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Cfd analysis of journal bearing with a heterogeneous rough / smooth surface

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Abstract

In the present study, a computational investigation into acoustic and tribological performances in journal bearings is presented. A heterogeneous pattern, in which a rough surface is engineered in certain regions and is absent in others, is employed to the bearing surface . The roughness is assumed to follow the sand-grain roughness model, while the bearing noise is solved based on broadband noise source theory. Three types of heterogeneous rough / smooth journal bearings exhibiting different placement and number of the rough zone are evaluated at different combinations of eccentricity ratio using the CFD method. Numerical results show that the heterogeneous rough / smooth bearings can supply lower noise and larger load-carrying capacity in comparison with conventional bearings.

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Advances in Lubricated Bearings

Edited by
Hubert Schwarze and Thomas Hagemann

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About the Editors

Hubert Schwarze

Hubert Schwarze (Prof. Dr.-Ing.) is a University Professor and head of the Institute of Tribology and Energy Conversion Machinery at Clausthal University of Technology since 2000. For several decades, the Institute of Tribology and Energy Conversion Machines has been conducting experimental and theoretical research in the field of static and dynamic behavior of sliding radial- and thrust bearings and their interactions with surrounding structures. Through numerous individual and cooperative investigations, practical case studies as well as theoretical studies, and model developments, the research institute has significant expertise in the field. Professor Schwarze's main research interests include tribology with a focus on rotor-slide bearing systems, tribo-life spans, rotor dynamics, and rheology.

Thomas Hagemann

Thomas Hagemann (Dr.-Ing. habil.) is a Senior Researcher at the Institute of Tribology and Energy Conversion Machinery at Clausthal University of Technology. His research focuses on improving the performance, efficiency, and robustness of thrust and journal bearings in challenging machinery applications ranging from high-speed turbomachinery to heavy-duty industrial ones. Besides the development of novel algorithms, he puts a special emphasis on validation with identification data of academic test rigs and practical applications. The results of his research contribute to the TEHL bearing codes of the Institute of Tribology and Energy Conversion Machinery have become valuable tools in practical industrial development and design processes. In his field, he is a key researcher in the German Research Associations for Combustion Engines (FVV) and Drive Technology (FVA).

Advances in Lubricated Bearings

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Article

CFD Analysis of Journal Bearing with a Heterogeneous Rough/Smooth Surface

Mohammad Tauviqirrahman [1,*], J. Jamari [1], Arjuno Aryo Wicaksono [1], M. Muchammad [1,2], S. Susilowati [3], Yustina Ngatilah [3] and Caecilia Pujiastuti [3]

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Abstract: In the present study, a computational investigation into acoustic and tribological performances in journal bearings is presented. A heterogeneous pattern, in which a rough surface is engineered in certain regions and is absent in others, is employed to the bearing surface. The roughness is assumed to follow the sand-grain roughness model, while the bearing noise is solved based on broadband noise source theory. Three types of heterogeneous rough/smooth journal bearings exhibiting different placement and number of the rough zone are evaluated at different combinations of eccentricity ratio using the CFD method. Numerical results show that the heterogeneous rough/smooth bearings can supply lower noise and larger load-carrying capacity in comparison with conventional bearings. Moreover, the effect on the friction force is also discussed.

Keywords: acoustic; computational fluid dynamics (CFD); lubrication; roughness

1. Introduction

Journal bearing is one of the most critical friction pairs in machine elements, in which the applied force is fully supported by the pressure of the lubricating film. The main function of the bearing is to keep the shaft always rotating about its axis, smoothing the rotary motion, reducing friction between the two surfaces, and dampening vibrations due to the rotating motion of the shaft and motor [1]. Within recent decades, a large quantity of research focusing on surface modification by texturing has been and continues to be performed. This is mainly because surface texturing has become a feasible way to improve journal bearing performance. Tala-Ighil, et al. [2] presented a detailed study relating to the effect of promoting a surface texture in the form of a cylindrical dimple by varying the location of the texture arrangement. The results of their study indicated that the application of texture on the entire bearing surface produces a detrimental effect, while on the other hand, the application of partial surface texture can improve the performance of journal bearings. Brizmer and Kligerman [3] found a potential benefit of micro-texture with laser surface texturing (LST) on the inner surface of bearings on the load-carrying capacity of journal bearings. Their finding was also confirmed by Ji et al. [4]. Later, Meng and his group [5–7] studied more deeply the effect of compound groove texture in various forms on tribological and acoustic performance through the computational fluid dynamics (CFD) method. Their main results stated that the optimal dimple compound can reduce noise levels and increase load-carrying capacity and frictional forces. This

