

CFD Analysis of Journal Bearing by Modifying The Roughness Surface

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Abstract. A journal bearing is a machine part that is used to ensure that the shaft always rotates in the opposite direction of the axis. Journal bearings are chosen because they are well-suited for use in mechanical systems that demand precision, speed, and a high load capacity. Recent years have seen an increase in research on how to improve the tribological performance of bearings by considering the design/architecture of these bearings. Numerous scientists have developed numerous methods for measuring pressure distribution, load-carrying capacity, acoustic power level, force friction, and cavitation phenomena in order to improve the performance of tribology, particularly in journal bearings. As a result, hydrodynamic lubrication was used in the investigation. The investigation was conducted using a computational fluid dynamics (CFD) three-dimensional journal bearing model that took cavitation into account. Additionally, the location of the heterogeneous rough/smooth bearing pattern was modified, as was the shaft rotational speed. The results of this study indicate that when the surface roughness is applied to journal bearings in a variety of locations with heterogeneous rough/smooth bearing patterns, the tribological performance of journal bearings is significantly improved, and that high shaft rotational speed has a significant effect on the tribological performance of journal bearings.

Keywords. CFD, hydrodynamic lubrication, surface roughness, heterogeneous rough

1 Introduction

Journal bearings are machine elements in which the applied force is fully supported by the lubricating film pressure. The bearing's primary function is to keep the shaft rotating about its axis at all times, smoothing the rotary motion, reducing friction between the two surfaces, and dampening vibration caused by the rotating motion of the shaft and motor [1]. Journal bearings are now widely used in a variety of industries, including shipbuilding, transportation equipment, food products, and pharmaceutical products [2]. Another advantage is its high angular speed, low manufacturing costs, and ease of manufacture. Journal bearings also have a long service life [3]. Another reason is that journal bearings are a more desirable choice in mechanical systems because they have several advantages such as easy installation, low maintenance costs, and high damping capacity despite being used for high loading, speed, and precision applications [4]. This makes journal bearings suitable for use in mechanical systems requiring high precision, speed, and loading. [6] conveyed this message.

Studies to improve the tribological performance of bearings have begun to consider the design/architecture of these bearings in recent years. Nanomechanics and

biomimetics researchers have investigated the modification of bearing surfaces and their applications. Surface texturing is modified by engineering the model, location pattern, and method of applying surface texturing. Tala-Ighil et al. [5] investigated the effect of creating a surface texture in the shape of a cylindrical dimple by varying the pattern of the texture arrangement. The study's findings concluded that applying texture to the entire bearing surface has a negative effect, but applying partial surface texture can effectively improve the performance of journal bearings. Blizmer and Kligerman [6] discovered the potential use of laser surface texturing (LST) to provide micro-texture on the inner surface of bearings on the bearing capacity of journal bearings in a subsequent study. The combined effect of surface texturing and the slip condition has been extensively explored by Tauviqirrahman and his group, for example, in [7-9] and it was revealed that such a surface leads to enhanced load support but reduced friction.

Later, Meng et al. [10] conducted another study using the experimental method. Using a tribotester, this experiment investigates the effect of compound textures in the form of grooves and dimples on journal bearings on noise values. As a result, adding textures to journal bearings can reduce noise. Furthermore, many studies

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have been conducted to investigate the benefits of surface roughness in journal bearings, one of which was conducted by Javorova, who stated that at a given surface roughness, a pressure peak will occur at every asperity [11]. In recent years, based on the numerical studies [12,13], it was found the application of heterogeneous.

Based on the rationale stated above, the purpose of this study is to compare the tribological performance of the application of a heterogeneous rough/smooth bearing pattern while accounting for the cavitation phenomenon to make the simulation more realistic. The Computational Fluid Dynamics (CFD) method is used to solve problems with the ANSYS 19.0 software.

2 Research Methods

According to the journal bearing's working principle, two sliding surfaces are required for the formation of bearing lubrication. The Navier-Stokes and continuity equations are used in this work to solve the lubrication problem using a finite-volume method. ANSYS FLUENT®, a commercial CFD software package, is used.

The momentum equation can be described as:

$$\rho \frac{Du_i}{Dt} = -\frac{\partial p}{\partial x_i} + \rho G_i + \frac{\partial}{\partial x_j} \left[2\eta e_{ij} - \frac{2}{3}\eta (\nabla u_i) \delta_{ij} \right] \quad (1)$$

The continuity equation is expressed as

$$\frac{\partial_i}{\partial x_j} (\rho u_i) = 0 \quad (2)$$

The flow is considered turbulent to be more representative of the bearing characteristic. As a near-wall treatment, the turbulent model of realizable k - is combined with standard wall functions. When the flow enters the divergent region in the journal bearing, pressure may fall below the saturation vapor pressure, causing the liquid to rupture and cavitation to occur. As a result, for more accurate results, the mass conserving multi-phase cavitation model of Zwart-Gelber-Belamri [14] is used in the current study.

