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Author: Mr. BEN JACOB
Indian Space Research Organization (ISRO), Liquid Propulsion Systems Centre (LPSC), India

Mr. PAUL P GEORGE
Indian Space Research Organization (ISRO), Liquid Propulsion Systems Centre (LPSC), India

DEVELOPMENT OF ULTRA HIGH DN CERAMIC BALL BEARING FOR CRYOGENIC ROCKET ENGINE TURBOPUMP

Abstract

Liquid Propulsion Systems Centre is presently developing a high thrust semi-cryogenic engine working on staged combustion cycle. The engine makes use of an inline turbopump assembly to feed fuel and oxidizer to the thrust chamber for combustion. The largest bearing used in this turbopump is of deep groove type with a bore diameter of 75 mm and is required to operate upto a speed of 21,000 rpm (1.58 million DN) which is quite close to the safe limit of operation of 1.6 million DN for deep groove ball bearings. This calls for development of special ball bearings with ceramic balls to enhance their speed capability. Furthermore, as these bearings are cooled by the cryogenic propellants, there exists a critical requirement to prevent excessive heat generation and phase change of the coolant. On the contrary, surplus coolant circulation is also undesirable due to the possibility of excessive pressure drop and hence high axial loading of the floating cages of these bearings. The present paper details the developmental aspects of a ceramic ball bearing for turbopump application.

The major design features involving critical design parameters of ceramic ball bearings are investigated in this paper. The design parameters critical to the performance of a high speed bearing like internal play, osculation ratio, cage ball pocket clearances, cage land guidance etc. were selected based on previous experience in developing bearings for different space applications. The variation of the geometric parameters of the bearing from ambient to cryogenic conditions is also considered in the bearing design. Dynamic tests are performed in liquid nitrogen medium to demonstrate its capability.

Tests were carried out upto 21,000 rpm to assess the performance improvement in using ceramic ball bearings. Experimental evaluation indicated substantial improvements in terms of rolling friction and vibration levels leading to higher speed capability and lower requirement of coolant flow. A performance improvement of upto 25

The ever-increasing speed requirement of turbopumps in liquid rocket engines have led to the need of developing high speed ball bearings. Hybrid bearings with ceramic balls prove to be a very ideal for high-speed operation. Ceramic ball bearing with large bore diameter was successfully designed and tested upto 21,000 rpm with substantial improvement in performance over those with SS440C balls.