NASA-Langley Windshear Model. The results show the evolution and structure of the storm, including hazard indices based on F-factor. Results of simulation show that the storm is of unusual structure, producing multiple low- to moderate-reflectivity microbursts formed downshear of the main precipitation shaft. The most intense of the microbursts contains a velocity differential exceeding 40 m/s, strong downdrafts, and hazardous windshear with F-factors approaching 0.2. A comparison with observations, including Doppler radar measurements and aircraft flight data, indicates that the model can proivide information that is not always apparent from observed data. AIAA

A93-50950
ADVANCED GENERATING TECHNOLOGIES - MOTIVATION AND SELECTION PROCESS IN ELECTRIC UTILITIES
MURTY P. BHAVARAJU (Public Service Electric and Gas Co., Newark, NJ) IEEE, Proceedings (ISSN 0018-9219) vol. 81, no. 3 March 1993 p. 480-485. refs
Copyright

Electric utilities are constantly seeking advanced methods for generating electricity to meet the future demand. The primary motivation for the development of advanced technologies is to generate electricity with minimum damage to the environment and with resources that are abundant. The utility planner evaluates the role of these technologies in the future system considering both quantifiable and nonquantifiable benefits and risks involved.

A93-51856
ATMOSPHERIC DISTURBANCES OVER MOUNTAINS AND THE FLIGHT SAFETY [VOZMUSHCHENIYA ATMOSFERY NAD GORAMI I BEZOPASNOST' POLETOV]
V. N. KOZHEVNIKOV and A. P. PAVLENKO (Moskovskij Gosudarstvennyj Univ., Moscow, Russia) Rossijskaya Akademiya Nauk, Izvestiya, Fizika Atmosfery i Okeana (ISSN 0002-3515) vol. 29, no. 3 June 1993 p. 302-314. In RUSSIAN refs
Copyright

The feasibility of estimating the aircraft flight safety by using a nonlinear stationary two-dimensional model simulating air flow over real mountain systems is investigated. General characteristics of vortex-wave zone origination and their scale are studied. The choice

of criteria for estimating the effect of air flow disturbances on the flight is discussed. Flow over nine different sample mountain reliefs was calculated to study the dependence of disturbance intensity on the relief shape. The results are illustrated by detailed figures. Author (revised)

15

MATHEMATICAL AND COMPUTER SCIENCES

Includes mathematical and computer sciences (general); computer operations and hardware; computer programming and software; computer systems; cybernetics; numerical analysis; statistics and probability; systems analysis; and theoretical mathematics.

A93-48323#
ON THE USE OF BACK PROPAGATION WITH FEED-FORWARD NEURAL NETWORKS FOR THE AERODYNAMIC ESTIMATION PROBLEM
ROBERT A. HESS (Simmonds Precision Aircraft Systems, Vergennes, VT) *In* AIAA Atmospheric Flight Mechanics Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers Washington American Institute of Aeronautics and Astronautics 1993 p. 233-241. refs
(AIAA PAPER 93-3638) Copyright

A method is presented for estimating aircraft aerodynamics using a technique known as back propagation (BPN). BPN is a 'supervised learning paradigm', i.e., a technique which allows feed-forward neural networks (FFNNs) to adjust themselves so that they match actual system response. This paper discusses feed-forward neural networks, a class of parallel computational system. The properties of FFNN systems are presented, and how such a system could be use to represent aircraft aerodynamics. An overview of the BPN algorithm is introduced, and examples of the use of BPN for estimating aircraft aerodynamics are shown. The use of BPN for real-time aerodynamic estimation, along with concepts for the use of FFNN systems for system fault detection and flight simulation development are also presented.

A93-48324#
ESTIMATION OF AERODYNAMIC COEFFICIENTS USING NEURAL NETWORKS
HUSSEIN M. YOUSSEF (Lockheed Advanced Development Co., Sunland, CA) and JYH-CHING JUANG (National Cheng Kung Univ., Tainan, Taiwan) *In* AIAA Atmospheric Flight Mechanics Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers Washington American Institute of Aeronautics and Astronautics 1993 p. 242-245. refs
(AIAA PAPER 93-3639) Copyright

Establishment and maintenance of aerodynamic data base is fundamental to every aircraft program. In this paper, neural network technologies are used to provide a universal data base for the storage and processing of aerodynamic data. In particular, neural estimation schemes are amenable to flight test data processing. Simulation examples demonstrate this feasibility.

A93-48967
SOME FUCHS-TYPE EQUATIONS IN FLUID MECHANICS [O NEKOTORYKH URAVNENIYAKH KLASSA FUKSA V GIDRO- I AEHROMEKHANIKE]
EH. N. BERESLAVSKIJ and P. YA. KOCHINA Rossijskaya Akademiya Nauk, Izvestiya, Mekhanika Zhidkosti i Gaza (ISSN 0568-5281) no. 5 Sept.-Oct. 1992 p. 3-7. In RUSSIAN refs
Copyright

The formalism of Fuchs-type differential equations makes it possible to analyze a wide range of steady-state plane problems in fluid mechanics. These problems include determining functions that implement conformal mapping onto an auxiliary canonic region of circular polyhedrons. In the case of a large number of apexes and coefficients, determining the unknown parameters is a rather difficult task. It is shown here that, in many cases where the polyhedron contains angles that are multiples of pi/2 (as is the case in many fluid mechanics problems), the problem of determining the unknown parameters can be fully solved. AIAA

A93-49186
A COMPUTER PROGRAM FOR MERIDIONAL FLOWS IN MULTISTAGE AXIAL FLOW COMPRESSORS WITH TURBULENCE AND MULTI-EFFECTS OF 3-D FLOWS
SHIMING LI (Tsinghua Univ., Beijing, China) and MAOZHANG CHEN (Beijing Univ. of Aeronautics and Astronautics, China) Journal of Aerospace Power (ISSN 1000-8055) vol. 8, no. 3 Oct. 1992 p. 213-216. In CHINESE refs

It has been shown that the spanwise mixing is caused by turbulent diffusion and different kinds of three-dimensional flow effects. This paper introduces a computer program based on this theory. A new kind of rotary enthalpy has been defined, and its related equation has been derived to simplify the present problem. The details for modeling all the unknown correlation mixing terms involved in the computations and the numerical scheme have been also presented. The results obtained agree well with the experiments for five compressors. The results also show some improvement over the previous theories. Author (revised)

A93-49306
STATISTICAL METHODS IN FLIGHT VEHICLE CONTROL THEORY [STATISTICHESKIE METODY V TEORII UPRAVLENIYA LETATEL'NYMI APPARATAMI]
V. V. SEMENOV, ED., A. A. PUNTUS, ED., V. M. ZAKALYUKIN, ED., A. YU. ARZHANENKO, ED. et al. Moscow Moskovskij Aviatsionnyj Institut 1990 95 p. In RUSSIAN No individual items are abstracted in this volume
Copyright

The papers presented in this volume focus on the analysis and synthesis of optimal controls for stochastic systems, observation processing, optimal estimation and filtering of processes, and solutions for some applied problems. Specific topics discussed include sufficient conditions of stochastic system optimality in problems with control and observation constraints, optimal control synthesis for nonlinear stochastic systems based on the concept of inverse dynamics problems, and approximate methods for solving optimal programmed control problems for linear stochastic systems using probability criteria. Attention is also given to an optimal structure of discrete nonlinear filters of arbitrary order, linear stationary nonparametric filtering of stochastic processes, and information expansions in a finite noncoalition game. AIAA

A93-49307
PROBLEMS IN THE OPTIMIZATION OF COMPLEX ENGINEERING SYSTEMS [ZADACHI OPTIMIZATSII SLOZHNYKH TEKHNICHESKIKH SISTEM]
A. A. LEBEDEV, ED., A. P. GRISHIN, ED., V. T. BOBRONNIKOV, ED., V. S. BRUSOV, ED. et al. Moscow Moskovskij Aviatsionnyj Institut 1990 78 p. In RUSSIAN No individual items are abstracted in this volume
Copyright

The papers contained in this volume deal with various optimization and modeling problems arising in the synthesis of complex engineering systems. In particular, attention is given to the decomposition approach to the problem of the information servicing of competing sources, a motion optimization problem for a system of communication satellites, and calculation of the Bayes risk in a problem from the theory of statistical solutions. Other topics discussed include consideration of the dynamic evolution of a fleet in an optimization problem for a system of flight vehicles, optimal control of the size and resources of a group of functioning elements, and cloud cover modeling. AIAA

A93-49347
CHANGING THE UTILITY SUBSYSTEM PARADIGM
ALAN BURKHARD (USAF, Wright Lab., Wright-Patterson AFB,

OH) *In* 1993 Aerospace Avionic Systems Division Conference, 3rd, Denver, CO, Apr. 22, 1993, Proceedings Warrendale, PA Society of Automotive Engineers, Inc. 1993 p. 53-56. refs
(SAE PAPER 931598) Copyright

The paradigm for aircraft utility subsystems has not changed over the past 30 years even though the technology being used in and supported by the utility systems has significantly changed. The Wright Laboratory Subsystem Integration Technology (SUIT) program has identified significant flight vehicle benefits that result from breaking out of the traditional paradigm for aircraft utility subsystems.

