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Analysis of a Solid Lubricant Effects on the Tribological and Structured Behavior of a Spherical Self-Lubricating Aerospace Plain Bearing:

Optimising the Lubrication and Tribological/Structural Performance

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ABSTRACT

The tribological behavior of self-lubricating spherical bearings in aerospace applications is crucial for ensuring reliability under dynamic loads. This study employs Computational Fluid Dynamics (CFD) to analyze the interactions between contacting surfaces, focusing on pressure distribution, shear stress, heat flux, and elastic deformation. By simulating various operational conditions, including different rotational speeds and the use of solid lubricants like talc and graphite, the research evaluates their effectiveness in reducing friction and managing thermal effects. Findings reveal that rotational speed significantly influences tribological performance, with graphite outperforming talc in minimizing friction, heat generation, and wear at high speeds. While talc reduces friction, it induces higher shear stresses and elastic deformation, making graphite a more suitable lubricant for demanding aerospace applications. This, study contributing to enhanced performance and durability of self-lubricating bearings in critical aerospace.

KEYWORDS

Aeronautical Spherical Bearing, Self-Lubricant, Solid Lubricant, Tribological Behavior, Elastic Behavior

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INTRODUCTION

The study of the tribological behavior of self-lubricating aerospace spherical bearings involves analyzing the interactions between contacting surfaces under conditions of motion and load. Aerospace bearings use the force generated by airflow to maintain separation between contacting surfaces, thereby reducing friction and wear. Self-lubricating bearings use special materials or coatings to provide continuous lubrication without the need for external lubricants. This numerical study is conducted using modeling software to simulate bearing behavior and predict its performance under various conditions, such as rotational speed and different types of solid lubricants like talc and graphite.

A study on the analytical foundations and software architecture of the computerized mathematical simulation of spherical roller bearing behavior was presented by Kleckner and Pirvics (1982), focusing on the mechanical aspects of bearing operation at a given temperature. The resulting software, SPHERBEAN (Spherical Bearing Analysis), facilitated the isothermal study of spherical bearing performance under axial, radial, or combined loads. The analysis considered elastohydrodynamic and hydrodynamic lubrication loads, roller inclination and skew, roller speeds, and mounting adjustments. Examples of problems illustrating the use of the program were presented in their study.

Cao et al. (2010) conducted a study on the thermal properties of textile-coated bearings with self-lubricating properties, combining finite element analysis (FEA) with experimental temperature comparisons. By integrating principles from heat transfer theory, tribology, and composite material mechanics, a sophisticated 3D thermo-mechanical FEA model of the bearing system was developed. This model incorporated the steady-state temperature distribution obtained from thermal analysis as a body load for the structural model. The analysis revealed key findings, including a maximum steady-state temperature of 78.1 °C, a von Mises stress of 299 MPa, a displacement of 0.0806 mm along the Z-axis of the bearing, and a maximum contact pressure of 324 MPa—critical data for structural design and optimization. The effect of temperature increase on contact pressure distribution was discussed. Agreement between the calculated temperature results and experimental data demonstrated that the method could be used to analyze nearly any bearing of this type.

In the same year, Yang et al. (2010) developed a new bidirectional collar forming technology for producing self-lubricating bearings to improve their quality. The bearing ring blank geometry was optimized using a parametric finite element (FE) method to minimize collar forces during the forming process. A bidirectional collar die was designed, and collar forming experiments were conducted. The results showed that bearings could be successfully manufactured using this bidirectional collar forming process, avoiding defects caused by unidirectional collar forming. The optimization method significantly reduced retraction forces during the collar forming process. The tribological properties of self-lubricating spherical plain bearings with woven polytetrafluoroethylene (PTFE) and aramid linings were investigated experimentally under progressive loads by Qiu et al. (2011). Scanning electron microscopy (SEM) and X-ray energy dispersive spectroscopy (EDS) techniques were used to analyze the wear mechanisms of the linings. The results revealed that wear loss, friction temperature rise and film-forming capacity were influenced by load ratio, slewing frequency and load cycle. During bearing operation, adhesive and abrasive wear phenomena were observed within the friction pairs. An increase in the load ratio led to a worsening of these wear mechanisms.

Orsolini and Booker (2012), examined a specific size step at the thin/thick section boundary, by comparing forming load predictions with experimental data and 2D and 3D finite element analysis results. Finite element modelling capabilities were analyzed, including the evolution of peak stresses, die interface pressures and temperature rises during the double-drawing cycle. These results have helped to improve the virtual modelling of the process, reducing the need for prototyping and physical testing.

To address the challenges posed by long test times and small sample sizes in assessing the service life of self-lubricating seals under heavy loads, an effective method was developed by Xiuhong et al. (2016). Initially, the support vector regression (SVR) algorithm is used to model wear depth

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