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Remarks on Modeling the Oil Film Generation of Rod Seals

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Abstract: The oil film generation of a U-cup rod seal and the oil film thickness on the rod after outstroke were analyzed analytically, numerically, and experimentally. The analyzed sealing system consists of an unmodified, commercially available U-cup, a polished rod, and mineral oil. The inverse theory of hydrodynamic lubrication (IHL) and an elastohydrodynamic lubrication (EHL) model—both based on the Reynolds equation for thin lubricating films—were utilized to simulate the oil film generation. In the EHL analysis, physical parameters and numerical EHL parameters were varied. Both the analytical and numerical results for the varied parameters show that the film thickness follows a square-root function (i.e., with a function exponent of 0.5) with respect to the product of dynamic viscosity and rod speed, also referred to as the duty parameter. In comparison to the analytical and numerical results, the film thickness obtained via ellipsometry measurements is a function of the duty parameter with an exponent of approximately 0.85. Possible causes for the discrepancy between theory and experiments are discussed. A potential remedy for the modeling gap is proposed.

Keywords: hydraulic rod seal; film thickness measurement; elastohydrodynamic simulation; Reynolds equation

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1. Introduction

The lubrication conditions in the sealing gaps of rod seals have a significant influence on friction, wear, and leakage. A thicker oil film reduces friction and wear but can result in leakage if it is wiped off at instroke. The oil film generation must be considered in the development process of rod seals to achieve optimum lubrication conditions as well as leak-tight operation [1–3].

The oil film generation depends on operating conditions [4,5] and seal geometry [6], as well as seal material properties [7]. Using a method based on ellipsometry, it was found that the oil film thickness in the sealing gap of typical polyurethane U-cups is only in the sub-micrometer to nanometer scale [5,7].

Empirical studies on rod seals and film thickness measurements require substantial experimental effort and thus great financial expense. With hundreds of different possible seal designs, materials, and operating conditions in various applications, predicting the lubrication conditions of rod seals using models greatly reduces empirical expense.

State-of-the-art simulation models for analyzing reciprocating seals are based on the two main approaches: the theory of elastohydrodynamic lubrication (EHL) [8–10] and the inverse theory of hydrodynamic lubrication (IHL) [11–14]. In an EHL problem, both the hydrodynamic pressure and the film thickness are determined simultaneously. In contrast, the IHL assumes a hydrodynamic pressure distribution and uses it to determine the film thickness. The IHL theory was developed by Blok [15].

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Inhibition of Mild Steel Corrosion by 4-benzyl-1-(4-oxo-4-phenylbutanoyl)thiosemicarbazide: Gravimetrical, Adsorption and Theoretical Studies

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Abstract: Gravimetric measurements were applied to study the inhibitory effect of 4-benzyl-1-(4-oxo-4-phenylbutanoyl)thiosemicarbazide (BOT) on the corrosion of mild steel in 1.0 M HCl. BOT has a good inhibitory efficacy of 92.5 percent at 500 ppm, according to weight loss results. The effect of inhibitor concentration on the mild corrosion behavior of steel was investigated and it was discovered that the higher the inhibitor concentration, the higher the damping efficiency. The results confirm that BOT is an effective corrosion inhibitor for mild steel in the presence of 1.0 M HCl. Furthermore, the higher protection efficiency with increasing temperature and the free energy value showed that BOT molecules participate in both chemisorption (coordination bonds between the active sites of BOT molecules and d-orbital of iron atoms) and physisorption (through the physical interactions on the mild steel surface). The adsorption mechanism on the mild steel surface obeys the Langmuir adsorption isotherm model. Quantum chemical calculations based on the DFT calculations were conducted on BOT. DFT calculations indicated that the protective efficacy of the tested inhibitor increased with the increase in energy of HOMO. The theoretical findings revealed that the broadly stretched linked functional groups (carbonyl and thionyl) and heteroatoms (sulfur, nitrogen and oxygen) in the structure of tested inhibitor molecules are responsible for the significant inhibitive performance, due to possible bonding with Fe atoms on the mild steel surface by donating electrons to the d-orbitals of Fe atoms. Both experimental and theoretical findings in the current investigation are in excellent harmony.

