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Surface roughness and fluid inertia effects on non-Newtonian THD performances of a journal bearing

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ABSTRACT – This theoretical work describes the development of mathematical models to include surface roughness and fluid inertia effects in non-Newtonian THD analysis of a journal bearing. The average Reynolds equation, the pressure induced mean velocities and velocity components are modified using Patir and Cheng's [7] flow factors. The expressions for the fluid-film pressure derivatives for the computation of fluid-film dynamic coefficients are also developed. Finite element method and its numerical algorithm for the simultaneous solution of modified average Reynolds, energy and conduction equations are described. The effects of roughness parameters on static and dynamic characteristics of journal bearing are studied by considering non-Newtonian behavior of lubricant, thermal and fluid inertia effects.

1. INTRODUCTION

The classical non-Newtonian thermohydrodynamic (THD) analysis of a journal bearing neglects the surface roughness and fluid inertia effects due to complexity in the development of mathematical models and their solution process. However, when the fluid-film thickness of bearing is of the order of few micrometers, the surface roughness alters the bearing performance. Further, for the bearing operating with low viscosity lubricants under high speed, the fluid inertia forces cannot be neglected. Hence, non-Newtonian THD analysis of journal bearings with surface roughness and fluid inertia effects is most essential.

From last few decades, Banerjee et al (1), Tichy and Bou-Said [2], Bou-Said and Ehret [3] and Kakoty and Majumdar [4] put their effort to develop several concepts and mathematical models for the inclusion of fluid inertia effects in the lubrication problems. However, these studies [1-4] were mainly based on ideal smooth surfaces of bearings.

Though, the studies from Sujith Prasad et al. [5, 6] address the combined influence of surface roughness and fluid inertia on journal bearing performances, their studies were restricted to the study of static performance characteristics of journal bearing only.

The present study is aimed to develop mathematical models for the prediction of surface roughness and fluid inertia effects on static and dynamic characteristics of journal bearing under non-Newtonian THD analysis.

2. METHODOLOGY

The modified average Reynolds equation and pressure induced mean velocities in x and y directions can be expressed in nondimensional form as

$$\frac{\partial}{\partial\alpha}\left[\phi_x\frac{\bar{h}^3}{12\bar{\mu}}\frac{\partial\bar{p}}{\partial\alpha}\right]+\frac{\partial}{\partial\beta}\left[\phi_y\frac{\bar{h}^3}{12\bar{\mu}}\frac{\partial\bar{p}}{\partial\beta}\right]=\frac{\Omega}{2}\frac{\partial\bar{h}_T}{\partial\alpha}+\frac{\Omega}{2\Lambda}\frac{\partial\phi_s}{\partial\alpha}$$
$$+\Omega\frac{\partial\bar{h}_T}{\partial\bar{t}}-\frac{\bar{R}_e^*}{12\bar{\mu}\Omega}\left[\frac{\partial}{\partial\alpha}\left(\bar{h}_T^2\bar{G}_x\right)+\frac{\partial}{\partial\beta}\left(\bar{h}_T^2\bar{G}_y\right)\right] \quad (1)$$

$$\bar{U}_m=\phi_x\frac{\bar{h}^2}{12\bar{\mu}}\frac{\partial\bar{p}}{\partial\alpha}+\frac{\bar{R}_e^*\bar{h}_T}{12\bar{\mu}\Omega}\bar{G}_x\,;\ \bar{V}_m=\phi_y\frac{\bar{h}^2}{12\bar{\mu}}\frac{\partial\bar{p}}{\partial\beta}+\frac{\bar{R}_e^*\bar{h}_T}{12\bar{\mu}\Omega}\bar{G}_y \quad (2)$$

Where ϕ_x,ϕ_y are the pressure flow factors and ϕ_s is the shear flow factors. These can be obtained from Patir and Cheng [7]. $\bar{R}_e^*$ and $\bar{G}_x,\bar{G}_y$ are the modified Reynolds number and inertia functions.

Non-Newtonian behavior of lubricant is accounted using power law model and equations (1) and (2) are simultaneously solved using Newton-Raphson iterative method to get fluid-film pressure for inertia solution. The static performance characteristics are computed from this pressure. The fluid-film dynamic coefficients are computed using pressure derivatives with respect to journal centre displacements and velocities using the appropriate expressions and iterative schemes developed in this work. A computer code is developed using FORTRAN 77.

3. RESULTS AND DISCUSSION

Results showing the influence of transversely $(\gamma=1/6)$ and longitudinally ($\gamma=6$) oriented roughness patterns and roughness characteristics of opposing surfaces such as stationary (rough bearing and smooth journal, $\bar{V}_{rj}=0$), two-sided (both surfaces rough, $\bar{V}_{rj}=0.5$) and moving (smooth bearing and rough journal, $\bar{V}_{rj}=1$) roughness on performance characteristics of a finite journal bearing with non-Newtonian, thermal and fluid inertia effects are computed for the nondimensional parameters shown in each figures. The results of rough bearings are compared with the results of smooth bearing.

Figure 1 shows that the longitudinal roughness, which restrict the dominant pressure induced axial flow of lubricant, provides maximum enhancement for the load carrying capacity of bearing for all the cases considered. Though the transverse roughness pattern enhances the pressure induced axial flow, it provides a marginal enhancement for load capacity by restricting the pressure induced circumferential flow of lubricant at converging section. From Figure 2, the stationary roughness with transverse type roughness pattern partially compensates the reduction in load carrying capacity of smooth bearing due to non-Newtonian behavior of lubricant.