In the present work, the sand-grain model is adopted to characterize the roughness profile of the sleeve surface. For modelling the surface roughness, the modified law-of-the-wall for mean velocity is employed. This equation can be expressed as follows [14]:

$$\frac{u_p u^*}{\tau_w / \rho} = \frac{1}{\kappa} \ln \left(E \frac{\rho u^* y_p}{\eta} \right) - \Delta B \quad (3)$$

Where $u^* = C_\eta^{1/4} k^{1/2}$ and $\Delta B = (1/\kappa) \ln f_r$

The CFD model and schematic illustration of a journal bearing with artificial roughness are shown in Fig. 1. To determine the flow characteristics using steady CFD, a three-dimensional computational model of the bearing with roughness is required. The commercial software ANSYS DesignModeler is used in this work to generate a three-dimensional computational model.

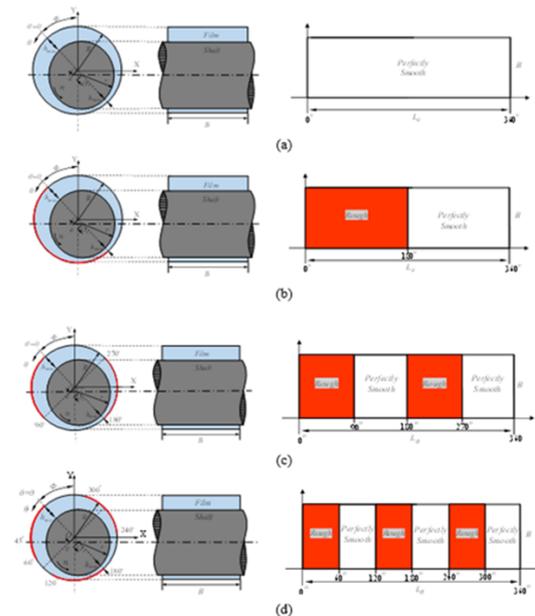


Fig. 1. Schematic of the location of the artificial roughness of the journal bearing (a) Smooth (S); (b) One layer (1L); (c) Two layers (2L); and (d) Three layers (3L).

3 Result and Discussion

This section is a simulation to find the rotational speed of the shaft on the tribological and acoustical performance of the journal bearing geometry Meng, et al. [10] by modifying the addition of surface roughness. The analysis was carried out on four bearing models (one conventional bearing and three heterogeneous rough/smooth bearings). The following is a graph of the pressure distribution that occurs in the simulation of all surface roughness location patterns with different shaft rotational speeds.

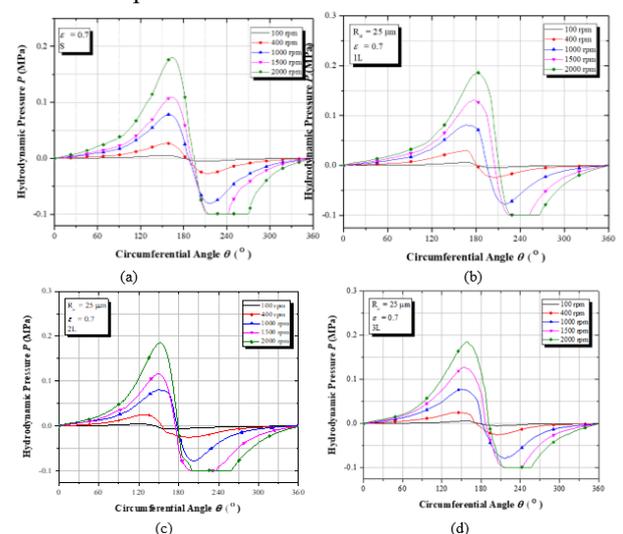


Fig. 2. Hydrodynamic pressure distribution of journal bearings with variations in shaft rotation on surface roughness models (a) smooth, (b) 1L, (c) 2L and (d) 3L.

4 Conclusion

Journal bearing modeling by applying various heterogeneous rough/smooth bearing patterns showed better tribological and acoustic performance than conventional bearing (smooth) models. In journal bearings with eccentricity ratio = 0.7, shaft rotational speed $n = 2000$ rpm and surface roughness $R_a = 25$ m, the results show that the 1L pattern shows the most optimal performance compared to the 2L and 3L patterns. The load carrying-capacity performance of the 1L pattern increased by 1.79 times compared to conventional bearings, but the friction force that occurred for the 1L pattern also increased by 1.16 times compared to conventional bearings.

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