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Numerical investigation of the combined effects of slip and texture on tribological performance of bearing

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ABSTRACT – In order to enhance the load support and decrease the friction force, a combined textured surface bearing using boundary slip is discussed. A modified Reynolds equation with slip is adopted. The results show that combined techniques of slip and texture have a significant effect on the improvement of the tribological performance of bearing, that is, a high load carrying capacity but low friction force. The influences of the gap ratio of the bearing are also explored, and are found to significantly affect the lubrication behavior. In addition, it is shown that even with a parallel gap, high load support can also be produced.

1. INTRODUCTION

As commonly known, surface texturing has been considered as a technique to improve the tribological performance of the bearing [1-4]. This technique has been proven to enhance the load support and/or reduce the friction force. However, recently, direct experimental [5] and numerical evidences [6-10] have also been presented to show that the boundary slip can alter the flow pattern of the lubrication behavior at the bearing. In this way, the boundary slip, as well as surface texturing, can be engineered to generate a positive effect with respect to the lubrication performance. Based on the literature survey, very few researchers [8-10] appear to have considered the interplay of the surface texture and the boundary slip on tribological performance.

This paper presents the combined effects of slip and texture on tribological performance of bearing by numerical analysis. The modified Reynolds equation developed by Tauviqirrahman et al. [9] is adopted. The load support and friction force behavior are studied under various gap ratio values of the bearing.

2. NUMERICAL METHOD

An artificial complex slip can be applied to bearings without geometrical wedge, i.e. parallel bearings [8]. In this paper, the wedge effect of slip textured bearing has been taken into account. The physical configuration of such bearing is shown in Figure 1. The slip and texturing techniques are applied on the stationary surface.

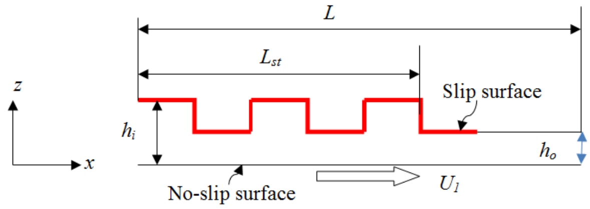

Figure 1 Schematic of a lubricated parallel sliding contact with boundary slip and surface texture. (Note: h_i = inlet film thickness, h_o = outlet film thickness, L_{st} = length of slip textured zone, L = total length of lubricated contact, U_1 = moving wall velocity).

The modified Reynolds equation is discretized over the flow using the finite volume method, and is solved using tridiagonal matrix algorithm (TDMA). By employing the discretization scheme, the computed domain is divided into a number of control volumes using a grid with uniform mesh size. The grid independency is validated by various numbers of mesh sizes. An assumption is made that the boundary pressures are null at both sides of the contact. However, the Reynolds cavitation model is adopted.

The simulation results will be presented in dimensionless form, i.e. $W = wh_i^2 / (U_1 \mu L^2)$ for dimensionless load support in which w is the load per unit length, and μ = the lubricant viscosity, while $F = fh_i / \mu U_1 L$ for dimensionless friction force (where f is the unit width friction force).

3. RESULTS AND DISCUSSION

As reported in the literature, the surface texturing, as well as the boundary slip, plays a vital role in the lubrication performance. In this work, the load support and the friction force are of main particular interest with various gap ratio values. In this work, gap ratio of the bearing is defined as ratio of the inlet film thickness (h_i) over the outlet film thickness (h_o), see Figure 1.

Figure 2 shows the influence of the length of slip textured zone, L_{st} on the dimensionless fluid load support W at various gap ratio of the bearing. It can be observed that when L_{st} = 0.65 L for gap ratio of 1 (i.e. parallel sliding bearing), the load support achieves the maximum value. It is interesting to note, that this result is quite similar to the modified smooth bearing with boundary slip, see [6, 9]. In addition, based on Figure 2, it can be stated that when $L_{st} = L$ for gap ratio of 1, the load support W becomes zero, while for other gap ratio values, the hydrodynamic pressure presents. This indicates that the wedge effect plays a dominant role to create the pressure rather than the full slip effect.

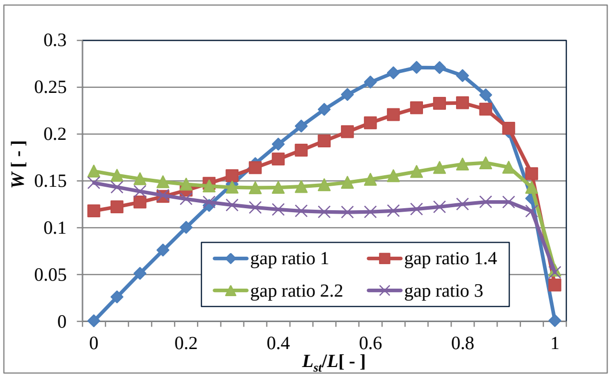

Figure 2 Effect of the length of slip textured zone, L_{ss} on the dimensionless fluid load support W at various gap ratio of the bearing.

