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NASA TECH BRIEF

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Design and Testing of Liquid Hydrogen-Cooled, Ultrahigh-Speed Ball Bearings

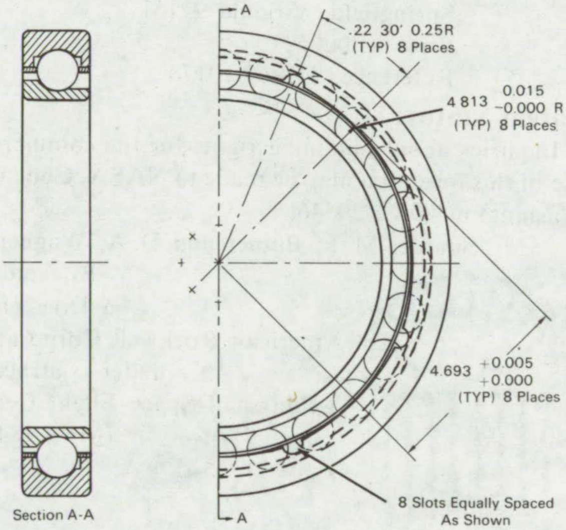

Figure 1
Bearing Design

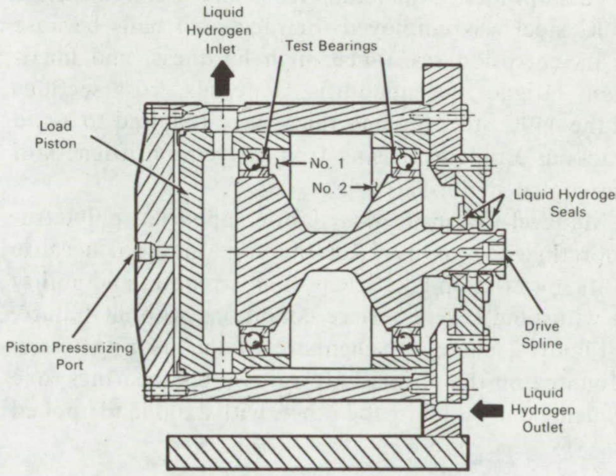

Figure 2
Bearing Tester Schematic

Use of large-bore, liquid hydrogen-cooled, ultrahigh-speed, rolling-contact bearings of an optimum design allows optimization of large rocket engine turbopumps in which bearing speed is a limiting factor. Extensive information is now available on these bearings.

Optimum design for the bearings resulted from extension of knowledge based on previous work. Butner and Rosenberg (Note 1) in 1962 reported that liquid hydrogen can be used as a rolling contact bearing coolant. Ball bearings of 45- and 60-mm bore were operated at high loads for rocket engine design life durations at speeds from 1.0 to 1.6 × 10^6 DN. (DN = bore of bearing in mm multiplied by speed in rpm). Subsequent tests demonstrated some performance limitations for 150-mm ball bearings operating in liquid hydrogen at speeds in excess of 2.0 × 10^6 DN.

A large, extra light series bearing was designed having a 200-mm bore chosen on the basis of requirements of a large liquid hydrogen pump. A design goal of 15,000 rpm (3.0 × 10^6 DN) and a design life of one hour were established for this bearing.

For design purposes, a steady-state load of 5000 pounds was established for the bearing with requirements for a peak transient load of 15,000 pounds. The 5000-pound load, applied by a compliant preloading device, represents the load required to obtain reasonable radial stiffness for shaft critical speed control.

Dynamic geometry and stress and life curves were calculated for a 200-mm bore bearing.

Results of bearing tests under axial loads from 1000 to 8700 pounds at speeds from 3750 to 15,000 rpm for 5 to 60 minutes at liquid hydrogen flows of 60 to

(continued overleaf)

274 gpm were successful. This indicated that the optimization procedure was feasible.

Figure 1 shows the bearing design. This bearing has a bore of 7.8740 in., outside diameter of 11.0236 in., and width of 1.4961 in. The ball diameter is 0.875 in.

For optimizing the bearing for high speed operation, the effects of variations in internal geometry were determined and the best compromise was selected based on results of varying ball size, race radius, and contact angle. This involved establishing minimum operating diametral clearance and selecting the design displaying minimum heating with adequate fatigue life.

Special bearing design features for improved cooling, i.e., cooling slots in the outer race, and thin-section cage were effective in achieving high speed capability.

Vacuum-melt American Iron and Steel Institute 440C steel was employed for races and balls because of its corrosion resistance, high hardness, and maximum fatigue life capability. Generous cross sections in the 440C steel bearing races were required to avoid cracking problems arising from extreme brittleness of the cooled material.

Mandrel-wrapped, glass fabric-supported polytetrafluorethylene was used for the cage material because of its low friction coefficient, high strength, and ability to withstand severe service conditions without failure.

Figure 2 shows a schematic of the bearing tester. Mounted on the tester shaft are two test bearings, one loaded axially against the other, with axial load applied by pressurizing the piston with gaseous helium. Transmission of the axial load is through bearing No. 1 to the shaft and through bearing No. 2 to the housing. Careful balancing of the tester shaft in place assures observation of no sign of unbalance in the test bearings. Utilization of small-diameter liquid hydrogen seals maintains rubbing speeds at conservative values to avert seal problems. The test fluid enters the tester, flows through both test bearings, and exits near the load piston.

Notes:

1. M. F. Butner and J. C. Rosenberg: "Lubrication of Bearings with Rocket Propellants," Lubrication Engineering, ASLE Paper Vol. 18, 17-24 (1962).
2. Documentation is available from:

   Clearinghouse for Federal Scientific
   and Technical Information
   Springfield, Virginia 22151
   Price $3.00
   Reference: TSP69-10178

Patent status:

Inquiries about obtaining rights for the commercial use of this invention may be made to NASA, Code GP, Washington, D.C. 20546.

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