Keywords: corrosion inhibition; phenylbutanoyl; HCl; weight loss; DFT

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1. Introduction

Mild steel is frequently used in a variety of industrial environments. Due to the strength of its impact, this material has been used in a variety of fields [1]. On the other hand, cleaning, pickling and descaling cause its corrosion [2]. In a variety of industrial processes, acid solutions are commonly used to remove unwanted deposits and rust [3]. To achieve this, it must be protected from unexpectedly occurring metal disintegration [4]. Inhibitors are among the most effective strategies for protection against corrosion, especially in acidic environments where alloys are at risk of melting [5]. Due to their biodegradable ability, environmental friendliness, low cost and availability, investigators have recently focused on the use of environmentally acceptable chemicals, such as natural and synthetic organic compounds [6]. Organic molecules employed as corrosion inhibitors produce coordination complexes with a metallic surface utilizing the active sites, and these metallic complexes occupy a significant surface area, therefore coating the metallic surface and

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Optimization of the Rheological Properties and Tribological Performance of SAE 5w-30 Base Oil with Added MWCNTs

Bahaa M. Kamel [1,*], Vineet Tirth [2,3], Ali Algahtani [2,3], Mohamed S. Shiba [4], Ahmed Mobasher [5], Hassan Abu Hashish [1] and Sameh Dabees [6,*]

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Abstract: The augmentation of lubricant oil properties is key to protecting engines, bearings, and machine parts from damage due to friction and wear and minimizing energy lost in countering friction. The tribological and rheological properties of the lubricants are of utmost importance to prevent wear under unembellished conditions. The marginal addition of particulate and filamentous nanofillers enhances these properties, making the lubricant oil stable under severe operating conditions. This research explores the improvement in SAE 5w-30 base oil performance after the addition of multiwalled carbon nanotubes (MWCNTs) in six marginal compositions, namely, Base, 0.02, 0.04, 0.06, 0.08, and 0.10 weight percentage. The effect of the addition of MWCNTs on flash and pour points, thermal conductivity, kinematic viscosity, friction coefficients, and wear are investigated and reported. X-ray diffraction and transmission electron microscopy are used to characterize the MWCNTs. The purity, crystallinity, size, shape, and orientation of the MWCNTs are confirmed by XRD and TEM characterization. Pour points and flash points increase by adding MWCNTs but inconsistency is observed after the 0.06 wt.% composition. The thermal conductivity and kinematic viscosity increase significantly and consistently. The friction coefficient and wear scar diameter reduce to 0.06 wt.% MWCNTs and then the trend is reversed due to agglomeration and inhomogeneity. A composition of 0.06 wt.% is identified as the optimum considering all the investigated properties. This composition ensures the stability of the tribo-film and hydrodynamic lubrication.

Keywords: nanolubricants; four-ball tribo-tester; thermal conductivity; flash and pour points; friction coefficient; wear scar diameter

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Highlights

- SAE 5w-30 oil-based nanolubricants were prepared by the addition of MWCNTs in six compositions.
- The tribological and rheological properties of the nanolubricants were measured and compared.
- The flash point, pour point, thermal conductivity, and kinematic viscosity increased whereas the friction and wear decreased with the addition of nanofillers.
- The 0.06 wt.% MWCNT/SAE 5w-30 nanolubricant emerged as the optimum best-performing composition.