A93-49350
INTELLIGENT ROBOTICS; PROCEEDINGS OF THE INTERNATIONAL SYMPOSIUM, BANGALORE, INDIA, JAN. 2-5, 1991

M. VIDYASAGAR, ED. (Centre for Artificial Intelligence and Robotics, Bangalore, India) and MOHAN M. TRIVEDI, ED. (Tennessee Univ., Knoxville) New Delhi Tata McGraw-Hill Publishing Co., Ltd. (SPIE Proceedings. Vol. 1571) 1991 746 p. For individual items see A93-49351 to A93-49360
(SPIE-1571; ISBN 0-8194-0701-1) Copyright

The present volume on intelligent robotics discusses parallel vision algorithms using sparse array representations, vision-based techniques for rotorcraft low-altitude flight, the design of direct-drive robots using indigenously developed dc torque motors, and an end-effector for 3D manipulation of multiple-ply apparel workpieces. Attention is given to a robot vision algorithm for manipulating objects in a cluttered scene, a sensor-based part feeding gate, the development of a four-axis robot for automation in the nuclear industry, and the design of a composite controller for a two-link flexible manipulator. Topics addressed include two-time scale control for an arm with joint and link compliance, point-to-point control of elastic joint robots, intelligent robotic polishing, and a robotic system for the inspection of turbine disks. Also discussed are measures of intensity of collision between convex objects and their efficient computation, efficient coordinated motion, observer-based control laws for robotic manipulators, and multipolynomial resultant algorithms. AIAA

A93-49480
AN INTRODUCTION TO THE ONBOARD LAN (OLAN)

MARC COHN (Raychem Corp., Advanced Development Div., Menlo Park, CA) *In* Specialty fiber optic systems for mobile platforms and plastic optical fibers; Proceedings of the Meeting, Boston, MA, Sept. 9-11, 1992 Bellingham, WA Society of Photo-Optical Instrumentation Engineers 1993 p. 234-241. refs
Copyright

OLAN defines a LAN profile based on commercial communications standards that have been optimized for the airborne environment. LLC provides an accepted means for interfacing with standard upper layer protocols. FDDI defines a high-speed, fault-tolerant LAN that offers the functionality, management, and robustness needed for advanced avionics applications. Commercial protocols are extensively validated and exercised. The most significant systems benefits include enabling the transition from a control-driven architecture to a data-driven system architecture. AIAA

A93-49481
ONBOARD CONNECTIVITY NETWORK FOR COMMAND AND CONTROL AIRCRAFT

TIMOTHY J. ARTZ (Booz, Allen & Hamilton, Inc., Falls Church, VA) *In* Specialty fiber optic systems for mobile platforms and plastic optical fibers; Proceedings of the Meeting, Boston, MA, Sept. 9-11, 1992 Bellingham, WA Society of Photo-Optical Instrumentation Engineers 1993 p. 242-253.
Copyright

The Onboard Connectivity Network (OCN), which is being prototyped for application on the U.S. Government's Special Air Mission aircraft, is discussed. Significant weight reduction and simplified future systems integration are the primary benefits of the OCN. The OCN design integrates voice, data, control, and video communications on a 3-GHZ single mode fiber backbone. Communications within the aircraft use 500 MHz coaxial cable subnetworks connected to the backbone. The entire network is a dual redundant system for enhanced reliability. Node topologies are based on VMEbus to encourage use of commercial products and facilitate the future evolution of the backbone topology. AIAA

A93-49605
REDUCED ORDER PROPORTIONAL INTEGRAL OBSERVER WITH APPLICATION

MEHRDAD SAIF (Simon Fraser Univ., Burnaby, Canada) Journal of Guidance, Control, and Dynamics (ISSN 0731-5090) vol. 16, no. 5 Sept.-Oct. 1993 p. 985-988. Research supported by NSERC and Center for Systems Science of Canada refs
Copyright

A systematic procedure is proposed for the design of reduced-order robust estimates capable of estimating accurately the state of a system as well as constant disturbances acting on it. The conditions for the existence of this estimator are outlined. The linearized dynamics of the L-1011 aircraft are described as an example. AIAA

A93-49696#
METHODOLOGY FOR COMMERCIAL ENGINE/AIRCRAFT OPTIMIZATION

J.-M. JACQUET (SNECMA, Moissy Cramoyel, France) and D. L. SEIWERT (GE Aircraft Engines, Evendale, OH) Jun. 1993 12 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993
(AIAA PAPER 93-1807) Copyright

This paper describes the structure of the integrated technical methodology being jointly developed by General Electric Aircraft Engines and SNECMA. They are teaming to investigate a new propulsion system that will augment the successful CFM56 family in the years beyond 2000.

A93-49884#
USER-FRIENDLY CODES FOR THE TRAINING ON GAS TURBINE ENGINES

GIOVANNI TORELLA (Italian Air Force Academy, Pozzuoli, Italy) Jun. 1993 10 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2051) Copyright

The main steps of the design and the development of a user-friendly code for gas turbine engine simulation are presented and discussed. A study for selecting the most suitable computer environment and language has been carried out. The main requirements for the selection are the interactivity and the easiness of use. Successively a package for the full simulation of engines with different configurations is presented. Finally, examples of utilization of codes during typical training sessions are shown and discussed. Author (revised)

A93-50489
COMPUTER AIDED DESIGN OF TURBO-MACHINERY COMPONENTS

S. G. A. PASHA (Gas Turbine Research Establishment, Bangalore, India) Institution of Engineers (India), Journal, Mechanical Engineering Division (ISSN 0020-3408) vol. 73, pt. MC4 Nov. 1992 p. 219-221.
Copyright

CAD of turbomachinery components including a spline, a centrifugal compressor impeller, and an axial compressor blade is described. The CAD process starts with a geometric modeling of the component, followed by a finite element mesh generation. An optimum design is obtained making the desired modifications on the original geometric model. AIAA

A93-50631
A NEW APPROACH TO ROBUST FAULT DETECTION AND IDENTIFICATION

MEHRDAD SAIF (Simon Fraser Univ., Burnaby, Canada) and YUPING GUAN (National Research Council of Canada, Western Labs., Vancouver) IEEE Transactions on Aerospace and Electronic Systems (ISSN 0018-9251) vol. 29, no. 3 July 1993 p. 685-695. Research supported by NSERC and Center for Systems Science refs
Copyright

A new methodology for instrument fault detection and identification (FDI) in linear dynamical systems subject to plant parameter variations or uncertainties is presented. At the heart of this approach is a robust estimator for which the necessary and sufficient conditions to its existence are outlined. The robust estimator can simultaneously estimate the unmeasurable state variables of the system for the purpose of control, and provide necessary information for FDI purposes as well. A novel feature of this approach is that it can actually identify the shape and magnitude of the failures. The scheme allows for fast and accurate FDI, and can account for structural uncertainties and variations in the parameters of the dynamical model of the system. The overall fault tolerant control system strategy proposed is verified through simulation studies performed on the control of a vertical takeoff and landing (VTOL) aircraft in the vertical plane.

A93-50638
PERFORMANCE PREDICTION OF THE INTERACTING MULTIPLE MODEL ALGORITHM
XIAO R. LI and YAAKOV BAR-SHALOM (Connecticut Univ., Storrs) IEEE Transactions on Aerospace and Electronic Systems (ISSN 0018-9251) vol. 29, no. 3 July 1993 p. 755-771. refs
(Contract N00014-91-J-1950; NSF ECS-91-09962)
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The interacting multiple model (IMM) algorithm has been shown to be one of the most cost-effective estimation schemes for hybrid systems. Its performance, however, could only be evaluated via expensive Monte Carlo simulations. An effective hybrid approach to the performance evaluation without recourse to simulations is presented here. This approach is based on a scenario-conditional performance measure of hybrid nature in the sense that it is a continuous-valued matrix function of a discrete-valued random sequence - the system mode sequence. This system mode sequence is an essential description of the scenario of the problem of interest on which the performance of the algorithm is to be predicted. The performance measure is calculated efficiently in an off-line recursion. The ability of this approach to predict accurately the average performance of the algorithm is illustrated via two important examples: a generic air traffic control tracking problem and a nonstationary noise identification problem.
Author (revised)

