N93-26932

MSFC NUCLEAR THERMAL PROPULSION TECHNOLOGY PROGRAM

MSFC

NON-NUCLEAR MATERIALS ASSESSMENT

"IDENTIFY AND EVALUATE CANDIDATE MATERIALS FOR USE IN NTP TURBOMACHINERY AND PROPELLANT FEED SYSTEM APPLICATIONS."

THE APPROACH WAS TO DEVELOP AND IMPLEMENT DETAILED TEST PLANS AND EVALUATION CRITERIA FOR EFFECTS OF A HOT HYDROGEN ENVIRONMENT ON NTP CANDIDATE MATERIALS.

THE FOLLOWING MATERIALS WERE SELECTED FOR SURFACE EROSION TESTING:

- INCONEL 718 (BASELINE MATERIAL)
- IMAR 246 (IMPROVED MARAGING STEEL)
- NASA 23 (NICKEL BASED STEEL)

THE FOLLOWING TEST PLANS WERE DEVELOPED:

- STATIC HOT HYDROGEN TESTING UP TO 1000 C AND 5000 psi. TEST TO INCLUDE:
  - TENSILE PROPERTIES
  - LOW CYCLE FATIGUE
  - CREEP
  - FRACTURE TOUGHNESS
- FLOWING HOT HYDROGEN TESTING AT TEMPERATURES UP TO 1000 C FOR MICROSTRUCTURE CHARACTERIZATION OF EXPOSED MATERIALS

MATERIAL SAMPLES WERE TESTED AT AUBURN UNIVERSITY IN A 700 C HYDROGEN ENVIRONMENT WITH ADDITIONAL TESTS TO BE PERFORMED AT MSFC, ALSO AT 700 C.

MSFC FACILITY IS CAPABLE OF MATERIAL EXPOSURE TESTING UP TO 980 C AND 5000psi IN A HYDROGEN OR HELIUM ENVIRONMENT.

NON-NUCLEAR MATERIALS ASSESSMENT

The objective of the MSFC materials effort is to identify and evaluate candidate materials for use in NTP turbomachinery and propellant feed system applications. The initial task was to develop a set of test plans and evaluation criteria that could be applied to screen candidate materials for application in NTR components. In order to be a viable candidate, the material must be resistant to degradation due to the effects of exposure to hydrogen. A set of baseline materials were selected which included Inconel 718, NASA 23, and IMAR 246. These material samples were provided to Auburn University for exposure in a 700 C hydrogen environment and characterization of the induced surface erosion. Similar hydrogen environment testing was performed at MSFC for obtaining the mechanical properties of the samples through in situ testing in 10 MPA (1500 psi) hydrogen at 700 C. In situ test capabilities include tensile strain properties, fatigue, crack growth, fracture toughness, creep, and four point bend.

MSFC

NON-NUCLEAR MATERIALS ASSESSMENT

HIGH TEMPERATURE TESTING OF VARIOUS CARBIDE BASED COATINGS FOR APPLICATION TO TURBOPUMPS, TURBINE BLADES, FLOW SYSTEMS, AND NOZZLES HAVE ARE BEING PERFORMED.

TaC, WC, & NbC HAVE BEEN EXPOSED TO HYDROGEN AT 1 ATMOSPHERE AND TEMPERATURES OF 830, 1350, & 1460 C TO DETERMINE % WEIGHT LOSS

	% weight loss at temperature		
Material	830 C	1350 C	1460 C
TaC	0.03	0.03	0.06
WC	0.07	0.10	0.04
NbC	0.10	0.36	1.14

SILICON NITRIDE AND ALUMINA CERAMICS HAVE BEEN TESTED FOR HIGH TEMPERATURE COATING APPLICATIONS. COMPARATIVE TESTING WAS PERFORMED IN AIR AND HYDROGEN AT AMBIENT TEMPERATURE AND AT 700 C FOR PERIODS OF 1 HOUR.

A FOUR-POINT BEND FIXTURE WAS USED TO TEST BASIC MECHANICAL PROPERTIES OF MEAN STRENGTH AND WEIBULL MODULUS.

NON-NUCLEAR MATERIALS ASSESSMENT

High temperature testing of carbide based coatings for application to turbopumps, turbine blades, flow systems, and nozzles are being performed. These coatings include the carbides of Tantalum, Niobium, Tungsten, and Silicon. These materials are being exposed to elevated temperatures over the range of 830 C to 1460 C in a vacuum and hydrogen environment for periods of one hour. Analysis consists of in situ weight loss determinations and residual gas analysis with subsequent examination of microstructure via Scanning Electron Microscopy and Transmission Electron Microscopy. The objective of this investigation is to characterize microstructural changes in these materials as a result of exposure to hydrogen.

Further material evaluations involve the preparation of Silicon Nitride and Alumina, candidate ceramics for high temperature coatings, for comparative tests in air and hydrogen at room temperature and 700 C for periods of one hour. At MSFC a four point bend fixture was configured to perform in situ testing of these materials for determination of their basic mechanical properties of mean strength and Weibull modulus.

MSFC

NTP TURBOMACHINERY TECHNOLOGIES

"DEVELOP AND VALIDATE ADVANCED TURBOMACHINERY TECHNOLOGIES AT THE COMPONENT AND TURBOPUMP ASSEMBLY LEVELS."

THE NASA REFERENCE SIZE WAS BOUNDED BY 50K AND 75K LB THRUST ENGINE.

