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A study of micropolar lubricated conical undulated journal bearings

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ABSTRACT –The present work examines the effect of circumferential undulations on journal the performance of orifice compensated conical hybrid journal bearing operated with micropolar lubricant. To govern the flow of micropolar lubricant in clearance space of conical journal bearing, the modified Reynolds equation is derived by using Eringen’s theory of micropolar fluids and solved by using FEM. Numerically simulated results indicate that the undulations on journal significantly affect the performance of conical journal bearing operating with either of Newtonian and micropolar lubricant. Further, the use of micropolar lubricant results in better bearing performance than Newtonian lubricant.

1. INTRODUCTION

In recent years, the area of conical bearings received worth attentions of researchers due to its important features viz. ability to support both radial and axial load, adjustability of clearance space in bearing system etc.

The studies related to conical hydrostatic journal bearings are mainly related to effect of wear, effect of micropolar lubricant, effect of semicone angle etc. [1-3].

Manufacturing process may result in several form of irregularities in machine element. Likewise, different geometric irregularities may exist during manufacturing of journal. These irregularities usually result in degradation in the bearing performance [4-5].

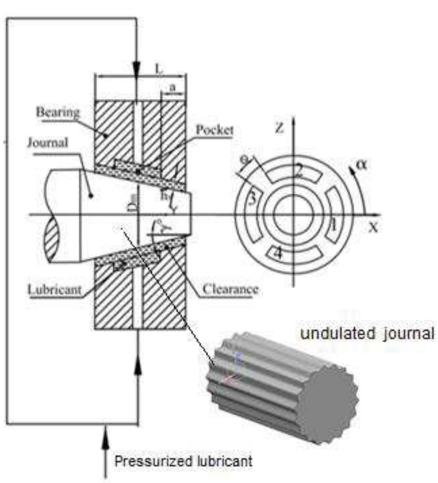

Figure 1 A Schematic of four pocket conical hybrid undulated journal bearing system.

The bearing performance is mainly depending on the lubricant. Different types of additives are blended in the base oil to improve the performance of lubricant. Such lubricant no longer behaves as a Newtonian lubricant. The Eringen’s theory of micropolar fluid [6] gives the best descriptions of the non-Newtonian fluids containing additives substructures. This class of fluids exhibit special properties to support couple stress and body couple due to their microstructure and micro-rotational inertia at microscopic level. There are many physical examples of micropolar fluids as ferrofluids, blood flows, bubbly liquids, liquid crystals [7].

In view of the above, the present study is aimed to examine the influence of undulation of journal in conjunction with the influence of micropolar lubricant on the performance of four pocket conical hydrostatic journal bearings system as shown in Figure 1.

2. ANALYSIS

To govern the flow of micropolar lubricant in clearance space of conical journal bearing, Eringen’s theory of micropolar fluid is used. Using the suitable non-dimensional parameters, the modified Reynolds equation is obtained in non-dimensional form as follows [3].

$$\frac{Sin^2\gamma}{\beta}\frac{\partial}{\partial\beta}\left[\frac{\beta\bar{\Phi}(\mathrm{N},\bar{\mathrm{l}},\bar{\mathrm{h}})}{12\bar{\mu}}\frac{\partial\bar{p}}{\partial\beta}\right]+\frac{1}{\beta^2}\frac{\partial}{\partial\alpha}\left[\frac{\bar{\Phi}(\mathrm{N},\bar{\mathrm{l}},\bar{\mathrm{h}})}{12\bar{\mu}}\frac{\partial\bar{p}}{\partial\alpha}\right]=\frac{1}{2}\Omega\frac{\partial\bar{h}}{\partial\alpha}+\frac{\partial\bar{h}}{\partial\bar{t}} \quad (1)$$

For the values of the micropolar parameters parameter, Coupling number N=*0* and characteristics length $\bar{l}=\infty$, the modified Reynolds equation (1) reduces to the general form of Reynolds equation governing the flow of Newtonian lubricant in a conical journal bearing system.

For a conical journal bearing system having circumferential undulation in journal, the fluid-film thickness between bearing and journal yieldsas [3-4]

$$\bar{h}=\left(1-\bar{X}_J cos\alpha-\bar{Z}_J sin\alpha+0.5\bar{a}.\sin(\mathrm{n}\alpha+\xi)\right)\cos\gamma \quad (2)$$

The flow rate of lubricant through fixed flow restrictors in non-dimensional form yield as follows.

$$\bar{Q}_R=\bar{C}_{s2}\sqrt{(1-\bar{p}_c)} \quad (3)$$

The governing Reynold equation is solved by using Galerkin’s technique. The fluid film domain is discretized by using four noded isoparamtric element. Globalization of elemental equations as per the connectivity of elements, the following algebraic system equation is obtained in Matrix form [2-3].

$$[\overline{F}]\{\overline{p}\} = \{\overline{Q}\} + \Omega\{\overline{R}_H\} + \dot{\overline{X}}_J\{\overline{R}_{X_J}\} + \dot{\overline{Z}}_J\{\overline{R}_{Z_J}\} \quad (4)$$

3. RESULTS AND DISCUSSION

Incorporating the usual boundary conditions, the system equation (4) is solved in conjunction with the restrictor flow equation (3). Newton Raphson Method is used to linearize the non-linear flow equation of an orifice restrictor. Based on methodology illustrated, a computer program is developed to obtain the characteristics parameters of the bearing system. The geometric and operating parameters of the bearing system are selected as per the literature [1-5].