A93-50726* National Aeronautics and Space Administration, Washington, DC.
WNN 92; PROCEEDINGS OF THE 3RD WORKSHOP ON NEURAL NETWORKS: ACADEMIC/INDUSTRIAL/NASA/DEFENSE, AUBURN UNIV., AL, FEB. 10-12, 1992 AND SOUTH SHORE HARBOUR, TX, NOV. 4-6, 1992
MARY L. PADGETT, ED. (Auburn Univ., AL) San Diego, CA/Bellingham, WA Society for Computer Simulation/Society of Photo-Optical Instrumentation Engineers (SPIE Proceedings. Vol. 1721) 1993 679 p. For individual items see A93-50727 to A93-50780
(SPIE-1721; ISBN 1-56555-007-2) Copyright

The present conference discusses such neural networks (NN) related topics as their current development status, NN architectures, NN learning rules, NN optimization methods, NN temporal models, NN control methods, NN pattern recognition systems and applications, biological and biomedical applications of NNs, VLSI design techniques for NNs, NN systems simulation, fuzzy logic, and genetic algorithms. Attention is given to missileborne integrated NNs, adaptive-mixture NNs, implementable learning rules, an NN simulator for travelling salesman problem solutions, similarity-based forecasting, NN control of hypersonic aircraft takeoff, NN control of the Space Shuttle Arm, an adaptive NN robot manipulator controller, a synthetic approach to digital filtering, NNs for speech analysis, adaptive spline networks, an anticipatory fuzzy logic controller, and encoding operations for fuzzy associative memories.
AIAA

A93-50744
CONTROL OF TAKEOFF OF A HYPERSONIC AIRCRAFT USING NEURAL NETWORKS
CHADWICK J. COX, OSCAR E. MARTINEZ (Accurate Automation Corp., Chattanooga, TN), ROBERT M. PAP (Accurate Automation Corp.; Tennessee State Univ., Nashville), and TERRANCE CARNEY (Accurate Automation Corp., Chattanooga; Tennessee State Univ., Nashville) In WNN 92; Proceedings of the 3rd Workshop on Neural Networks: Academic/Industrial/NASA/Defense, Auburn Univ., AL, Feb. 10-12, 1992 and South Shore Harbour, TX, Nov. 4-6, 1992 San Diego, CA/Bellingham, WA Society for Computer Simulation/Society of Photo-Optical Instrumentation Engineers 1993 p. 161-168. refs
(Contract NSF ESC-90-15159)
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Results are presented from a preliminary investigation into the use of neural-networks concepts to control a National Aerospaceplane-like hypersonic flight vehicle identified with the General Hypersonic Aerodynamic Model Example of Bowers et al. (1988). Attention is given to the neurocontrol learning algorithms, neurocontroller architecture, training, and performance, and the 'adaptive critic' neurocontroller concept. The approach is found to succeed as long as the takeoff conditions for the vehicle closely resembled those of the training set.
AIAA

A93-50779
THE USE OF GENETIC ALGORITHMS IN THE DESIGN OF FUZZY LOGIC CONTROLLERS
D. L. MEREDITH (Alabama Univ., Tuscaloosa), C. L. KARR (U.S. Bureau of Mines, Tuscaloosa, AL), and K. K. KUMAR (Alabama Univ., Tuscaloosa) *In* WNN 92; Proceedings of the 3rd Workshop on Neural Networks: Academic/Industrial/NASA/Defense, Auburn Univ., AL, Feb. 10-12, 1992 and South Shore Harbour, TX, Nov. 4-6, 1992 San Diego, CA/Bellingham, WA Society for Computer Simulation/Society of Photo-Optical Instrumentation Engineers 1993 p. 549-555. refs
Copyright

An account is given of ways of combining fuzzy logic control with the learning capabilities of genetic algorithms. Attention is given to the use of a genetic algorithm to choose high performance fuzzy membership functions for a controller that manipulates a mathematical model of a helicopter hovering in turbulent wind conditions. The functions thus chosen provide for a more efficient fuzzy logic controller than membership functions otherwise chosen.
AIAA

A93-50951
INTELLIGENT SYSTEMS OF FLIGHT-VEHICLE CONTROL [INTELLEKTUAL'NYE SISTEMY UPRAVLENIYA LETATEL'NYKH APPARATOV]
V. V. MALYSHEV, ED. Moscow Moskovskij Aviatsionnyj Institut 1991 67 p. In RUSSIAN For individual items see A93-50952 to A93-50961
Copyright

The papers presented in this volume focus on the use of artificial intelligence in flight vehicle control, including the use of on-board expert systems to control flight safety in real time and accumulation of knowledge in the process of learning using pilot's experience. Papers are included on multilevel control systems and optimization of their structures, a target search system, prediction and planning of the flight vehicle route in the presence of motion inhibiting factors, and generation of a plant description dictionary based on expert survey data.
AIAA

A93-50952
BEHAVIOR OF THE PARTICULAR QUALITY CHARACTERISTICS OF AN INTELLIGENT FLIGHT VEHICLE CONTROL SYSTEM IN A MULTICRITERIAL FORMULATION [POVEDENIE CHASTNYKH POKAZATELEJ KACHESTVA INTELLEKTUAL'NOJ SISTEMY UPRAVLENIYA LETATEL'NYM APPARATOM V MNOGOKRITERIAL'NOJ POSTANOVKE]
N. N. ANDRONOV, L. A. KOVZAN, G. N. LEBEDEV, and V. V. PODAFEJ *In* Intelligent systems of flight-vehicle control Moscow Moskovskij Aviatsionnyj Institut 1991 p. 4-12. In RUSSIAN refs
Copyright
The objective of the study was to develop a method for determining the dynamics of change of the weight coefficients of particular quality criteria using a multicriterial formulation. An approach is proposed whereby the Bellman equation, written for the case of alternative control, is replaced by a power-law polynomial in terms of phase coordinates. In addition to determining a general quality criterion, the development of a second feedback level in an artificial intelligence control system involves definition of the safe motion region and the development of an expert system which makes decisions on the basis of the acquired data using logic inference procedures. AIAA

A93-50953
DEFINITION OF THE STRUCTURE OF EXPERT PREFERENCES FOR THE MULTICRITERIAL ANALYSIS OF CONTROL SYSTEMS [VYYAVLENIE STRUKTURY PREDPOCHTENIJ EHKSPERTA DLYA MNOGOKRITERIAL'NOGO ANALIZA UPRAVLYAYUSHCHIKH SISTEM]
K. A. AFONIN and P. A. BOSIN *In* Intelligent systems of flight-vehicle control Moscow Moskovskij Aviatsionnyj Institut 1991 p. 12-17. In RUSSIAN refs
Copyright
The use of a multidimensional utility function (UF) as a generalized criterion for formalizing expert data is examined. The existing methods for obtaining the UF are briefly reviewed, and an approach to the derivation of multidimensional UFs is proposed which facilitates the formal definition of a system of expert preferences. The fundamental principles of the approach are discussed, and their implementation in an interactive system for the construction of multidimensional UFs is described. AIAA

A93-50954
MULTILEVEL CONTROL SYSTEMS AND OPTIMIZATION OF THEIR STRUCTURES [MNOGOUROVNEVYE SISTEMY UPRAVLENIYA I OPTIMIZATSIYA IKH STRUKTUR]
A. A. BOGOLYUBOV and V. B. GALYUTIN *In* Intelligent systems of flight-vehicle control Moscow Moskovskij Aviatsionnyj Institut 1991 p. 17-25. In RUSSIAN refs
Copyright
The paper is concerned with the problem of selecting the optimal structure of a multilevel control system and formalizing the procedure of selecting the number of hierarchy levels. The formalization method is based on an aggregation-decomposition approach whereby a system is represented as a set of interconnected elements. The relations between the system elements are formalized using an alternative-graph method whereby the elements of the system are specified as graph apexes while the relations between the elements are shown by arcs. Methods of determining the complexity and controllability functions of a system are also discussed. AIAA

A93-50955
MULTILEVEL INTELLIGENT CONTROL SYSTEMS FOR FLIGHT VEHICLES [MNOGOUROVNEVYE INTELLEKTUAL'NYE SISTEMY UPRAVLENIYA LETATEL'NYMI APPARATAMI]
V. E. KRAJZMAN *In* Intelligent systems of flight-vehicle control Moscow Moskovskij Aviatsionnyj Institut 1991 p. 25-30. In RUSSIAN refs
Copyright
The implementation of complex adaptive optimal control systems with elements of artificial intelligence is made difficult by the limited capabilities of the existing computer systems. The solution of this problem is possible in a class of systems with a multilevel hierarchical structure. Here, a multilevel hierarchical system, which can be used as a 'pilot's assistant', is described. The development of algorithms for the synthesis of a terminal guidance system for flight vehicles is discussed. AIAA