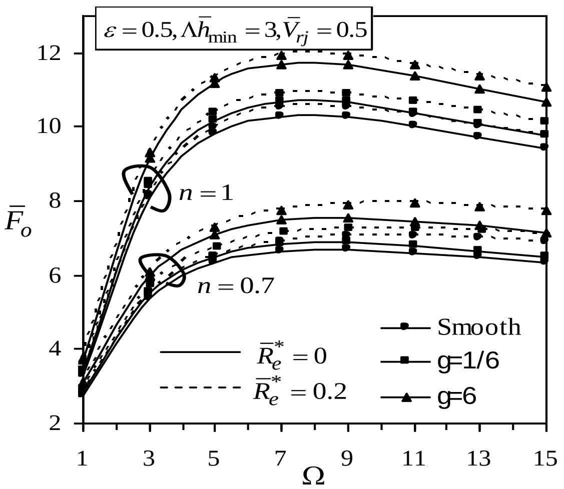

Figure 1 Load carrying capacity.

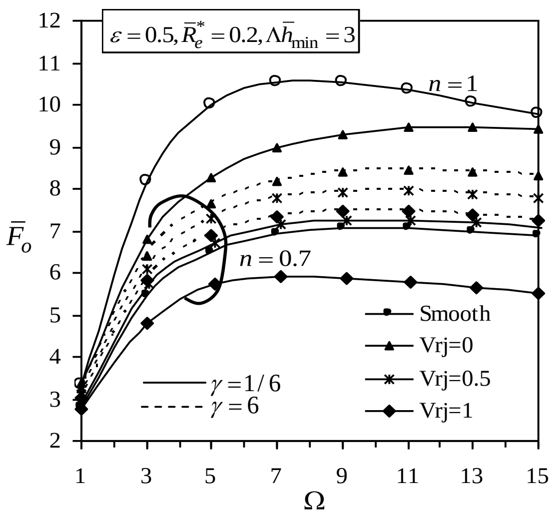

Figure 2 Load carrying capacity.

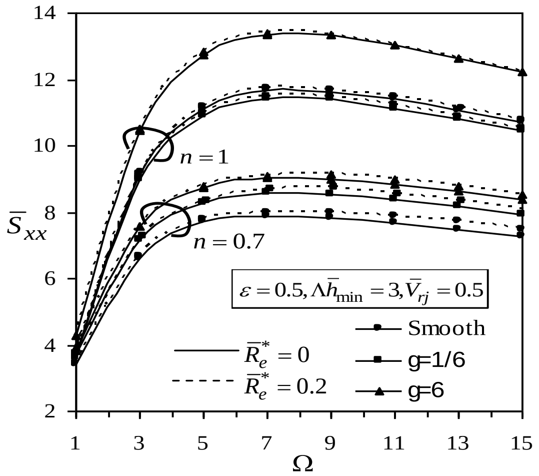

Figure 3 Fluid-film stiffness coefficient.

As seen from Figure 3, the transverse roughness pattern in two-sided type rough bearing provides reduced fluid-film stiffness coefficient ($\bar{S}_{xx}$) when non-Newtonian behavior of lubricant is not considered while it provides enhanced coefficient when non-Newtonian behavior of lubricant is considered. Similar trend on stiffness coefficient ($\bar{S}_{zz}$) and damping coefficients ($\bar{C}_{xx}, \bar{C}_{zz}$) has been observed for this transverse roughness pattern (these results are not presented).

4. CONCLUSIONS

a) Influence of fluid inertia becomes considerable only when the viscosity variation of lubricant due to rise in fluid-film temperature and/or non-Newtonian behavior of lubricant is considered.

b) The longitudinal roughness pattern in two-sided type rough bearing and transverse roughness pattern in stationary type rough bearing provides the maximum possible compensation for the reduction in load carrying capacity of smooth bearing due to non-Newtonian behavior of lubricant.

c) In a two-sided type rough bearing, the influence of roughness orientations, especially transverse roughness pattern, on fluid-film stiffness and damping coefficients is tied with non-Newtonian behavior of lubricant.

5. REFERENCES

[1] M. B. Banerjee, R. G. Shandil, S. P. Katyal, G. S. Dube, T. S. Pal, and K. Banerjee, “A nonlinear theory of hydrodynamic lubrication”. Jr. Math. Analysis Applic., vol 117, pp 48-56, 1986.

[2] J. Tichy, and B. Bou-Said, “Hydrodynamic lubrication and bearing behavior with impulsive loads”. STLE Tribo. Trans., vol. 34, no. 4, pp. 505-512, 1991.

[3] B. Bou-Said, and P. Ehret, “Inertia and shear-thinning effects on bearing behavior with impulsive loads”, ASME Jr. of Trib., vol. 116, pp. 535-540, 1994.

[4] S. K. Kakoty, and B. C. Majumdar, “Effect of fluid inertia on the dynamic coefficients and stability of oil journal bearings”. Pro. of IMechE., vol 214, pp 229-242, 2000.

[5] E. Sujith Prasad, T. Nagaraju, and J. Prem Sagar, “Thermohydrodynamic performance of a journal bearing with 3D-surface roughness and fluid inertia effects,” Int. Jr. of Applied Research in Mech. Engg., vol. 2, no. 1, pp. 58-65, 2012.

[6] E. Sujith Prasad, K. M. Jagadeesha, T. Nagaraju, and J. Sharana Basavaraja, “Steady state non-Newtonian THD analysis of journal bearing considering 3D surface roughness and fluid inertia effects,” in International Conference on Industrial Tribology, Paper # TSI 812556, 2012.

[7] N. Patir, and H. S. Cheng, “Application of average flow model to lubrication between rough sliding surfaces,” ASME Jr. of Lub. Tech., vol. 101, pp. 220-230, 1979.