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Characterization of starved hydrodynamic lubricating films

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ABSTRACT – This paper presents a study on the characterization of lubrication films with various lubricant quantities. Experiments were conducted with an optical slider-bearing test rig. Under limited lubricant supply, there exists a critical speed beyond which the film thickness will no longer increase with increasing speeds due to starvation at the inlet. The critical speed depends significantly on the lubricant quantity, as well as lubricant viscosity and load. Comparison between experimental and calculated results indicated that the starvation area with fragmented films has certain load-carrying capacity but very small viscous resistance. Friction does not show much deviation for different lubricant quantities.

1. INTRODUCTION

The great concerns of environment and non-renewable petroleum-based oils promote the idea of minimizing lubricant consumption [1]. Industrial engineers have shown that the most effective way of lubricant supply is small amounts over frequent intervals [2]. This approach can be found in oil/air lubrication [3]. The challenge of using less lubricant is how to maintain efficient lubrication since most of the lubricant is naturally diverted out of the lubrication track during operation. On the other hand, thin liquid film lubrication is a promising approach for the lubrication of miniature devices, and the quantity of supplied lubricant has to be just right. Limited lubricant supply is also found in elastohydrodynamic lubricated contacts (EHL) under starvation conditions, which has been well studied in past decades [4-7]. Starvation in EHL is the result of the competition between lubricant depletion and replenishment. Conformal contacts are not uncommon in industrial practices, and its lubrication behaviors could be different from EHL under limited lubricant supply. In this study, film thickness and friction in a small slider-on-disc contact were measured, and the film building behavior was characterized under different lubricant volumes.

2. APPARATUS AND SPECIMENS

An optical slider-bearing test rig [8] used in the present study is schematically shown in Figure 1, where the lubricated contact consists of a stationary steel slider and a rotating glass disc. The test rig features a constant slider inclination angle α under different speeds and loads. The slider surface is polished to high-precision finish with a size of 4 mm × 4 mm. The disc is coated with a thin Cr layer at the bottom and a SiO_2 layer on the top (referred to as *Beam splitter* in Fig.1) to facilitate interferometry measurement of the lubricating film thickness h_0 at the outlet.

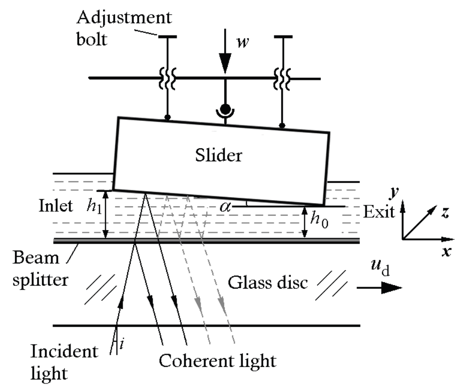

Figure 1 Illustration of the optical slider-bearing test rig.

The lubricant volume ranging from 0.5 - 3.0 μL was employed. Lubrication track radius which was counted from its centre line was 43 mm. The slider inclination was kept constant ($\alpha = 5.75\times10^{-4}$). Experiments were carried out at ambient temperature (20 - 21 °C). The lubricants used include PAO4 and PAO10.

3. RESULTS AND DISCUSSION

Figure 2 presents a typical interferogram of lubricating films generated by the slider-on-disc contact. Under limited lubricant supply, an area with fragmented /rippled fringes appears at the inlet of the contact, indicating incomplete oil supply (labelled as *Starvation area* in Figure 2).

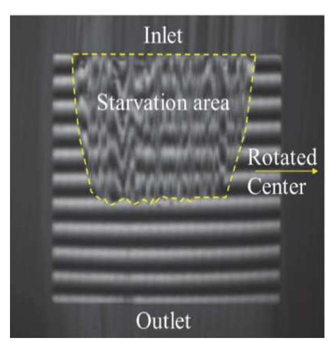

Figure 2 Interferogram of a slider-on-disc contact under limited lubricant supply (PAO10, load = 4 N, lubricant volume = 1 μL, u_d = 20.79 mm/s).

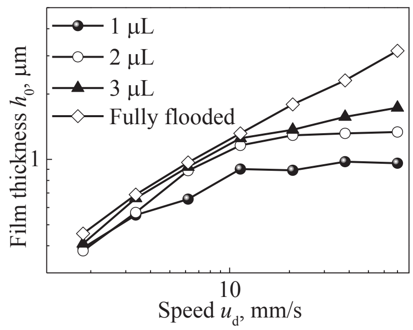

Figure 3 Film thickness vs. speed for different lubricant quantities (PAO10, 4 N).