A93-50956
GENERATION OF A PLANT DESCRIPTION DICTIONARY BASED ON EXPERT SURVEY DATA [FORMIROVANIE SLOVARYA OPISANIYA OB"EKTA PO DANNYM EHKSPERTNOGO OPROSA]
P. S. KUDRYAVTSEV *In* Intelligent systems of flight-vehicle control Moscow Moskovskij Aviatsionnyj Institut 1991 p. 31-35. In RUSSIAN refs
Copyright
The objective of the study is to develop methods for interviewing a group of experts and formalizing the expertise results within a structured format. The problem of compiling a description dictionary for complex systems is examined as an example of a problem where such methods are applicable. The methods proposed here can be implemented on a computer in the form of a dialog system. AIAA

A93-50957
AN INFORMATION-SEARCH SYSTEM IN CYBERNETICS [INFORMATSIONNO-POISKOVAYA SISTEMA V OBLASTI KIBERNETIKI]
A. YA. LASHCHEV and M. P. POPOV *In* Intelligent systems of flight-vehicle control Moscow Moskovskij Aviatsionnyj Institut 1991 p. 35-42. In RUSSIAN refs
Copyright
An information-search system is described which makes it possible to solve a variety of problems in the design of on-board control systems with elements of artificial intelligence. In particular, the tasks handled by the information-search system include the selection of an optimal functional scheme based on a set of parameters characterizing the on-board control system, search for the closest engineering solution based on elements of the functional scheme, and automatic generation of a patent application. Methods by which these tasks are implemented are discussed. AIAA

A93-50958
ARCHITECTURE OF MULTIPROCESSOR DATA PROCESSING MACHINES AND DISPATCHING OF THE KNOWLEDGE ACQUISITION PROCESS IN FLIGHT CONTROL [ARKHITEKTURA MNOGOPROTSESSORNYKH MASHIN OBRABOTKI INFORMATSII I DISPETCHERIZATSII PROTSESSA PRIOBRETENIYA ZNANIJ PRI UPRAVLENII POLETOM]
A. EH. METLOVA *In* Intelligent systems of flight-vehicle control Moscow Moskovskij Aviatsionnyj Institut 1991 p. 42-46. In RUSSIAN refs
Copyright
The use of multiprocessor architectures for evaluating a current situation, including the current technical condition of a controlled plant, is examined, with emphasis on parallel processing. The problem of dispatching the computational procedures in such systems is analyzed. Possible implementations of a multiprocessor architecture are briefly reviewed, with attention given to the DIRECT system and neural nets. AIAA

A93-50960
CONTROL PROBLEM FOR A PLANT WITH ARTIFICIAL INTELLIGENCE [O ZADACHE UPRAVLENIYA OB"EKTOM S ISKUSSTVENNYM INTELLEKTOM]
L. G. RAJKOV *In* Intelligent systems of flight-vehicle control Moscow Moskovskij Aviatsionnyj Institut 1991 p. 50-58. In RUSSIAN refs
Copyright
The control problem for a plant with artificial intelligence is

formulated using J calculus techniques. An approach to the solution of such a problem is proposed which is based on the method of formal descriptions. Possible applications of the approach proposed here are briefly discussed. AIAA

A93-51062
OPTIMIZATION OF ALGORITHMS FOR INFORMATION PROCESSING AND CONTROL [OPTIMIZATSIYA ALGORITMOV OBRABOTKI INFORMATSII I UPRAVLENIYA]
V. V. MALYSHEV, ED. Moscow, Russia Moskovskij Aviatsionnyj Institut 1992 92 p. In RUSSIAN For individual items see A93-51063 to A93-51065
Copyright

The papers presented in this volume focus on the optimization of dynamic system control and processing of measurement data in the presence of stochastic and undetermined disturbances, with particular reference to flight vehicle control problems. Specific topics discussed include analytical solution of a three-dimensional pursuit problem, synthesis of invariant control stabilizing the motion system of a robot, and synthesis of the optimal control of flight vehicle braking with allowance for the discrete nature of control action generation. Other topics discussed include control of a linear scalar system in the presence of uncontrollable factors, algorithm for optimizing a program of parameter-dependent measurements, and optimal filtering of the phase coordinates of linear nondeterministic stochastic systems with discrete time. AIAA

A93-51063
SYNTHESIS OF THE OPTIMAL CONTROL OF FLIGHT VEHICLE BRAKING WITH ALLOWANCE FOR THE DISCRETE NATURE OF CONTROL ACTION GENERATION [SINTEZ OPTIMAL'NOGO UPRAVLENIYA TORMOZHENIEM LA S UCHETOM DISKRETNOSTI VYRABOTKI UPRAVLYAYUSHCHIKH VOZDEJSTVIJ]
A. V. PANTELEEV and T. I. KULIKOVA *In* Optimization of algorithms for information processing and control Moscow, Russia Moskovskij Aviatsionnyj Institut 1992 p. 30-38. In RUSSIAN refs
Copyright

The paper is concerned with the problem of flight vehicle braking control at the soft landing stage with allowance for the discrete nature of flight data acqusition and control action generation. Two formulations are considered which involve the synthesis of a control system with a full feedback with respect to discrete measurements of the coordinates of the plant state vector and synthesis of programmed control in the absence of current information on the plant status. The problems are solved by using the corresponding sufficient conditions for the optimality of control of continuous deterministic systems with incomplete discrtete information. Numerical solution algorithms are developed, and their efficiency is demonstrated. AIAA

A93-51065
OPTIMAL STRUCTURE OF DISCRETE ALGORITHMS OF FINITE-DIMENSIONAL CONTINUOUS-DISCRETE FILTERING IN THE PRESENCE OF MARKOV NOISE [OPTIMAL'NAYA STRUKTURA DISKRETNYKH ALGORITMOV KONECHNOMERNOJ NEPRERYVNO-DISKRETNOJ NELINEJNOJ FIL'TRATSII PRI MARKOVSKIKH POMEKHAKH]
E. A. RUDENKO *In* Optimization of algorithms for information processing and control Moscow, Russia Moskovskij Aviatsionnyj Institut 1992 p. 62-70. In RUSSIAN refs
Copyright

With reference to the problem of estimating the current state of the perturbed motion of a flight vehicle from discrete measurements in the presence of noise, a simple adaptive nonlinear low-order filter is synthesized which estimates only the required components of the extended state vector of a continuous object of observation on the basis of discrete measurements in the presence of Markov noise. Algorithms are obtained for determining both an exact optimal filter and two approximate suboptimal filters (Gaussian and linearized). The synthesis of the latter is reduced, respectively, to statistical or conventional linearization of the nonlinearities of the device for monitoring the state of a flight vehicle. AIAA

A93-51189
COUPLING CHARACTERISTICS ANALYSIS OF ELASTIC VEHICLE
SHUO TANG and SHILU CHEN (Northwestern Polytechnical Univ., Xian, China) Northwestern Polytechnical University, Journal (ISSN 1000-2758) vol. 11, no. 3 July 1993 p. 259-264. In CHINESE refs

As is well known, aeroelastic effect must be carefully considered in analysis and design of modern flight control system. Especially, when the vehicle is regarded as object of control, there exist complex interactions between the flight control system and elastic freedom, including both aeroelastic and aeroservoelastic couplings. Needness to say, the investigation about these coupling motions are very valuable to understanding the stability and dynamic behavior of vehicle motion. In this paper, we establish the dynamic modeling of elastic vehicle with rigid-body attitude motion considered. The stability of elastic vehicle is investigated by Nyquist loci of system return-difference matrix with coupling motion between rigid-body and elastic vibration motion taken into consideration; and an error estimation, which is based on the singular value theory, is derived for the case of open/closed-loop control to indicate interactions between system variables, e.g. attitude variable, elastic vibration variables. control and observation variable, etc. At the end, a practical example is given to demonstrate the proposed method.

A93-51198
A U-D FACTORIZATION-BASED ADAPTIVE EXTENDED KALMAN FILTER AND ITS APPLICATION TO FLIGHT STATE ESTIMATION
YOUMIN ZHANG, HONGCAI ZHANG, and GUANZHONG DAI (Northwestern Polytechnical Univ., Xian, China) Northwestern Polytechnical University, Journal (ISSN 1000-2758) vol. 11, no. 3 July 1993 p. 345-350. In CHINESE refs

A new U-D factorization-based robust adaptive extended Kalman filter (EKF) is proposed and applied to the estimation of the flight state and longitudinal motion of two types of Chinese aircrafts. By using Bierman's U-D factorization filter, the numerical stability of adaptive EKFs can be greatly improved. In order to insure that the estimation for noise covariance matrices Q and R are semipositive and positive, respectively, the computation formulations for continuous on-line revision are introduced. These render the new algorithm robust and efficient. It is shown that the new algorithm will yield more accurate estimation results than EKFs for different initial values and noise statistics, especially for solving flight state estimation problems corrupted by time-variant noises. AIAA

A93-51279
NUMERICAL ASPECTS OF A BLOCK STRUCTURED COMPRESSIBLE FLOW SOLVER
B. J. GEURTS and H. KUERTEN (Twente Univ., Enschede, Netherlands) Journal of Engineering Mathematics (ISSN 0022-0833) vol. 27, no. 3 Aug. 1993 p. 293-307. Research supported by National Computing Facilities Foundation and NWO refs
Copyright

A block structured compressible flow solver based on a finite volume approach with central spatial differencing is described and its performance in 2D on flow around an airfoil is studied. Variations in the number and dimensions of the blocks do not influence the convergence behavior nor the solution, irrespective of the relative positions of a possible shock and the block-interfaces. Mixed calculations, in which the governing equations, either Euler or Reynolds averaged Navier-Stokes, differ per block, give accurate results provided the Euler blocks are defined outside the boundary layer and or in the far field wake region. Likewise, extensive grid distortions near block interfaces can be allowed for outside the

boundary layer. Finally, an unbalanced advancement in time, in which each block is advanced independently over several time steps gives no serious decrease in convergence rate.

