BEARINGS WORKING GROUP

Introduction

The service life of the Space Shuttle Main Engine (SSME) turbomachinery bearings has been a predominant factor in engine durability and maintenance problems. Recent data has indicated that bearing life is about one order of magnitude lower than our goal of seven and one-half hours particularly those in the High Pressure Oxidizer Turbopump (HPOTP). There are several reasons for this limited life situation as follows: The turbopumps are high speed, very high power-to-weight ratio, high efficiency units. The turbopump mainshaft rotors operate above the first critical speed; therefore, rotor loads imposed on the bearings are relatively high. Engine systems' pressures impose high transient axial loads on the HPOTP bearings during start and shutdown, particularly at shutdown. Finally the bearings operate submerged in the cryogenic fluid being pumped so conventional fluid lubricants cannot be utilized and the dry film lubricants being applied have limited life. In addition to working toward reducing the loads being imposed on turbopump bearings, it was decided that improvements in bearing design, modeling, materials, substrate surface modification, coatings, and lubrication methods would be researched, since the 440C steel being used was not particularly good in either rolling contact fatigue or wear resistance, the other materials and techniques being applied were not recent state-of-the-art and significant improvement was believed possible.

In order to structure a program which would have a high probability of success and one which would fully address the SSME problems being encountered, a Bearings Working Group was established which included technological expertise from both the Lewis Research and the Marshall Space Flight Centers in areas of turbopump and engine development, mechanical design, stress, rotor dynamics, instrumentation, metallurgy, lubrication, bearings, hydrostatic bearings, bearing modeling, seals, and test engineering. The objective adopted is shown below.

Objective

To advance the state-of-the-art in bearing technology, primarily cryogenic turbomachinery bearing technology, by exploring the life and performance effects of design changes, design concept changes, materials changes, manufacturing technique changes and lubrication system changes, and to compare each new variation against the current bearing design in full scale cryogenic tests.

Program Elements

Cryogenic Turbopump Bearing Data Analysis and Computer Modeling Updating - The compilation and analysis of cryogenic bearing test data and its use in generating a computer math model.

Cryogenic Turbopump Roller Bearing Research and Technology - A feasibility study, which if successful, would advance to the design and manufacture of cryogenic turbopump roller bearings for test and use.

Hydrostatic Bearing for LH_2 and Lox Turbopumps - A feasibility study, which if successful, would lead to the design, fabrication and test of a hydrostatic or hybrid cryogenic bearing.

Investigate and Characterize Magnetic Bearings in a Cryogenic Environment - A feasibility study, which if successful, would be followed by the design and manufacture of demonstration unit hardware which would be tested at MSFC with contractor assistance.

Application of Powder Metallurgy Techniques to Produce Improved Bearing Elements - A feasibility study, which if successful, would lead first to the manufacture of balls for evaluation and full scale tests, then second to the manufacture of entire bearings for evaluation and test.

Cryogenic Turbopump Ball Bearing Research and Technology - An in-house MSFC cryogenic bearing test program wherein measurements of bearing stiffness, damping and coolant requirements will be made, test of new bearing materials, surface treatments and coatings, and different lubrication schemes will be made, plus where data will be accumulated which will permit the adjustment of a cryogenic bearing math model.

Ion Plated Bearing Materials Study and Evaluation - A feasibility study, which if successful, would lead to the manufacture of ion plated bearings for full scale tests.

Although all of the Program Elements in the bearings area are active and good progress is being made in each, four were chosen for the presentation of papers because of their relative accomplishments. The paper given concerning detailed internal cryogenic bearing thermal modeling reported that current jet engine models are not appropriate and that a model has been generated which can accommodate bearing heat transfer across the phase change of a cryogenic coolant. It can also accommodate different LN_2 or LO_2 coolant inlet conditions, flowrates and axial loads. More work remains to be accomplished in modeling LH_2 coolant, radial load cases, and coupling the thermal and mechanical models needed for this application. The paper concerning development of a hydrostatic bearing reported successful design optimization, bearing manufacture, and completion of the first test series in LH_2 (liquid hydrogen). More test work remains with LH_2 and configurations for test and use in LO_2. The paper presented concerning the application of powder metallurgy bearing elements showed data which indicated improved rolling contact fatigue resistance with three of the alloys being tested. One of them appears to be a significant improvement over 440C. Again, this was a status report and considerable work remains to be accomplished.

The paper concerning chromium ion plated 440C reported improved rolling contact fatigue life with thin coatings. This effort has been expanded to include ion implantation methods and much work remains to be done in this area.