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OPTIMIZING PALM MID-OLEIN-INFUSED HYDRODYNAMIC JOURNAL BEARINGS: UNRAVELING THE DYNAMICS OF DIMPLE EFFECTS ON MOVING SURFACES

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ABSTRACT

The research project aims to investigate the mechanism of the dimple's impact on the moving textured surface in the hydrodynamic journal bearing incorporated with bio-based lubricant. The key objectives are to optimize the design of the dimple pattern on the journal surface, investigate the impact of the textured surface on the journal bearing performance, and evaluate the tribological performance of palm mid-olein as a bio-based lubricant in the journal bearing. The research methodology involves experimental studies and optimization techniques. The experimental conditions will follow the ASTM D4712 standard. The optimization study will determine the optimal blending ratio of additives to improve the performance of the palm mid-olein bio-based lubricant. The journal bearing performance, including pressure distribution, friction coefficient, load-carrying capacity, and oil film thickness, will be evaluated and compared to a smooth surface. The research findings have the potential to benefit industry by prolonging the lifespan of journal bearings, reducing maintenance costs, and promoting the use of environmentally friendly bio-based lubricants.

KEYWORD

Tribology, journal bearing, surface texture, bio-based lubricant

INTRODUCTION

Enhancing the tribological characteristics is important, as it can yield optimal performance and minimize losses. The use of surface textures, specifically dimples, on journal bearings are being researched to improve their tribological performance, particularly in boundary lubrication regimes. The research aims to investigate the impact of texturing the journal surface instead of the bearing surface, the effect of dimple geometry and distribution on journal bearing performance, and the synergy between bio-based lubricants and textured journal surfaces.

PROBLEM STATEMENT

Surface texturing is recognized as a key technique for improving the tribological performance of journal bearings by reducing friction and wear. Dimples, particularly spherical and conical shapes, serve as micro-reservoirs that enhance lubrication under boundary conditions. However, the challenge lies in optimizing the shape, arrangement, and distribution of these textures to maximize performance across different operating conditions. Additionally, while bio-based lubricants such as palm mid-olein offer environmentally friendly alternatives to mineral-based lubricants due to their biodegradability and performance in boundary lubrication, they face significant limitations. These include low oxidative stability and a narrow viscosity range, which can limit their effectiveness under demanding conditions. Therefore, there is a need to optimize both surface texturing and the properties of bio-based lubricants to achieve enhanced performance in journal bearings. This research addresses these challenges by focusing on the optimization of surface textures and the enhancement of palm mid-olein's oxidative stability and viscosity through additives, followed by the evaluation of their combined effects on journal bearing performance.

LITERATURE REVIEW

Surface Texturing for Tribological Performance Enhancement

Surface texturing, particularly the use of dimples, has been widely explored to enhance tribological characteristics, minimizing friction and wear. Dimples serve as miniature reservoirs for lubricating oil and can capture debris carried by contaminated oil during abrasive wear, helping to maintain lubrication under suboptimal conditions. According to studies, the effectiveness of dimples is influenced by various factors, including their geometric design, arrangement, location, concentration, and the shape of their bottom profile. The proper design of dimples is critical, as improper configurations can lead to adverse effects on performance. For instance, Nanbu et al., (2008)conducted numerical analyses that highlighted how applying dimples to the moving surface could increase fluid flow and improve the minimum oil film thickness. However, Galda et al., (2019) observed through experimental studies that dimple placement, particularly on moving surfaces, could either enhance or degrade journal bearing performance depending on specific operating conditions.

Influence of Dimple Placement and Design on Journal Bearing Performance

The placement of dimples on stationary or moving surfaces has been a focus of numerous studies, as it directly impacts bearing performance. Nanbu et al. (2008) showed that applying dimples on the journal surface improves lubrication by increasing the fluid flow into the contact area, resulting in enhanced oil film thickness. In contrast, Galda et al. (2019) found that the effect of dimples during start-and-stop operations could be inconsistent, with performance improvements in some scenarios and potential degradation in others. This highlights the importance of careful consideration of dimple placement to maximize their benefits in practical applications.

Bio-Based Lubricants in Tribology

In addition to surface texturing, bio-based lubricants have emerged as promising alternatives to mineral-based oils due to their environmental advantages. Bio-based lubricants offer significant potential for reducing friction between contact surfaces, exhibiting favorable properties such as high thermal resistance, low volatility, and excellent biodegradability. These lubricants also possess a high flash point and reduced toxicity, making them attractive for sustainable lubrication practices. However, further research is necessary to optimize their performance under different operating conditions, particularly when integrated with advanced surface texturing techniques.

RESEARCH GAPS

Research Gap in Texture Design and Journal Bearing Performance

Despite the recognition of surface textures as a potential solution for improving journal bearing performance, there remains a significant gap in understanding how specific geometric parameters such as texture shape, depth, and distribution affect lubrication and friction. Current literature acknowledges the benefits of surface texturing but lacks clarity on the detailed interactions between these geometric factors and bearing performance, particularly under varying operational conditions. This research aims to address this gap by systematically exploring different texture designs and their nuanced impact on the tribological characteristics of journal bearings.