A93-51328#
CONTROL AUGMENTATION SYSTEM (CAS) SYNTHESIS VIA ADAPTATION AND LEARNING
PETER J. MILLINGTON, WALTER L. BAKER, and MARK A. KOENIG (Charles Stark Draper Lab., Inc., Cambridge, MA) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 1 Washington American Institute of Aeronautics and Astronautics 1993 p. 265-275. refs
(AIAA PAPER 93-3728) Copyright

A method of synthesizing a control augmentation system via adaptation and learning is described, and simulation results based on the application of this hybrid controller to a six-degree-of-freedom nonlinear aircraft are presented. Two related compensators (one linear, one adaptive) are used for purposes of comparison. Each controller is designed to improve the basic handling qualities of the aircraft. The hybrid controller was trained by exposing it to a number of transient responses, initiated from trim by applying different pilot stick inputs, at randomly selected flight conditions. Desired responses corresponding to matching inputs and conditions were generated by a simple linearized reference model, scheduled on altitude and Mach number. Performance statistics were obtained by analyzing pitch rate tracking errors. At each evaluation point, a pitch doublet stick input was applied to both the aircraft and reference models. In terms of the mean RMS pitch rate tracking error (averaged over 286 points covering the subsonic flight envelope), the learning augmented system outperformed both the adaptive and linear compensators by 195 percent and 700 percent, respectively.

A93-51330#
MULTIPLE RADIAL BASIS FUNCTION NETWORKS IN MODELING AND CONTROL
HUSSEIN M. YOUSSEF (Lockheed Advanced Development Co., Sunland, CA) and JYH-CHING JUANG (National Cheng Kung Univ., Tainan, Taiwan) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 1 Washington American Institute of Aeronautics and Astronautics 1993 p. 285-293. refs
(AIAA PAPER 93-3731) Copyright

A blending of radial basis function networks and general regression neural networks is proposed and shown to be suitable for the modeling and control of dynamical systems. In this blended scheme, the radial basis function networks account for long term and global dynamics, while the general regression neural networks govern short term and local dynamics. Due to the similarity between radial basis function networks and general regression neural networks, which are both synthesized using Gaussian nodes, the blended scheme can be congruently implemented as a multiple radial basis function network. Training techniques of the two constituting networks are explored in the multiple radial basis function networks so as to achieve a balance in temporal as well as spatial characterization. This leads to a high precision, highly dynamical neural network system. Applications of this multiple radial basis function network in aircraft modeling and control are conducted. Real-time training and precision enhancement are demonstrated.

A93-51342*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
THE GENERALIZED LEGENDRE-CLEBSCH CONDITION ON STATE/CONTROL CONSTRAINED ARCS
HANS SEYWALD (Analytical Mechanics Associates, Inc., Hampton, VA) and EUGENE M. CLIFF (Virginia Polytechnic Inst. and State Univ., Blacksburg, VA) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 1 Washington American Institute of Aeronautics and Astronautics 1993 p. 397-405. Research supported by NASA refs
(AIAA PAPER 93-3746) Copyright

An extension of the Generalized Legendre-Clebsch Condition is obtained for problems with singular control along arcs with active state or control constraints. This is achieved by first transforming the Accessory Minimum Problem associated with constrained singular arcs into an unconstrained singular, linear quadratic problem. In a second step whose theorems and proofs are largely based on Goh's work (1966), necessary conditions are derived for such singular linear quadratic problems to yield nonnegative cost. Author (revised)

A93-51344*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
NEAR-OPTIMAL, ASYMPTOTIC TRACKING IN CONTROL PROBLEMS INVOLVING STATE-VARIABLE INEQUALITY CONSTRAINTS
N. MARKOPOULOS and A. J. CALISE (Georgia Inst. of Technology, Atlanta) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 1 Washington American Institute of Aeronautics and Astronautics 1993 p. 417-426. refs
(Contract NAG1-1257)
(AIAA PAPER 93-3748) Copyright

The class of all piecewise time-continuous controllers tracking a given hypersurface in the state space of a dynamical system can be split by the present transformation technique into two disjoint classes; while the first of these contains all controllers which track the hypersurface in finite time, the second contains all controllers that track the hypersurface asymptotically. On this basis, a reformulation is presented for optimal control problems involving state-variable inequality constraints. If the state constraint is regarded as 'soft', there may exist controllers which are asymptotic, two-sided, and able to yield the optimal value of the performance index. AIAA

A93-51394#
DESIGN OF A LOW SENSITIVITY AND NORM MULTIVARIABLE CONTROLLER USING EIGENSTRUCTURE ASSIGNMENT AND THE METHOD OF INEQUALITIES
R. J. PATTON, G. P. LIU, and J. CHEN (York Univ., United Kingdom) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 2 Washington American Institute of Aeronautics and Astronautics 1993 p. 924-929. refs
(AIAA PAPER 93-3802) Copyright

In this paper a parameter insensitive design method is presented for multivariable control systems using eigenstructure assignment and the method of inequalities. The vector design objective is described by a set of performance inequalities, which include closed-loop stability, low feedback gains and insensitivity to model parameter variations, in preference to the use of a scalar performance index. The designed controller has the best eigenstructure and insensitivity to perturbations of the system parameter matrices. Compared with earlier approaches, the conservatism of the eigenstructure sensitivity is reduced. The capability of the method is illustrated in the design of a flight control system.

A93-51431#
SYSTEM IDENTIFICATION OF UNSTABLE MANIPULATORS USING ERA METHODS
ANREN HU and DARRELL MARTIN (Dynacs Engineering Co., Inc., Palm Harbor, FL) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 3 Washington American Institute of Aeronautics and Astronautics 1993 p. 1264-1273. refs
(AIAA PAPER 93-3842) Copyright

Many mechanical systems, such as aircraft and missiles operating in certain flight, envelopes, are inherently unstable and require a controller to ensure overall system stability and to achieve the desired performance. An open-loop model for such systems may be required and can often be obtained using system

identification techniques. For both stable and unstable systems, unlike many other identification techniques, the Eigensystem Realization Algorithm (ERA) can be used for model identification. In this paper, we shall perform ERA identification for a two-link flexible manipulator. The initial configuration of the open-loop model for the robotic manipulator is unstable. Numerical simulations will be performed to identify the open-loop plant using the following two approaches: (1) identify the system with direct numerical open-loop response, and (2) extract the open-loop model from closed-loop response data. Some important issues concerning identifications of unstable systems are also discussed.
Author (revised)

A93-51454#
FUZZY LOGIC CONTROL ALGORITHM FOR SUPPRESSING E-6A LONG TRAILING WIRE ANTENNA WIND SHEAR INDUCED OSCILLATIONS
ROBERT G. BORST, GLEN F. GREISZ, and ALLEN G. QUYNN (Boeing Defense & Space Group, Seattle, WA) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 3 Washington American Institute of Aeronautics and Astronautics 1993 p. 1508-1516. refs
(AIAA PAPER 93-3868) Copyright

The E-6 mission requires deployment of approximately five miles of Long Trailing Wire Antenna (LTWA) and maintaining it nearly vertical to conduct Very Low Frequency (VLF) radio communication with the Navy ballistic missile submarine fleet. To accomplish this mission, the E-6 aircraft flies an 'orbit' profile characterized by slow airspeeds and high bank angles with the principal objective of maximizing LTWA verticality. Wind shear present in the surrounding air mass produces an undesirable 'yoyo' altitude oscillation in the end of the LTWA. A LTWA model and fuzzy logic control algorithm were developed and evaluated. The fuzzy logic control algorithm was found to be very effective in suppressing the LTWA yoyo oscillation. The results of this development effort are presented.

