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5.3 Space Propulsion – John Kazaroff, Lewis Research Center

Lewis Research Center is developing broad-based new technologies for space chemical engines to satisfy long-term needs of ETO launch vehicles and other vehicles operating in and beyond Earth orbit. Specific objectives are focused on high performance LO_2/LH_2 engines providing moderate thrusts of 7,5-200 klb. This effort encompasses research related to design analysis and manufacturing processes needed to apply advanced materials to subcomponents, components, and subsystems of space-based systems and related ground-support equipment.

High-performance space-based chemical engines face a number of technical challenges. Liquid hydrogen turbopump impellers are often so large that they cannot be machined from a single piece, yet high stress at the vane/shroud interface makes bonding extremely difficult. Tolerances on fillets are critical on large impellers. Advanced materials and fabricating techniques are needed to address these and other issues of interest.

Turbopump bearings are needed which can provide reliable, long life operation at high speed and high load with low friction losses. Hydrostatic bearings provide good performance, but transients during pump starts and stops may be an issue because no pressurized fluid is available unless a separate bearing pressurization system is included. Durable materials and/or coatings are needed that can demonstrate low wear in the harsh LO_2/LH_2 environment.

Advanced materials are also needed to improve the lifetime, reliability and performance of other propulsion system elements such as seals and chambers.

SPACE PROPULSION

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SPACE CHEMICAL ENGINES TECHNOLOGY

INTRODUCTION

LOOKS TOWARD LONG-TERM MISSIONS IN AND BEYOND EARTH ORBIT AND INTO THE SOLAR SYSTEM. BROAD BASED TO BE UTILIZED BY EARTH TO ORBIT (ETO) ENGINES.

OBJECTIVES

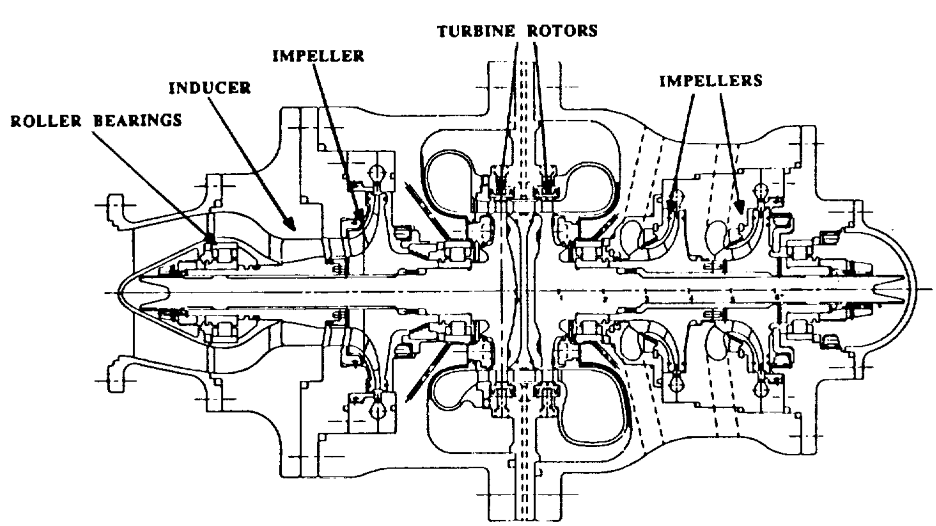
GOAL IS TO PROVIDE THE TECHNOLOGY NECESSARY TO CONFIDENTLY PROCEED WITH THE DEVELOPMENT OF A MODERATE-THRUST (7.5-200 KLBF) HIGH PERFORMANCE LIQUID OXYGEN/LIQUID HYDROGEN ENGINE FOR VARIOUS SPACE TRANSPORTATION APPLICATIONS. MAJOR PROGRAM OBJECTIVES INCLUDE:

- IDENTIFICATION AND ASSESSMENT OF PROPULSION TECHNOLOGY REQUIREMENTS;
- IDENTIFICATION, CREATION, AND/OR VALIDATION OF DESIGN AND ANALYSIS METHODOLOGIES/SOFTWARE, MATERIALS WITH REQUIRED/DESIRABLE PROPERTIES, AND RELIABLE, COST EFFECTIVE MANUFACTURING PROCESSES;
- DEVELOPMENT AND VALIDATION OF ENGINE SUBCOMPONENT, COMPONENT, SUBSYSTEM, AND SYSTEM TECHNOLOGIES FOCUSED ON IMPROVING PERFORMANCE, COMPACTNESS, DURABILITY, RELIABILITY, AND OPERATIONAL EFFICIENCY, AS WELL AS REDUCED COST;
- DEVELOPMENT AND VALIDATION OF TECHNOLOGIES FOR OPERATIONALLY-EFFICIENT SPACE-AND/OR GROUND-BASED PROPULSION SYSTEM SUPPORT EQUIPMENT.