Unexplored Synergy Between Bio-Based Lubricants and Surface Textures

A crucial gap in existing research is the integration of bio-based lubricants with textured surfaces to enhance journal bearing performance, particularly in boundary lubrication conditions. While bio-based lubricants are recognized for their environmental and tribological benefits, there has been limited investigation into their compatibility with surface textures. This research seeks to bridge this knowledge gap by examining the synergy between bio-based lubricants and texture designs, focusing on moving surfaces. Understanding how these elements collaborate could offer valuable insights into optimizing bearing performance while promoting sustainability.

MATERIAL AND METHODOLOGY

The dimples will be created using a Laser Surface Texturing (LST) machine and applied to the journal surface. Various dimple shapes, concentrations, aspect ratios, and distribution patterns will be examined and optimized. The study will employ a journal-bearing test rig, as shown in Figure 1, which is specifically designed to assess key parameters in journal bearing operation. This test rig includes a journal driven by an electric motor, a bearing, a lubricant oil supply tank, an oil collector, and a robust steel frame. It is also equipped with six high-precision pressure sensors to measure the hydrodynamic pressure along the bearing's circumference. Additionally, a load cell is installed to measure friction torque. Data from these devices will be collected and monitored through a data acquisition system. The journal and bearing are made of Stainless steel 304 as illustrated in Figure 2

Figure 1: Journal bearing test rig

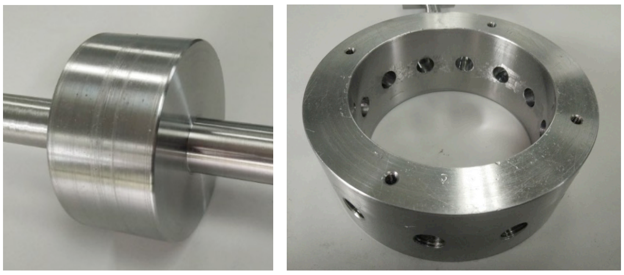

Figure 2: Journal (left) and bearing (right)

Experiment conditions

The experimental condition for the journal-bearing experiment is tabulated in Table 1.

Table 1: Experimental condition for journal-bearing test

Parameter	Description
Radial load	10N/20N/40N/60N/80N/100N
Shaft speed	200rpm/400rpm/600rpm/800rpm/1000rpm
Duration	20 minutes/cycle
Oil tank level control	80%
Oil inlet temperature	35°C
Lubricant	Shell Omala VG68 and Palm mid Olein

Materials

The steel balls utilized in this experiment are made from chrome alloy steel, with a diameter of 12.7 mm, conforming to the AISI E-52100 standard. They are of extra polish (EP) grade 25, with a hardness rating of 64–66 HRC (Rockwell C Hardness). Before the experiment, each ball was cleaned with acetone to remove any debris and then wiped using a fresh, lint-free industrial wipe.

Lubricants

In this experiment, Palm mid Olein will serve as the lubricant, with results compared to the mineral-based oil Shell Omala VG68. The viscosity of Palm mid Olein will be modified using a viscosity improver, Ethylene Vinyl Acetate (EVA), for comparison. Additionally, the antioxidant Tertiary-butyl hydroquinone (TBHQ) will be used to enhance the oxidative stability of Palm mid Olein, and its effectiveness will be assessed by measuring the oil induction time (OIT) using Differential Scanning Calorimetry (DSC).

RESULT AND DISCUSSION

The geometry of dimples plays a crucial role in determining the performance of journal bearings. Dimples, when applied to the surface of the bearing, influence the distribution of lubricant, the formation of lubricant films, and the overall frictional characteristics. The shape, size, and depth of these dimples can significantly alter the hydrodynamic pressure distribution within the bearing, which in turn affects load-carrying capacity, friction reduction, and wear resistance. Understanding the specific mechanisms behind these geometric impacts is essential for optimizing journal bearing performance.

Texturing the moving part of a journal bearing, rather than the stationary part, also has a notable effect on its performance. Surface texturing on the rotating component can enhance the interaction between the lubricant and the surface, improving lubricant retention and promoting better hydrodynamic lubrication. This can lead to reduced friction and wear, as well as enhanced load-carrying capacity. The placement and pattern of surface texturing are key factors in achieving these performance improvements.

In addition to surface geometry and texturing, the use of antioxidant additives in bio-based lubricants can significantly improve their oxidative stability, which directly impacts the tribological properties of journal bearings. These additives work by inhibiting the oxidation process that would otherwise degrade the lubricant over time, thus preserving its lubricating qualities. By improving the oxidative stability, antioxidant additives enhance the lubricant's ability to maintain a consistent film, reducing friction and wear in the journal bearing, and ultimately prolonging the bearing's operational life.

CONCLUSION

This study will explore the complex interactions between surface textures and the friction-reducing properties of bio-based lubricants, offering valuable insights into their combined effects on journal bearing efficiency. By addressing this research gap, the study aims to fully harness the potential of bio-based lubricants alongside surface textures, presenting a comprehensive approach to enhancing the tribological performance of journal bearings under different operating conditions.

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