A93-51455#
AIRCRAFT FAILURE DETECTION AND IDENTIFICATION USING NEURAL NETWORKS
MARCELLO R. NAPOLITANO, STEVE NAYLOR, and CHING I. CHEN (West Virginia Univ., Morgantown) *In* AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 9-11, 1993, Technical Papers. Pt. 3 Washington American Institute of Aeronautics and Astronautics 1993 p. 1517-1526. refs
(AIAA PAPER 93-3869) Copyright

In this document, a Neural Network is proposed as an approach to the task of Failure Detection following damage to an aerodynamic surface of an aircraft flight control system. Several drawbacks of other Failure Detection techniques can be avoided by taking advantage of the flexible learning and generalization capabilities of a Neural Network. This structure, used for state estimation purposes, can be designed and trained on-line in flight and generates a residual signal indicating the damage as soon as it occurs. From an analysis of the cross correlation functions between some key state variables the identification of the damage type can also be achieved. The results of a non-linear numerical simulation for a damaged control surface are reported and discussed.

A93-51648* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
CLUSTERING METHODS FOR REMOVING OUTLIERS FROM VISION-BASED RANGE ESTIMATES
B. HUSSIEN and R. SUORSA (NASA, Ames Research Center, Moffett Field, CA) *In* Intelligent robots and computer vision X: Neural, biological, and 3-D methods; Proceedings of the Meeting, Boston, MA, Nov. 14, 15, 1991 Bellingham, WA Society of Photo-Optical Instrumentation Engineers 1992 p. 326-337. refs
Copyright

The present approach to the automation of helicopter low-altitude flight uses one or more passive imaging sensors to extract environmental obstacle information; this is then processed via computer-vision techniques to yield a time-varying map of range to obstacles in the sensor's field of view along the vehicle's flight path. Attention is given to two related techniques which can eliminate outliers from a sparse range map, clustering sparse range-map information into different spatial classes that rely on a segmented and labeled image to aid in spatial classification within the image plane.
AIAA

A93-51944
IMPLICIT SCHEMES FOR UNSTEADY EULER EQUATIONS ON UNSTRUCTURED MESHES
A. S. SENS and G. D. MORTCHELEWICZ (ONERA, Chatillon, France) ONERA, TP no. 1993-64 1993 18 p. International Forum on Aeroelasticity and Structural Dynamics, Strasbourg, France, May 24-26, 1993 refs
(ONERA, TP NO. 1993-64)

An algorithm for the solution of the time-dependent Euler equations is presented for unsteady aerodynamic analysis of oscillating airfoils. The method was developed for use on an unstructured mesh made up of triangles. The flow solver involves an implicit time stepping scheme with a spatial discretization based on the finite element method. The implementation of wall boundary conditions which allow us to treat aeroelastic problems on a fixed mesh, is presented. Steady and unsteady results are presented to demonstrate application of the Euler solver.

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PHYSICS

Includes physics (general); acoustics; atomic and molecular physics; nuclear and high-energy physics; optics; plasma physics; solid-state physics; and thermodynamics and statistical physics.

A93-48140*# National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.
INTERACTION OF THE SONIC BOOM WITH ATMOSPHERIC TURBULENCE
Z. RUSAK and J. D. COLE (Rensselaer Polytechnic Inst., Troy, NY) Jul. 1993 12 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(Contract NAG1-1362)
(AIAA PAPER 93-2943) Copyright

Theoretical research has been carried out to study the effect of free-stream turbulence on sonic boom pressure fields. A new transonic small-disturbance model to analyze the interactions of random disturbances with a weak shock has been developed. The model equation has an extended form of the classic small-disturbance equation for unsteady transonic aerodynamics. An alternative approach shows that the pressure field may be described by an equation that has an extended form of the classic nonlinear acoustics equation that describes the propagation of sound beams with narrow angular spectrum. The model shows that diffraction effects, nonlinear steepening effects, focusing and caustic effects and random induced vorticity fluctuations interact simultaneously to determine the development of the shock wave in space and time and the pressure field behind it. A finite-difference algorithm to solve the mixed-type elliptic-hyperbolic flows around the shock wave has also been developed. Numerical calculations of shock wave interactions with various deterministic and random fluctuations will be presented in a future report. Author (revised)

A93-48288#
A STUDY ON AERODYNAMIC SOUND GENERATED BY INTERACTION OF JET AND PLATE
S. ATSUCHI, Y. NAKAMURA (Nagoya Univ., Japan), and H. KAWAZOE (Toyota Central Research and Development Labs., Aichi, Japan) Jul. 1993 11 p. AIAA, Fluid Dynamics Conference,

24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-3118) Copyright

A simple experimental equipment is devised, where a low sound noise wind tunnel is provided, and the representative flow velocity is fixed to 20 m/s. A flow tone is generated by inserting a plate with a knife edge, or a round edge, perpendicularly to the axisymmetric jet axis. A generated sound varies with the location and shape of the plate edge in the flow field. A drastic sound with a distinct peak of frequency is generated when the knife edge is placed in the shear layer of jet. The aim of this research is to seek the relation between flow and sound from experimental data, and to clarify the essential mechanism of generating this flow tone. In this study, it is made clear that the sound intensity depends on the distance from the edge to the point at which velocity fluctuations normal 10 the jet axis are large. Furthermore, the flow was observed to have the same frequency peak in this region as a distinct peak of sound. Thus, it is confirmed that normal velocity fluctuations to primary axial velocity have a significant role in generating aerodynamic sound.

A93-48411
DIFFRACTION LIMITED COLLIMATING OPTICS FOR HIGH ASPECT RATIO LASER DIODE ARRAYS
N. W. WALLACE and G. S. MECHERLE (TRW, Inc., Redondo Beach, CA) *In* Free-space laser communication technologies IV; *Proceedings of the 4th Conference*, Los Angeles, CA, Jan. 23, 24, 1992 Bellingham, WA Society of Photo-Optical Instrumentation Engineers 1992 p. 345-360. refs
Copyright

An algorithm is derived for the design of a collimator for high aspect ratio laser diode arrays. An illustrative design is presented, showing the potential of these high-aspect-ratio, large-emitting-area laser diode arrays in practical transmitting systems. AIAA

A93-48507
ACOUSTIC EXPERIMENTS OF TWO SCALED-MODEL PROPELLERS ON THE GROUND
XIAODONG LI, XIAOFENG SUN, ZONG'AN HU, and SHENG ZHOU (Beijing Univ. of Aeronautics and Astronautics, China) Journal of Aerospace Power (ISSN 1000-8055) vol. 8, no. 2 April 1993 p. 121-124. In CHINESE refs

Propeller acoustic experiments have been completed on the ground. The experimental results show that the aerodynamic and acoustic performances of 4-blade ARA-D propeller are better than that of the 3-blade NACA64 propeller. The sound field of propellers has directional properties, and it is dominated by discrete tones, especially the 1-5 x BPG tones. So, increase of the blade number and application of the advanced aerofoil will be very effective for improving aerodynamic and acoustic performances of the propeller. The best way to reduce propeller noise and suppress aircraft fuselage noise is to reduce the propeller discrete tones, especially the 1-5 x BPF tones. Author (revised)

A93-48522
ACOUSTICAL PROPERTIES OF SOUND ABSORBING STRUCTURES AT HIGH TEMPERATURE
WEI LIU and DAOMIN TANG (Xian Aero-Engine Corp., Design Inst., China) Journal of Aerospace Power (ISSN 1000-8055) vol. 8, no. 2 April 1993 p. 184-186. In CHINESE refs

The acoustical properties of sound absorbing layers used in a gas turbine exhaust silencing component at high temperature with temperature gradient are investigated by analyzing the effect of temperature on the acoustical properties of porous materials. Some experimental results are given and a good agreement is found between theoretical prediction and measurements of acoustical properties at various temperatures up to 500 C. Author (revised)

A93-48538
REPAIR AND MAINTENANCE OF FIBER OPTIC DATA LINKS ON NAVY AIRCRAFT
ERIC FRYLAND (U.S. Navy, Naval Air Engineering Center, Lakehurst, NJ) *In* Fiber optic components and reliability; Proceedings of the Meeting, Boston, MA, Sept. 3-6, 1991 Bellingham, WA Society of Photo-Optical Instrumentation Engineers 1992 p. 104-111. refs
Copyright

This paper will examine the problems and concerns of repairing fiber optic data links on carrier based Navy aircraft and will present the results of fiber optic splice testing that was performed aboard the USS Abraham Lincoln (CVN-72) in January 1991. Mechanical splicing of 50/125 micrometer fiber was performed at the various Navy maintenance levels in order to quantify the effects of the aircraft carrier environment on fiber optic splicing. Results, conclusions and recommendations will be given.