SPACE ENGINE LIQUID HYDROGEN TURBOPUMP

CHARACTERISITICS

	PRIMARY	SECONDARY
FLOWRATE	773 GPM	503 GPM
DISCHARGE PRESSURE	1917 psi	4503 psi
DESIGN SPEED	99220 rpm	98240 rpm
TURBINE POWER	1295 hp	1180 hp



IMPELLER - FABRICATION DIFFICULTIES

- DIMENSIONS ARE SUCH, CANNOT MACHINE OUT OF ONE PIECE
- HIGH STRESS AT VANE/SHROUD INTERFACE, BONDING ON SHROUD DIFFICULT
- TOLERANCE ON FILLETS CRITICAL DUE TO SIZE

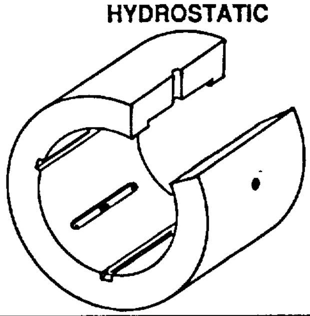
SBE TURBOPUMP BEARINGS

DESIRED ATTRIBUTES IN A BEARING

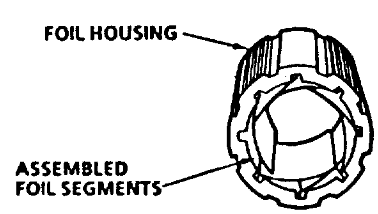
- LONG LIFE AT HIGH SPEED
- HIGH LOAD CAPACITY
- LOW FRICTION LOSS
- RELIABILITY
- LOW COOLING FLOW
- ADDED DAMPING

LEADS TO FLUID FILM BEARINGS AS PRIMARY CANDIDATES

HYDROSTATIC



FOIL



MATERIAL ISSUES FOR FLUID FILM BEARINGS

MOST IMPORTANT ISSUE IS ACCOMMODATING TRANSIENTS - THE TURBOROTOR'S STARTS AND STOPS WHERE NO PRESSURIZED FLUID IS AVAILABLE AND WEAR IS MOST SEVERE

DIRECT SLIDING STARTS & STOPS OFFER SEVERAL ADVANTAGES

- NO NEED FOR SEPARATE BEARING PRESSURIZATION SYSTEM
- LESS ENGINE WEIGHT
- SIMPLER, FEWER PARTS

NEED

DURABLE MATERIALS/COATINGS THAT PROVIDE LOW WEAR/LUBRICITY IN LH_2 AND LOX ENVIRONMENTS

MATERIAL CONCERNS FOR SEALS IN SPACE BASED ENGINES

OBJECTIVE: LONG LIFE, LOW LEAKAGE, LOW POWER LOSS SEALS

CANDIDATE SEALS	PROBLEMS	APPROACH
LOX SPIRAL-GROOVE FACE SEAL	• Oxygen Compatibility • Floating Ring Must Have Low Inertia • Wear During Start/Stop	• Inconel 718 Runner with Silver Plate on Lands • P5N Carbon Floating Ring
SOFT WEAR- RING SEAL	• Oxygen Compatibility • Rubbing Contact Creates Ignition Source • Uneven Wear Opens Clearance • Large Debris	• Frictional Ignition Tested VESPEL SP21 and KEL-F against MONEL K-500 Rotor in 300 PSI LOX at 17,000 RPM - VESPEL SP21 Ignited - KEL-F Did not Ignite • KEL-F Generates Stringy Debris
BRUSH SEAL	• Hydrogen Compatibility • Wear of Bristles • Wear of Rotor/Coatings • Frictional Heating • Bonding Coatings to Rotor for Either LH_2 Use or 1500°F GH_2 Use	• Bristles made of Haynes 25 • Will Test Bare Inconel 718 Rotor & Coatings of AL_2O_3, Silver, and Chrome Carbide in LH_2

LONG LIFE RELIABLE CHAMBERS

- HIGH HEAT FLUX ENGINES NEED LONG LIFE MATERIAL FOR CHAMBERS
- LOW COST CONSTRUCTION
- PRESENT METHODS AND MATERIALS; CHANNEL AND ADVANCED COPPER ALLOYS
- OTHER METHODS AND MATERIALS BEING INVESTIGATED