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Numerical Analysis of Deterministic Micro-Textures on the Performance of Hydrodynamic Journal Bearing

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Abstract

Now-a-days a lot of thrust is given on the research related to geometrical modifications of hydrodynamic lubricated bearing systems. Introducing deterministic micro-textures on the journal surface is considered to be one of the key approaches for improving the bearing performance. In this paper, bearing performance analysis is done without considering the effect of cavitation to study the effect of different triangular, circular and rectangular micro-textured grooves and ribs on the hydrodynamic journal surfaces using COMSOL Multiphysics software. Initially, the static performance analysis is carried out for hydrodynamic journal bearing system with smooth surface using thin fluid film analysis method and the results of the same are validated using analytical results. In the later part of the paper, the numerical analysis is carried out for different micro-textured journal surfaces. The simulation results of these studies shows that the value of maximum fluid pressure and frictional power loss are significantly affected by introduction of these deterministic micro-textures. Bearing with rectangular micro-textured ribs on the journal surface resulted in maximum pressure is development and frictional power losses as compared with other deterministic micro-textures. Similarly the rectangular micro-texture grooves gave minimum pressure development and frictional power losses as compared with other deterministic micro-textures.

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Keywords: Surface micro-textures, fluid film pressure, frictional power loss, Numerical analysis, etc.

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1. Introduction

Generally, the position of the journal center is eccentric with the bearing center in hydrodynamic journal bearings which are used to support radial loads. A small lubricant film fills in the small circumferential gap or clearance between the journal and the bearing. The eccentricity of the journal is related to the pressure that is generated in the bearing to balance the radial load. Therefore, it is necessary to analyze the fluid film of lubricant for bearing analysis.

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Recently many researchers have focused their studies on the effect of micro-textures on the performance of fluid film bearing. They have concluded that the surface micro-textures have considerable influence on wear resistance, frictional power loss, pressure development and load carrying capacity of the bearings [1-3]. Satish et al. [4] showed that values of load carrying capacity, maximum pressure and frictional power losses are significantly affected with textured surfaces. Nacer [5] studied the effect of different micro-textures and observed that the cylindrical shape micro-texture and its location improve the performance of hydrodynamic journal bearing. Ashwin et al. [7] investigated friction characteristics of micro-textured surfaces. They solved Navier-Stroke equation to predict textured induced lift and concluded that textured surfaces exhibit friction as much as 80% lower than smooth surfaces.

In most of the available literature, related to the effect of surface micro-texture, the focus has been concentrated mainly on negative texturing on the surfaces preferable on bearing surface. However, very few studies have been carried out on the effect of positive surface texturing of the journal. Therefore, in the present work, deterministic surface micro-textures like rectangular, triangular, circular grooves and ribs are placed on journal surface to study the bearing performance as shown in Fig.2. A numerical study is carried out to analyze the characteristics of journal bearing for such micro-textures. The characteristics like maximum fluid film pressure and frictional power losses are studied at different clearance values (c), eccentricity ratio (ε), speed (RPM) and oil viscosity (μ).

2. Numerical Modeling

The hydrodynamic theory as applied to the hydrodynamic lubricated bearing is mathematically explained by Reynolds’s Equation. The thickness of the lubricant film h and the pressure in the lubricating film for a journal operating at steady state, is governed by the following equation [6]:

$$\frac{\partial}{\partial\theta}\left(h^{\partial}\frac{\partial p}{\partial\theta}\right)+\left(\frac{R}{L}\right)^{2}\frac{\partial}{\partial \mathrm{Z}}\left(h^{\partial}\frac{\partial p}{\partial \mathrm{Z}}\right)=6\,\mu R^{2}\left[(\omega_{2}-\omega_{1})\frac{\partial h}{\partial\theta}\right] \qquad 1$$

The hydrodynamic action creates dynamic pressure in the lubricant; mainly in the convergent part of the journal-bearing gap, so as to counteract the load, there by separating the journal surface from the bearing surface with a thin lubricant film. The hydrodynamic pressure ultimately terminates in the divergent part of the gap, and the pressure may go below the vapour pressure. When equilibrium state is reached, the journal is displaced from the bearing center through a distance, which is referred to the journal eccentricity (e). The eccentricity ratio (ε) and the clearance(c) are important parameters to be measure for calculating the load carrying capacity and pressure distribution of the journal bearing. Also with the help of these parameters, lubricant film thickness is determined. In above equation (1), P is the fluid film pressure; h is the fluid film thickness. The fluid film thickness h is described by equation (2) as shown below. Equations (2) and (3) are applied for journal bearing with surface micro-texture ribs and grooves respectively. Minimum fluid film thickness is dependent on the radial clearance (c), angular position (θ), eccentricity ratio (ε) and $\Delta h(\theta, Z)$, the fluid film thickness due to surface micro-textures.

$$h = h_{smooth}(\theta) + \Delta h(\theta, \mathrm{Z}) \qquad 2$$

$$h = h_{smooth}(\theta) - \Delta h(\theta, \mathrm{Z}) \qquad 3$$