A93-49005* National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
BOUNDARY CONDITIONS FOR DIRECT COMPUTATION OF AERODYNAMIC SOUND GENERATION
TIM COLONIUS, SANJIVA K. LELE (Stanford Univ., CA), and PARVIZ MOIN (Stanford Univ.; NASA, Ames Research Center, Moffett Field, CA) AIAA Journal (ISSN 0001-1452) vol. 31, no. 9 Sept. 1993 p. 1574-1582. DGLR/AIAA Aeroacoustics Conference, 14th, Aachen, Germany, May 11-14, 1992, Proceedings. Vol. 1, p. 438-447. Previously cited in issue 05, p. 825, Accession no. A93-19176 refs
(Contract N00014-88-K-0592)
Copyright

A93-49466
DESIRABLE CHARACTERISTICS FOR ROTORCRAFT OPTICAL COMPONENTS
RICHARD S. TEAL (Boeing Defense & Space Group, Helicopters Div., Philadelphia, PA) *In* Specialty fiber optic systems for mobile platforms and plastic optical fibers; Proceedings of the Meeting, Boston, MA, Sept. 9-11, 1992 Bellingham, WA Society of Photo-Optical Instrumentation Engineers 1993 p. 103-113.
Copyright

Transition of optical components from laboratory concept demonstrations to flight-worthy production-ready devices is of great interest to both system integrators and potential component manufacturers. Technology limitations have been one barrier to success, though limited communication between airframe system engineers and optical developers appears to be as significant. The current presentation addresses some of the detailed requirement characteristics for application in military rotorcraft, with emphasis on performance, redundancy, size, weight, and environmental conditions. Author (revised)

A93-49475
OPTICAL ACTUATORS FOR FLY-BY-LIGHT APPLICATIONS
SONNY H. S. CHEE, KEXING LIU, and RAYMOND M. MEASURES (Toronto Univ., Downsview, Canada) *In* Specialty fiber optic systems for mobile platforms and plastic optical fibers; Proceedings of the Meeting, Boston, MA, Sept. 9-11, 1992 Bellingham, WA Society of Photo-Optical Instrumentation Engineers 1993 p. 187-193. Research supported by Ontario Light and Laser Research Centre and National Research Council of Canada refs
Copyright

A review of optomechanical interfaces is presented. A detailed quantitative and qualitative analysis of the University of Toronto Institute for Aerospace Studies (UTIAS) box, optopneumatics, optical activation of a bimetal, optical activation of the shape memory effect, and optical activation of the pyroelectric effects is given. The UTIAS box is found to display a good conversion efficiency and a high bandwidth. A preliminary UTIAS box design has achieved a conversion efficiency of about 1/6 of the theoretical limit and a bandwidth of 2 Hz. In comparison to previous optomechanical interfaces, the UTIAS box has the highest pressure development to optical power ratio (at least an order of magnitude greater). AIAA

A93-49478
FIBER OPTICS FOR AIRCRAFT ENTERTAINMENT SYSTEMS
GREGORY L. TANGONAN, HARRY T. M. WANG (Hughes Research Labs., Malibu, CA), and SANG NGUYEN (Douglas Aircraft

Co., Long Beach, CA) *In* Specialty fiber optic systems for mobile platforms and plastic optical fibers; Proceedings of the Meeting, Boston, MA, Sept. 9-11, 1992 Bellingham, WA Society of Photo-Optical Instrumentation Engineers 1993 p. 226-230.
Copyright

We describe the development of a fiber based video distribution for aircraft entertainment. The fiber system delivers live satellite video to every seat in the aircraft and can be interfaced to the interactive services presently being deployed on commercial aircraft.

A93-49619
EFFECTS OF EXTERNAL CONTROL CIRCUIT ON COAL-FIRED SUPERSONIC DIAGONAL-TYPE MHD GENERATOR
M. ISHIKAWA, T. SUEMURA, M. FUJITA, and J. UMOTO (Kyoto Univ., Japan) Journal of Propulsion and Power (ISSN 0748-4658) vol. 9, no. 5 Sept.-Oct. 1993 p. 749-756. refs
Copyright

The paper examines through numerical analyses the behavior of the coal-fired diagonal channel which suffers from the electrical nonuniformities caused by coal slag polarization. The channel is designed for a pilot-plant and is controlled with external circuits such as the master/slave current controller and a sideby-side power shuffling circuit. The MHD channel and external circuits are simultaneously analyzed. A two-dimensional equivalent circuit method is applied for electrodynamics, while the gasdynamical behavior is treated with time-dependent one-dimensional approximation. The following results are obtained: (1) the channel works well with the external circuits, although the supersonic channel suffers from shock when operated near opencircuit; the channel is dynamically stable without fluctuation when the load is changed and (2) the external circuits can control interanode voltage and electrode current even when large electrical nonuniformities grow on cathode wall due to coal slag polarization. The loss due to slag leakage current becomes about 20 percent of power output at 10-MW scale. Author (revised)

A93-49694#
THE EFFECT OF UNSTEADY BLADE LOADING ON THE AEROACOUSTICS OF A PUSHER PROPELLER
CLAY S. MAUK and SAEED FAROKHI (Kansas Univ., Lawrence) Jun. 1993 12 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-1805) Copyright

A theoretical/computational approach is developed to predict the change in near-field noise due to a momentum-deficit upstream of a propeller plane, specifically for a pylon wake in a pusher configuration. The acoustic pressure is computed using blade geometry and unsteady blade surface pressure history. The steady blade surface pressure is predicted using blade-momentum theory and two-dimensional airfoil characteristics. Unsteady blade pressures are derived from in-flight measurements. In-flight acoustic measurements are used for code validation purposes. Overall sound pressure levels (OSPL) are computed for an array of observer locations parallel to the propeller axis of rotation. In order to clearly realize the effect of the wake encounter on the radiated sound, the wake signature is eliminated from the unsteady blade pressures. By subtracting the OSPL computed with the smoothed data from that computed with the original unsteady data, the change in noise resulting from the wake encounter is deduced. In general, the noise was increased due to the propeller-wake chopping activity. For all flight conditions, the largest increase in radiated noise occurred for a highly loaded propeller. The results indicate that the propeller noise due to periodic wake encounter may possess a unique directivity pattern.

A93-49989*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.
COMPOUND CURVATURE LASER WINDOW DEVELOPMENT
VINCENT G. VERHOFF (NASA, Lewis Research Center, Cleveland, OH) Jun. 1993 8 p. AIAA, SAE, ASME, and ASEE, Joint Propulsion Conference and Exhibit, 29th, Monterey, CA, June 28-30, 1993 refs
(AIAA PAPER 93-2177) Copyright

The NASA Lewis Research Center has developed and implemented a unique process for forming flawless compound curvature laser windows. These windows represent a major part of specialized, nonintrusive laser data acquisition systems used in a variety of compressor and turbine research test facilities. This report summarizes the main aspects of compound curvature laser window development. It is an overview of the methodology and the peculiarities associated with the formulation of these windows. Included in this discussion is new information regarding procedures for compound curvature laser window development.

A93-50488
FIBER-OPTIC TECHNOLOGY FOR TRANSPORT AIRCRAFT
Aerospace Engineering (ISSN 0736-2536) vol. 13, no. 7 July 1993 p. 35-40.
Copyright

A development status evaluation is presented for fiber-optic devices that are advantageously applicable to commercial aircraft. Current developmental efforts at a major U.S. military and commercial aircraft manufacturer encompass installation techniques and data distribution practices, as well as the definition and refinement of an optical propulsion management interface system, environmental sensing systems, and component-qualification criteria. Data distribution is the most near-term implementable of fiber-optic technologies aboard commercial aircraft in the form of onboard local-area networks for intercomputer connections and passenger entertainment. AIAA

A93-51867
DEVELOPMENT AND APPLICATION OF THE MONTE CARLO METHOD FOR SOLVING THE BOLTZMANN EQUATION AND ITS MODELS [RAZVITIE I PRIMENENIE METODA MONTE-KARLO DLYA RESHENIYA URAVNENIYA BOL'TSMANA I EGO MODELEJ]
V. I. VLASOV, I. V. VOLKOV, S. L. GORELOV, K. V. NIKOLAEV, and YU. I. KHLOPKOV TsAGI, Trudy no. 2436 1990 p. 3-21. In RUSSIAN refs
Copyright

The paper examines variants of the Monte Carlo method, the method of direct statistical modeling and the test particle method, for solving the Boltzmann equation and the model kinetic equation, as well as the Ulam-Neumann method for solving the linearized Boltzmann equation. The application of these variants is shown with reference to the solution of rarefied gas dynamics problems: the heat transfer between two parallel plates, the aerodynamic characteristics of a flat plate given a small temperature factor, and a Knudsen layer on a rough surface. AIAA

A93-51937
HIGH-FREQUENCY ACOUSTIC RADIATION FROM A CURVED DUCT OF CIRCULAR CROSS SECTION
S. LEWY (ONERA, Chatillon, France) ONERA, TP no. 1993-55 1993 7 p. National Conference on Noise Control Engineering, Williamsburg, VA, May 2-5, 1993 Research supported by DRET refs
(ONERA, TP NO. 1993-55)

Acoustic radiation from helicopter turboshaft engines or aircraft auxiliary power units is often due to high-frequency waves propagating in curved inlets or nozzles of circular cross section, where a single spinning mode at the source is split into all the propagating modes. In this paper, a computer program is developed for predicting far-field acoustic radiation from a curved duct, based on the hypothesis that the propagating modes are temporally coherent. A comparison of the theoretical results with test data explains the strong asymmetries found by tests. It is suggested that better predictions using the present method would require the measurement of the actual mode phases in the duct exit cross section. AIAA

A93-52447
ROTOR WAKE/STATOR INTERACTION NOISE - PREDICTIONS VS DATA
D. A. TOPOL (Pratt & Whitney Group, East Hartford, CT) Journal of Aircraft (ISSN 0021-8669) vol. 30, no. 5 Sept.-Oct. 1993 p. 728-735. AIAA, Aeroacoustics Conference, 13th, Tallahassee, FL, Oct. 22-24, 1990, AIAA Paper 90-3951. Previously cited in issue 02, p. 230, Accession no. A91-12467 refs
Copyright

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SOCIAL SCIENCES

Includes social sciences (general); administration and management; documentation and information science; economics and cost analysis; law and political science; and urban technology and transportation.