Figure 3 gives the measured film thickness vs. speed for different lubricant quantities. Low speeds for different lubricant quantities present similar film thickness. At high speeds, the increase in film thickness slows down. Further on, the film thickness remains largely unchanged with speed.

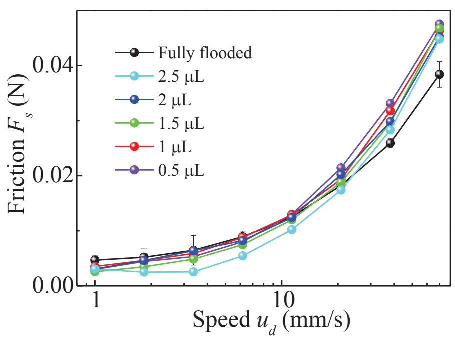

Figure 4 Friction vs. speed for various lubricant quantities (PAO10, 4 N).

On the contrary to the increase in film thickness with the quantity of lubricant supplied, friction does not change much. Figure 4 depicts the variations of friction against speed for various quantities of lubricant used in the tests. The size of the full-lubricated area (the complement of the starvation area as shown in Fig. 2) was measured. The starved hydrodynamic lubricating films were assumed to have a constant nominal viscosity, which was thus calculated based on the boundary conditions of the carrying load and the measured film thickness. The calculated viscous friction force is found well correlated with the experimental measurements. The magnitude of the nominal viscosity of the starved films is quite small, i.e. an order of magnitude less than that of the specimen lubricant. Hence, the viscous friction of starved lubricating films is small.

With the measured film thickness and zero pressure in the starvation area, numerical calculations present a theoretical load in the full film region. When starvation occurs, this theoretical load is smaller than the actual applied load, which indicates that the starvation area has certain load-carrying capacity. Figure 5 gives the calculated load-carrying capacity of the starvation area for two lubricant volumes.

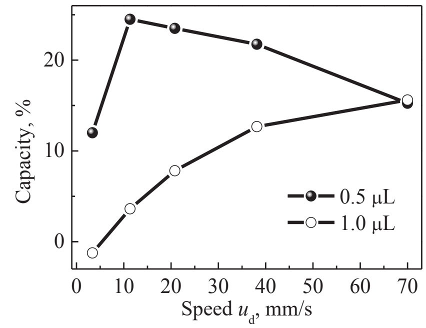

Figure 5 Load capacity of starvation area vs. speed for different lubricant volumes (PAO4, 4 N).

4. SUMMARY

This work studies the influence of lubricant quantity on lubricating film building in a conformal slider-on-disc contact. The film thickness presents obvious dependence on the lubricant quantity, and the friction, on the other hand, does not. The starved (fragmented/rippled) hydrodynamic lubricating films at the inlet have certain load-carry capacity but very small viscous friction.

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REFERENCES

[1] Nosonovsky, M., & Bhushan, B. (Eds.). (2012). *Green tribology: biomimetics, energy conservation and sustainability*. Springer Science & Business Media.

[2] Mang, T. (2014). *Encyclopedia of Lubricants and Lubrication*. Springer Berlin Heidelberg.

[3] Zeng, Q., Zhang, J., Hong, J., & Liu, C. (2016). A comparative study on simulation and experiment of oil-air lubrication unit for high speed bearing. *Industrial Lubrication and Tribology*, *68*(3), 325-335.

[4] Wedeven, L. D., Evans, D., & Cameron, A. (1971). Optical analysis of ball bearing starvation. *Journal of Lubrication Technology*, *93*(3), 349-361.

[5] Cann, P. M. E., Damiens, B., & Lubrecht, A. A. (2004). The transition between fully flooded and starved regimes in EHL. *Tribology International*, *37*(10), 859-864.

[6] Chevalier, F., Lubrecht, A. A., Cann, P. M. E., Colin, F., & Dalmaz, G. (1998). Film thickness in starved EHL point contacts. *Journal of tribology*, *120*(1), 126-133.

[7] Gershuni, L., Larson, M. G., & Lugt, P. M. (2008). Lubricant replenishment in rolling bearing contacts. *Tribology Transactions*, *51*(5), 643-651.

[8] Guo, F., Wong, P. L., Fu, Z., & Ma, C. (2010). Interferometry measurement of lubricating films in slider-on-disc contacts. *Tribology Letters*, *39*(1), 71-79.