Figure 3 shows the influence of the length of slip textured zone, L_{st} on the dimensionless friction force F at various gap ratio of the bearing. Based on this figure, the minimum friction force is achieved for all range of the length of slip textured zone when the gap ratio of 3 is applied at the bearing. This is expected because the wedge effect due to the presence of the gap ratio of the bearing leads to the decrease in the friction force. When slip is applied on the texture, the wall shear stress becomes smaller and thus the reduced friction force. The combined effects of the gap ratio and the presence of the boundary slip reduce the friction force.

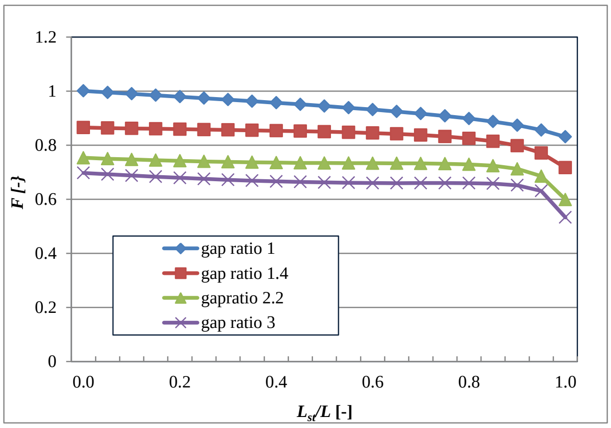

Figure 3 Effect of the length of slip textured zone, L_{st} on the dimensionless friction force F at various gap ratio of the bearing.

4. CONCLUSIONS

This paper was dedicated to a geometrical investigation of surface texture and boundary slip. The studies in this paper are summarized as follows:

(1) For maximum load support, the length of slip textured zone is set to 0.65 while the bearing configuration used is parallel.

(2) Full texturing with slip leads to decrease the friction force significantly for all gap ratio values. The minimum friction force is achieved when gap ratio of the bearing is high.

5. REFERENCES

[1] R. Rahmani, A. Shirvani, and H. Shirvani, “Optimization of partially textured parallel thrust bearings with square-shaped micro dimple,” *Tribology Transactions*, vol. 50, pp. 401–406, 2007.

[2] M., Giocopini, M. Fowell, D. Dini, and A. Strozzi, “A mass-conserving complementary formulation to study lubricant films in the presence of cavitation,” ASME *Journal Tribology*, vol. 132, pp. 041702–1, 2010.

[3] N. Tala-Ighil, M. Fillon, and P. Maspeyrot, “Effect of texture area on the performances of a hydrodynamic journal bearing,” *Tribology International*, vol. 44, pp. 211–219, 2011.

[4] J. Han, L. Fang, J. Sun, and S. Ge, “Hydrodynamic lubrication of microdimple textured surface using three-dimensional CFD,” *Tribology Transactions*, vol. 53, pp. 860–870, 2010.

[5] J.H., Choo, H.A. Spikes, M. Ratoi, R.P. Glovnea, and A.K. Forrest, “Friction reduction in low-load hydrodynamic lubrication with a hydrophobic surface,” *Tribology International*, vol. 40, pp.154–159, 2007.

[6] R.F. Salant, and A.E. Fortier, "Numerical analysis of a slider bearing with a heterogeneous slip/no-slip surface,” *Tribology Transactions*, vol. 47, pp. 328–334, 2004.

[7] F. Aurelian, M. Patrick, and Mohamed H, ”Wall slip effects in (elasto) hydrodynamic journal bearing,” *Tribology International*, vol. 44, pp. 868–877, 2011.

[8] M. Tauviqirrahman, Muchammad, Jamari, and D.J. Schipper, “Numerical study of the load carrying capacity of lubricated parallel sliding textured surfaces including wall slip,” *Tribology Transactions*, vol. 57, no. 1, pp. 134–145, 2014.

[9] M. Tauviqirrahman, R. Ismail., J. Jamari, and Schipper, D.J., 2013, “Combined effects of texturing and slippage in lubricated parallel sliding contact,” *Tribology International* vol. 66, pp. 274–281, 2013.

[10] T.V.V.L.N. Rao, A.M.A. Rani, T. Nagarajan, and F.M. Hashim, ”Analysis of slider and journal bearing using partially textured slip surface,” *Tribology International*, vol. 56, pp.121–128, 2012.