THE APPROACH USED WAS TO ASSESS AND DEFINE TURBOMACHINERY TECHNOLOGY REQUIREMENTS FOR A SPACE BASED/START NUCLEAR THERMAL ROCKET ENGINE. MSFC AND LeRC SPECIALISTS COLLABORATED TO DEFINE AN INITIAL TECHNOLOGY PLAN FOR TPA TECHNOLOGY.

THE PLAN ADDRESSES:

- BEARINGS (FLUID FILM & FOIL)
  - SLOW START TRANSIENT FOR FLUID FILM BEARINGS
  - RUB TOLERANT MATERIALS FOR FLUID BEARINGS
  - ROLLING ELEMENT CAGE MATERIAL FOR THRUST BEARING (IF REQUIRED)
  - MAGNETIC BEARINGS
- SEALS
  - DEFINITION OF SEAL REQUIREMENTS
  - RUB TOLERANT MATERIALS
- EARLY NEED FOR A PROPELLANT FEED SYSTEM TEST BED
  - EARLY DEFINITION OF TRANSIENT LOADS
  - EVALUATION OF FEED SYSTEM IMPACTS ON TURBOMACHINERY

NTP TURBOMACHINERY TECHNOLOGIES

The objective of the MSFC turbomachinery technology task is to develop and validate technologies at the component and turbopump assembly level for application in a Nuclear Thermal Rocket engine. Marshall Propulsion Laboratory personnel collaborated with turbomachinery specialists at LeRC on the assessment of the technology requirements and priorities as well as an initial technology development plan. The ground rules provided that the engine size be in the range of 50K to 75K lb thrust and space based. Space base/start imposes a need to assess the requirement for low NPSH technologies.

The technology assessment and development plan addresses both fluid film and foil bearings. Current thinking is that rolling element bearings would not be used unless in a thrust bearing application. There exist, to date, little experience with either foil or hydrostatic bearings. Most experience addresses only fast start transient systems and. therefore, indicate a need for research in the application of fluid film/foil bearings in a prolonged start transient such as the NTR application. This also illustrates the need for further materials research for materials that would be wear resistant in a hydrogen and radiation environment. The main concern for rolling element bearings is for application as a thrust bearing where research is needed to identify a cage material that will survive the radiation environment. The application of a magnetic bearing could eliminate wear at startup and is also being considered.

Additional technology is also required in the area of seals. Questions must be addressed as to the need for a positive seal between the pump and turbine for pre and post operation.

A propellent feed system test bed is needed early in any TPA technology/advanced development program. A preliminary study has begun to assess the possibility of using existing turbomachinery and test stand hardware to facilitate the development of a test stand. The testbed is needed to evaluate transient operation and provide early definition of transient loads. This facility could also be used to assess feed system impacts on the turbomachinery. The system could also be used to evaluate TPA control and health monitoring technologies.

MSFC

HIGH TEMPERATURE SUPERCONDUCTING MAGNETIC BEARING TECHNOLOGY

"DEVELOP AND VALIDATE ADVANCED TECHNOLOGY FOR HIGH TEMPERATURE SUPERCONDUCTOR (HTS) PASSIVE MAGNETIC/HYDROSTATIC BEARING"

- GREATLY REDUCE, OR ELIMINATE COMPLETELY, THE EXPECTED WEAR TO A CONVENTIONAL HYDROSTATIC BEARING AS A RESULT OF NTR SLOW STARTUP TRANSIENT
- SDIO CONTRACT WITH MTI JOINTLY FUNDED BY DARPA AND NASA
- HTS TECHNOLOGY WILL ENABLE THE DEVELOPMENT OF A NEAR ZERO-WEAR BEARING WHEN COMBINED WITH FLUID FILM BEARING CONCEPTS.
- CURRENTLY DESIGNING PROOF-OF-CONCEPT TEST RIG BASED ON MSFC SUPPLIED REFERENCE TPA PARAMETERS BASED ON J-2S TURBOMACHINERY.
- TESTS AND MATERIAL RESEARCH ONGOING TO INCREASE HTS BEARING LOAD CARRYING CAPABILITY AT LH2 TEMPERATURES. HTS LOAD CAPABILITY HAS BEEN IMPROVED BY 450%.
- MSFC INHOUSE EFFORTS ARE FOCUSED ON MEASUREMENT OF HTS MAGNETIZATION OVER TEMPERATURE RANGE FROM 25K TO 77K. NTP-TPA OPERATIONAL TEMPERATURE IS PREDICTED TO BE AROUND 30K.

HIGH TEMPERATURE SUPERCONDUCTING MAGNETIC BEARING TECHNOLOGY

The objective of the MSFC HTS technology task is to develop and validate advanced technology for High Temperature Superconductor (HTS) passive magnetic/hydrostatic bearings for application in a nuclear rocket engine. This bearing concept will greatly reduce, or eliminate completely, the expected wear to a conventional hydrostatic bearing as a result of the extremely slow startup transient of the NTR. This work was performed by Mechanical Technology Inc. under a SDIO contract funded jointly between NASA/MSFC and DARPA.

By combining HTS technology with that of fluid film bearings, it will be possible to suspend the pump shaft during the start-up and shut-down of the pump when the hydrostatic bearing is not fully functional. HTS stiffness has been improved by 450% during the course of this effort and further improvement to capabilities of >2000 lb/in/in2 is believed very possible. MTI was supplied reference parameters based on the J-2S turbopump in order to design a proof-of-concept test apparatus.

Additional inhouse efforts have focused on measurement of HTS magnetization over temperature ranges from 25K to 77K. The operational temperature of the turbomachinery for the NTR is predicted to be 30K.