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ScienceDirect

Procedia Manufacturing 20 (2018) 300–310

Procedia MANUFACTURING

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2nd International Conference on Materials Manufacturing and Design Engineering

Experimental and Numerical Analysis of Conical Shape Hydrodynamic Journal Bearing With Partial Texturing

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Abstract

In this paper, the numerical and experimental analysis is carried out for investigating the performance characteristics of conical shape hydrodynamic journal bearing (CSHJB) through partial texturing (ellipsoidal shape dimples). The numerical analysis is carried out using the thin film flow physics of COMSOL Multiphysics 5.0. The ellipsoidal dimples are developed using photochemical machining. The influence of 0^0-90^0 and 90^0-180^0 partial texturing on the bearing performance parameters viz. fluid film pressure (FFP), load carrying capacity (LCC) and coefficient of friction (COF) is studied numerically. Bearing surface with partial texturing along 90^0 -180^0 region results in 42.08 % enhancement in maximum FFP whereas 42.24 % enhancement in LCC as compared with smooth surface CSHJB with maximum 52.20% reduction of COF.

Peer-review under responsibility of the scientific committee of the 2nd International Conference on Materials Manufacturing and Design Engineering.

Keywords: Conical shape hydrodynamic journal bearing; partial texturing; ellipsoidal dimple; photochemical machining; fluid film pressure; load carrying capacity, coefficient of friction.

1. Introduction

Conical shape journal bearings are used in various engineering applications, such as precision machine tools, due to their ability to sustain both axial and radial external loads. Liu and Wang [1] obtained an analytical expression by taking the inertia effect of the Navier–Stokes equation in conical coordinates for the fluid film

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2351-9789
Peer-review under responsibility of the scientific committee of the 2nd International Conference on Materials Manufacturing and Design Engineering.
10.1016/j.promfg.2018.02.045

pressure distribution, velocity distribution and the fluid flow rate between conical surfaces. These equations were solved by using the method of iterative approximate solution. Yoshimoto et al. [2] examined two types of water-lubricated hydrostatic conical bearings with spiral grooves for high speed spindles. They showed that the complaint surface bearing has a larger load carrying capacity as compared with the rigid surface bearing. Lai et al. [3] studied the performance of a deep/shallow pockets hybrid conical journal bearing compensated by flat capillary restrictors. They considered governing equations of fluid film in the conical journal bearing together with the pressure boundary condition. These governing equations are solved by Finite Element Method (FEM). Their results showed that the hybrid conical journal bearing has the advantages of high load carrying capability and high stability under small eccentricity. Zuo et al. [4] developed mathematical models for variable slot compensated hydrostatic bearing (VSHB) and fixed slot compensated hydrostatic bearing (FSHB) with perturbation theory and solved by finite element method (FEM). They showed that the VSHB exhibits a better radial performance of load carrying capacity and stiffness, but a worse radial damping performance, compared with FSHB under the same geometric and operational conditions. Sharma et al. [5] studied theoretically the performance of a 4-pocket hydrostatic conical journal bearing system. They solved the Reynolds equation governing the flow of lubricant in the clearance space of bearing by using Finite element method and studied effect of semi cone angles on static performance characteristics like load carrying capacity and lubricant flow rate. They indicated that the lubricant flow rate is significantly reduced in case of conical journal bearing as compared with circular journal bearing. Khatri et al. [6] presented a comparative study between textured surface and non-textured surface non recessed hybrid journal bearing configurations. They computed performance parameters by solving the Reynolds equation, which governs the flow of lubricant in the clearance space, by using FEM. Their simulated results showed that the textured non-recessed hybrid journal bearing provides improved stability parameter than that of journal bearing with non-texturing. Yu et al. [7] examined the influence of different dimple shapes like circular, triangular and elliptical and their orientations on the fluid film pressure distribution. They numerically analysed single texture cells and concluded that the shape and orientation of dimples have a notable effect on the load carrying capacity. The best results were obtained with elliptical dimples.

Yu et al. [8] further investigated the effect of dimple shape texturing on the development of fluid film pressure. The dimple shape of circular, rectangular and elliptical dimples with different depths and densities were analyzed and compared. They found that individual shapes can be optimized for best performance and that elliptical dimples with the major axis perpendicular to the direction of sliding always showed the highest friction reduction under different load and speed conditions. Tala - Ighil et al. [9] studied the influence of spherical dimples on the performance characteristics of hydrodynamic journal bearing. They mentioned that, due to size, density, depth and distribution of dimples, texturing have positive as well as negative effect on the performance characteristics viz. load carrying capacity, axial flow rate, fluid film thickness and frictional torque. Tala-Ighil et al. [10] further developed a numerical model based on finite difference method to examine the influence of cylindrical shape textures distribution on the bearing surface subjected to a stationary load. They concluded that, the partial texturing present at the end of positive pressure zone increases locally the lubricant film thickness and decreases the friction force. Kim et al. [11] investigated the effects of the geometry and distribution of micro-dimples on the frictional behaviour of surfaces for applications in automotive engines. They selected a square array of circular dimples as the texture pattern and fabricated by using a laser beam with various dimensions on cast iron surfaces. Brizmer et al. [12] examined theoretically the use of laser surface texturing (LST) in hydrodynamic journal bearings. The partial and full dimple shape textures are fabricated using LST. They found that, the effect of such a texture on load capacity and on the attitude angle of the journal bearing is improved.

Previous most of studies are dealing with improving the performance of cylindrical shape hydrodynamic journal bearings using various methods of surface texturing. From literature, it was found that full surface texturing improves the frictional properties but does not improve the load carrying capacity of bearing system. It was also found that, partially texturing improves the load carrying capacity as well as frictional properties. Another method to enhance the performance of hydrodynamic bearing system is geometrical modification. Therefore in this paper, cylindrical shape journal bearing system is modified into CSHJB by introducing semi-cone angle by reducing the radius of other end of cylinder. Along with geometrical modification, surface texturing is also introduced and investigation is carried out for enhancing the performance characteristics. From the previous study, it was also found that, ellipsoidal shape dimples apart from other types of dimples, gave best performance. Hence, the static