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Study of instantaneous starvation at a finite-length line contact

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ABSTRACT – Starvation phenomenon widely exists in the non-conforming contacts when high-viscosity lubricating oil or greases are used. However, most of work focuses on the steady state starvation; the phenomenon of instantaneous starvation is not well explored by scholars. This paper experimentally studies the effect of speed, base oil viscosity and load on instantaneous starvation, and proposes some improvement measures to weaken the instantaneous starvation.

1. INTRODUCTION

Starvation often occurs in tribological contact due to reduced lubricant availability which generally accompanies with the decreased protective fluid film, and then even moderate surface roughness can lead to component damage. This is especially true with use of grease-lubricated or high-viscosity-oil-lubricated applications. Lots of theoretical and experimental work has been done to investigate the effects of the operating conditions and the lubricant properties on the starvation. Recently, Wang [1] et al. used the multiple-contact optical EHL test rig to investigate the starvation of grease-lubricated finite line contact, and they found even in a short period of time there is a significant change in the thickness of the film, as shown in Figure 1.

The film-thickness interference images of one period are showed in Figure 2. These high frequency fluctuations indicate "Instantaneous Starvation" phenomenon. Many factors may cause this phenomenon, such as the vibration of test rig, the variation of speed and the lubricant properties. In this paper, effect of speed, base oil viscosity and load on this phenomenon is firstly investigated with the elastohydrodynamic lubrication (EHL) test rig, and then some improvement measures are proposed to weaken this phenomenon.

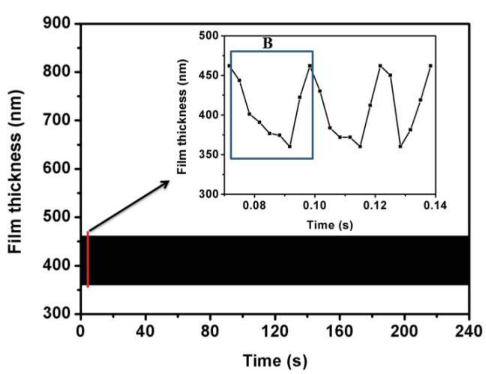

Figure 1 Change in film thickness over time [1].

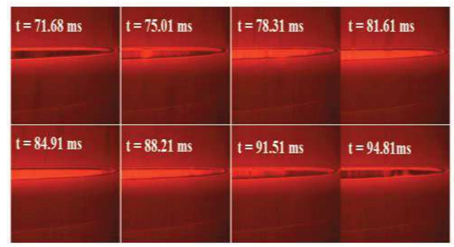

Figure 2 Variation of the oil film interference image in one cycle (corresponding to B in Figure 1) [1].

2. TEST RIG AND CONDITIONS

2.1 Test Rig

Figure 3 shows the schematic of finite line contact EHL test rig used in this work.

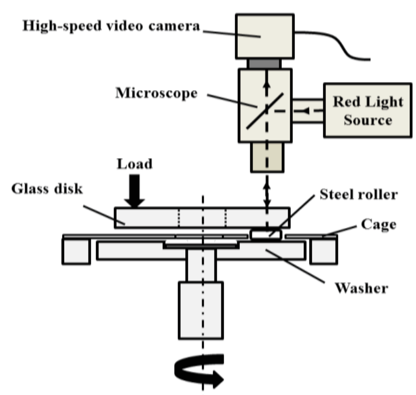

Figure 3 Schematic of EHL testing machine.

2.2 Test conditions and lubricants

Table 1 shows the test conditions used in this study. The kinematic viscosity of PAO at 40℃ varies from 30.5mm²/s to 1000mm²/s.

Table 1 Test conditions.

Needle roller	6×12
Load	293N ~ 672 N
Speed	0.107 m/s ~ 0.321 m/s
Experiment time	4 min
Frame rate	300 frames/s
Lubricant (Synthetic oil)	Poly Alpha Olefin (PAO)

3. EFFECT OF OPERATING CONDITIONS ON INSTANTANEOUS STARVATION

3.1 Effect of speed on instantaneous starvation

Figure 4 gives the effect of speed on instantaneous starvation. It can be found that when the high-viscosity base oil is used, as the speed increases, the film thickness increases, and the high frequency fluctuation of film thickness weakens and finally disappears. This is because as the speed increases, the amount of lubricating oil involved in the contact area increases correspondingly, and the volume of lubricant passing contact areas per unit of time also increases, which may weaken instantaneous starvation. Under this working condition, when the speed is larger than 0.321 m/s, the instantaneous starvation phenomenon disappears.