Figure 2 depicts the variation of $\bar{h}_{min}$ with respect to $\overline{W}_r$. The value of $\bar{h}_{min}$ gets decreased with an increase in the value of semi cone angle. The undulations on journal results in a significant decrease in the value of $\bar{h}_{min}$ vis-à-vis ideal journal. The use of micropolar lubricant in place of Newtonian lubricant results in a further increase in the value of $\bar{h}_{min}$. The variation of lubricant flow rate ($\overline{Q}$) with $\overline{W}_r$ is depicted in Figure 3. Undulation results in a significant increase in the flow requirement. The use of micropolar lubricant results in a decrease in flow requirement. Figure 4 shows that undulation results in a marginal reduction in the value of stiffness coefficient.

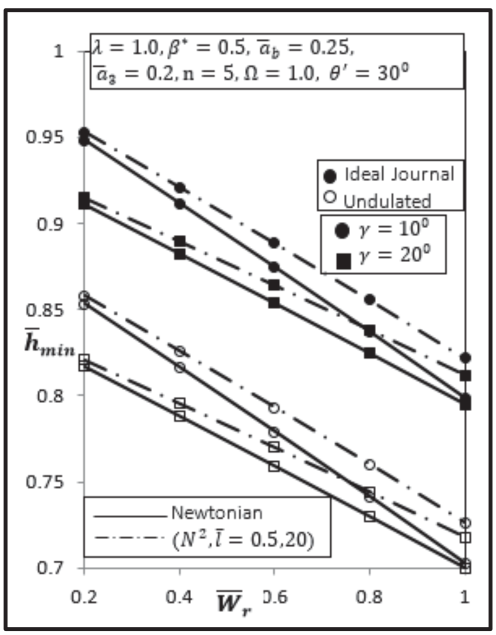

Figure 2 Variation of $\bar{h}_{min}$ with $\overline{W}_r$.

4. CONCLUSIONS

The numerically simulated results reveal that circumferential undulations on journal results in a significant deterioration in the performance of conical bearing system viz. minimum oil film thickness, lubricant flow rate and stiffness coefficients. This deterioration may be compensated by using smaller semi cone angle and micropolar lubricant instead of Newtonian lubricant.

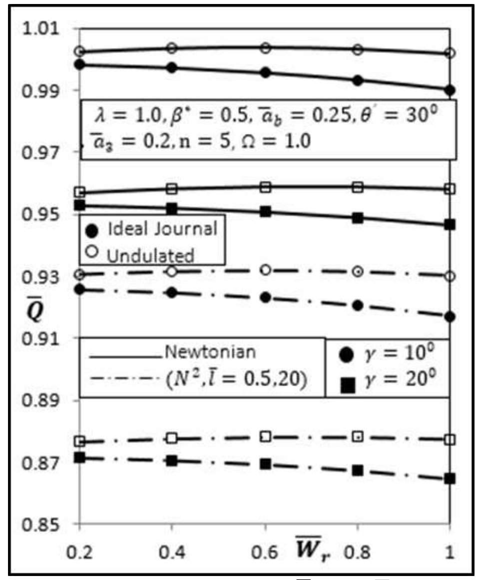

Figure 3 Variation of $\overline{Q}$ with $\overline{W}_r$.

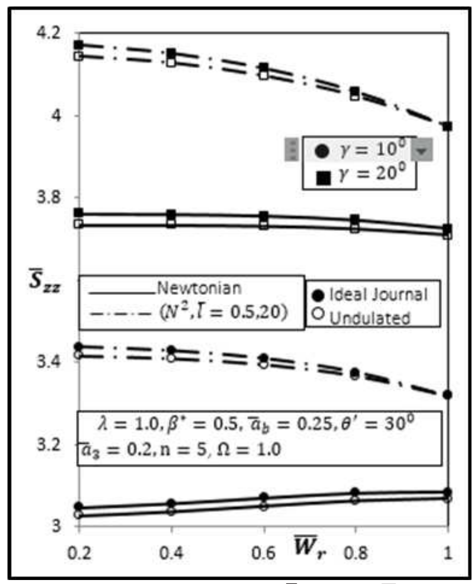

Figure 4 Variation of $\overline{S}_{zz}$ with $\overline{W}_r$.

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