NAVIER-STOKES CALCULATIONS OF
SCRAMJET-NOZZLE-AFTERBODY FLOWFIELDS

By
Oktay Baysal, Principal Investigator

Final Report
For the period ended August 15, 1991

Prepared for
National Aeronautics and Space Administration
Langley Research Center
Hampton, Virginia 23665

Under
Research Grant NAG-1-811
James L. Pittman, Technical Monitor
SMD-Aerothermal Loads Branch

Submitted by the
Old Dominion University Research Foundation
P.O. Box 6369
Norfolk, Virginia 23508-0369

July 1991
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equations for four species (Nitrogen, Oxygen, Freon-12, Argon). This has allowed $\gamma$ to be a field variable during the mixing of the multispecies gases, which have been assumed to be only thermally perfect with frozen chemistry. Two different mixing models have been used and comparisons between them as well as the perfect gas air calculations have been made to assess their relative merits. Finally, the three-dimensional Navier-Stokes computations were made for the full-span scramjet-nozzle-afterbody module. The computational results have been successfully compared with the wind tunnel data for the surface pressures (2-D air, 2-D multispecies, and 3-D air flows) and the pitot pressures of the off-surface flow (3-D airflow).

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Oktay Baysal and Wendy B. Hoffman
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ABSTRACT

A computational investigation is conducted to study the expansion of a supersonic air flow through an internal-external nozzle and its mixing with a hypersonic air flow. The impetus is to help the design of the nozzle-afterbody section of a hypersonic transport vehicle which is powered by a scramjet engine. Three-dimensional compressible Navier-Stokes equations are solved by the finite-volume and alternating-direction-implicit method. The convective and the pressure terms are differenced by an upwind-biased algorithm which uses the flux-difference splitting and various flux limiters. The Reynolds stresses are modeled algebraically. The simulated flowfield also allows detailed analyses of a supersonic duct flow, a supersonic flow through an asymmetric internal nozzle, a hypersonic flow over a double-corner, and three-dimensional shear layers. The computed pressure distributions compare favorably with the experimentally obtained surface and off-surface flow surveys.

INTRODUCTION

Propulsion-airframe integration for hypersonic airbreathing vehicles is an important feature for the design of a national aero-space plane configuration. The lower afterbody expands the supersonic exhaust gases from the scramjet engine, therefore it becomes a part of the nozzle. This strong coupling between the engine and the airframe necessitates a combined analysis of internal and external flows. The hypersonic freestream and the supersonic exhaust flow mix through a shear layer, where mass, momentum, and energy transfers occur. The interference of the exhaust on the control surfaces of the aircraft can have adverse effects on the stability of the aircraft. Therefore, some method of simulating this type of flow is required to properly design the nozzle and the afterbody region.

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NASA CONTRACTOR REPORT

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Fourth National Aero-Space Plane Technology Symposium
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