A93-48145#
THE BENEFITS OF MAGLEV TECHNOLOGY
RICHARD J. GRAN (Grumman Corp., Bethpage, NY) Jul. 1993 11 p. AIAA, Fluid Dynamics Conference, 24th, Orlando, FL, July 6-9, 1993 refs
(AIAA PAPER 93-2949) Copyright
A System Concept Definition (SCD) study to design a high-speed 134 m/s (300 m.p.h.) Maglev transportation system was recently completed. The Grumman design uses superconducting magnets mounted below the vehicle (canted at a 35 degree angle) to provide the required lift and lateral control forces. This configuration allows a large (5 cm) gap and precludes a secondary suspension system. In addition, the small pole pitch of the magnets allows a simple linear synchronous motor to be used to propel the vehicle. The primary development goal was to design a Maglev that is safe, reliable, environmentally acceptable, and low-cost. The cost issue was the predominant one, since previous studies have shown that an economically viable Maglev system requires a cost that is under $20 Million per mile. Author (revised)

A93-49279
BILATERAL TRANSFERS OF SAFETY OVERSIGHT WILL PROVE BENEFICIAL TO ALL STATES
MICHAEL B. JENNISON (FAA, Washington) ICAO Journal (ISSN 0018-8778) vol. 48, no. 4 May 1993 p. 16, 17.
Copyright
The entry into effect of Article 83 bis, the first substantive amendment to the Chicago convention, is discussed. It is noted that it will help clarify responsibility for safety oversight of aircraft operating from bases outside the state of registry. Article 83 bis enables a state to transfer safety oversight responsibilities to another state to the extent it deems prudent. AIAA

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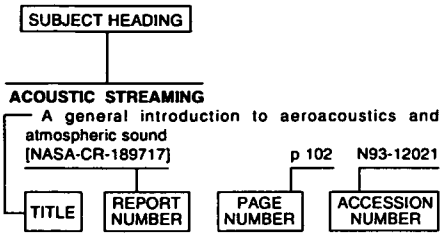
GENERAL

A93-50330
EVOLUTIONARY NASA - INVENTORS TO BUREAUCRATS
JAY R. GIROTTO Journal of Practical Applications in Space (ISSN 1046-8757) vol. 2, no. 4 Summer 1991 p. 15-26. refs
Copyright
The evolution of NASA from the National Advisory Committee for Aeronautics (NACA) is reviewed. The history of America's national aeronautics organizations is considered to be a transition from innovators to bureaucrats. In recent years NASA followed the path of bureaucratic stagnation and poor policy decisions. To recover from its failures it must return to the three ingredients that made the NACA so successful: personnel, structure, and purpose. AIAA

A93-50333
SPACE POLICY 2000
DANIEL O. GRAHAM (High Frontier, Inc., Arlington, VA) Journal of Practical Applications in Space (ISSN 1046-8757) vol. 3, no. 2 Winter 1992 p. 1-15. refs
Copyright
A survey of prospects for U.S. space policy recommends a fostering of fire-enterprise development initiatives, the deployment of missile-defense-related space forces, and the aggressive development of space-based energy systems. Lunar surface exploitation is noted to encompass both the siting of solar collectors and the mining of He-3 for terrestrial deuterium-He-3 fusion reactors. The space defense system to be developed is conceived as a constellation of interceptor satellites in permanent orbits which can through its highly accurate sensors deliver large quantities of remote sensing data during peacetime. AIAA

A93-51497
LIQUID ROCKET PROPULSION APPLIED TO MANNED AIRCRAFT - IN HISTORICAL PERSPECTIVE
C. M. EHRESMAN (Purdue Univ., West Lafayette, IN) British Interplanetary Society, Journal (ISSN 0007-094X) vol. 46, no. 7 July 1993 p. 255-268. refs
Copyright
The history of liquid rocket applications is briefly reviewed, starting with efforts in this field begun in the 1930s in Germany and Russia and in the 1940s in the United States. The early superperformance applications discussed include Heinkel 176 rocket plane, Messerschmitt 163-B rocket fighter, Walter HWK 109-509C1 rocket engine, Northtrop MX-334 rocket plane, Aerojet XCAL 200 rocket engine, F-80, and the YLR63-AJ-3 superperformance rocket. Attention is also given to high speed flight research applications and manned aircraft assisted take-off rocket applications, including the Bell X-1, Douglas D-558 Skyrocket, North Americal X-15, the Arado 234, the 38 ALDW-1500 ATO, and the YLR63-AJ-1. AIAA

Typical Subject Index Listing



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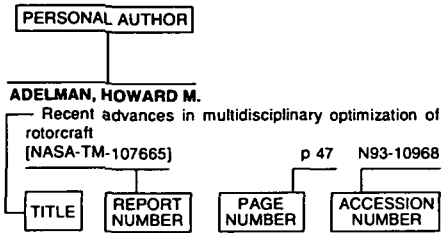
Typical Personal Author Index Listing



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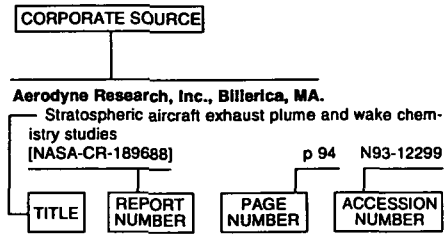
Typical Corporate Source Index Listing



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J

Jet Propulsion Lab., California Inst. of Tech., Pasadena.
JPL AIRSAR processing activities and developments p 1162 A93-47865

N

National Aeronautics and Space Administration, Washington, DC.
Absolute intensity measurements of impurity emissions in a shock tunnel and their consequences for laser-induced fluorescence experiments p 1147 A93-48044
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WNN 92; Proceedings of the 3rd Workshop on Neural Networks: Academic/Industrial/NASA/Defense, Auburn Univ., AL, Feb. 10-12, 1992 and South Shore Harbour, TX, Nov. 4-6, 1992
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A parallel implementation of a multisensor feature-based range-estimation method p 1099 A93-51967
A time-accurate high-resolution TVD scheme for solving the Navier-Stokes equations p 1093 A93-52006

National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.
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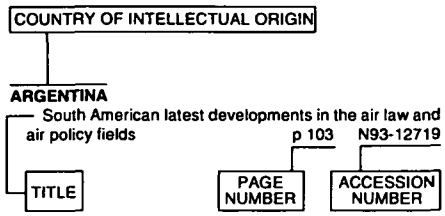

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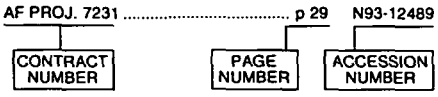

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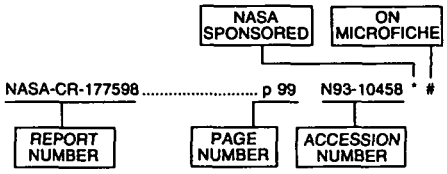

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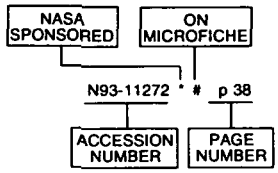

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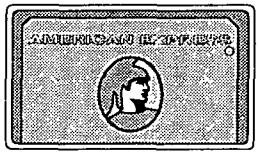

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1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA SP-7037 (297)		

4. Title and Subtitle	5. Report Date
Aeronautical Engineering A Continuing Bibliography (Supplement 297)	November 1993
	6. Performing Organization Code JTT
7. Author(s)	8. Performing Organization Report No.
	10. Work Unit No.
9. Performing Organization Name and Address NASA Scientific and Technical Information Program	11. Contract or Grant No.
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, DC 20546-0001	13. Type of Report and Period Covered Special Publication
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UNIV. OF NORTH CAROLINA - CHAPEL HILL
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Logan, UT 84322-3000
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