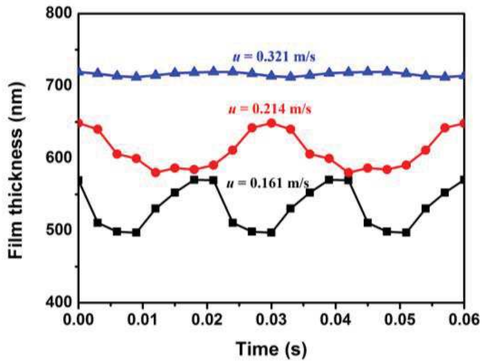

Figure 4 Variation of film thickness with time at different speeds (w = 200 N, v = 1000 mm^2/s).

3.2 Effect of base oil viscosity on instantaneous starvation

Figure 5 gives the effect of base oil viscosity on instantaneous starvation. It can be found that as the viscosity decreases, the film thickness decreases, and the high frequency fluctuation of film thickness weakens and finally disappears, since reducing the viscosity of base oil will decrease the internal shear stress of lubricant, which can improve the mobility of the lubricant and weaken instantaneous starvation. Thus, the instantaneous starvation phenomenon disappears. In this working condition, when the base oil viscosity is lower than 58mm^2/s, the instantaneous starvation phenomenon disappears.

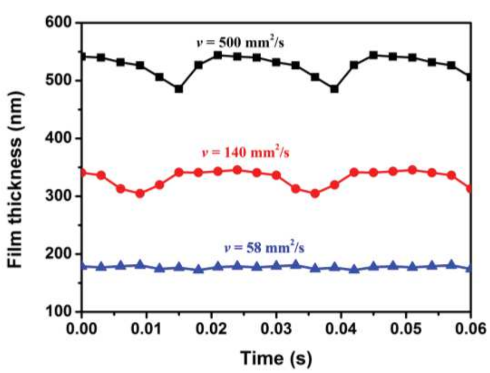

Figure 5 Variation of film thickness with time at different viscosities (w = 200 N, u =0.107 m/s).

3.3 Effect of load on instantaneous starvation

Figure 6 gives the effect of load on instantaneous starvation; it can be found as the load increases; the film thickness slightly decreases. In addition, the load has little influence on the instantaneous starvation.

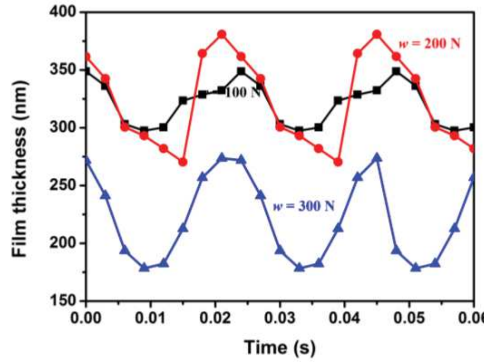

Figure 6 Variation of film thickness with time at different loads (u = 0.107 m/s, v = 242 mm^2/s).

3.4 Effect of non-Newtonian fluid

In order to investigate non-Newtonian fluid on instantaneous starvation, the viscosity improver additive (PMA) is added to base oil (PAO), which can form non-Newtonian fluid. From figure 7, it can be found that although two lubricants have the similar kinematic viscosity, the film thickness of non-Newtonian fluid is lower than that of Newtonian fluid, and the instantaneous starvation non-Newtonian fluid weakens comparing to Newtonian fluid. This is because shear-thinning behavior exists in non-Newtonian fluid under high shear stress which can cause temporary loss of viscosity. Thus, non-Newtonian fluid can weaken the instantaneous starvation.

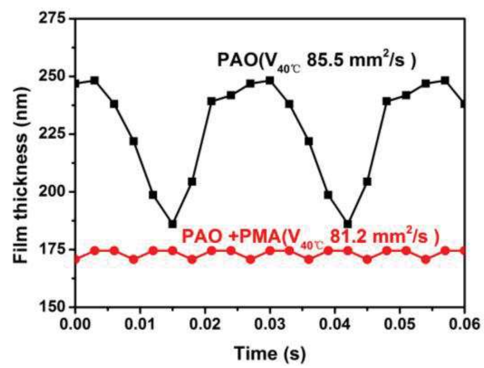

Figure 7 The influence of non-Newtonian fluid on instantaneous starvation.

4. CONCLUSION

The instantaneous starvation phenomenon is experimentally investigated by using the multiple-contact optical EHL test rig. It can be found that the operating speed and the base oil viscosity are the two primary factors in the instantaneous starvation phenomenon. The load has little influence on the instantaneous starvation. Using the non-newton fluid can weaken the instantaneous starvation.

REFERENCE

[1] Wang, Z. J., Shen, X. J., Chen, X. Y., Han, Q., & Shi, L. (2017). Experimental study of starvation in grease-lubricated finite line contacts. *Industrial Lubrication & Tribology*, *69*(10), 963-969.