Numerical Analysis of Grease Film Thickness in EHL – Effects of thickener concentration and base oil viscosity –

Minami Soma[1)*], Takashi Nogi[1)], Daming Dong[1)] and Yoshitsugu Kimura [2)]

[1)]Kyodo Yushi Co., Ltd,
2-2-30, Tsujido Kandai, Fujisawa-shi, Kanagawa 251-8588, Japan
[2)]University of Tokyo/Kagawa University
5-21-10-4, Nagayama, Tama-shi, Tokyo 206-0025, Japan
*Corresponding author: minami-soma@kyodoyushi.co.jp

A numerical analysis is described of the EHL film thickness with greases, having different initial concentration of thickener to give different consistency and base oils of different viscosity, focusing on an unusual behavior at low speeds. The key issue is the increase of the generalized viscosity of grease at the inlet region caused by the increase in the concentration of thickener by the squeezing-out of the base oil. A two-phase flow analysis is performed and the results shows agreement with experimental ones with sufficient accuracy.

Keywords: Elastohydrodynamic lubrication, grease, rheology, permeability

1. Introduction

Grease often forms a much thicker film than its base oil in EHL contacts at low speeds [1-4]. In a preceding paper it was suggested that this phenomenon was caused by an increase of the generalized viscosity of grease at the inlet region due to the increase in the concentration of thickener, and that this increase was caused by the squeezing out of the less viscous component [2]. A numerical analysis of the grease film thickness taking this effect and non-Newtonian grease rheology into account has shown that the film thickness of greases with different thickeners can be predicted [3, 4]. The present paper describes effects of the difference in the initial concentration of thickener and difference in the viscosity of base oil on the above-mentioned behavior of EHL film thickness.

2. Analytical Methods

A two-phase flow analysis is conducted. The flow of grease is assumed to be composed of Couette flow of grease as a whole, Poiseuille flow of thickener network, and Darcy flow of base oil relative to the thickener network. The permeability characterizing Darcy flow was determined from oil separation in centrifugation [4]. The analysis is performed for five sample greases listed in Table 1, and the results are compared with those obtained in a series of ball-on-disk experiments [2].

Table 1: Sample greases

Sample name	A	B	C	D	E
Thickener type	Li(12OH)St				
Thickener concentration, mass%	6	9.5	12.5	9.5	
Base oil type	PAO				
Base oil viscosity @25°C, mPa·s	50			144	403
Worked penetration	356	302	261	268	256

3. Results and Discussion

With all sample greases, analytical results agree with experimental ones with sufficient accuracy. The effect of base oil viscosity is described below.

Figure 1 shows the film thickness of the three sample greases with the base oils of different viscosity. The curves have a common feature. At high speeds, they follow straight lines representing the film thickness with their base oil alone. As the speed decreases, the film thickness deviates from the straight line and tends to increase with further decrease in the speed. However, this occurs at a different speed depending on the viscosity of their base oil, i.e. at higher speeds for lower viscosity. The reason is clear. A low viscosity oil is more easily squeezed out from the grease according to Darcy's law.

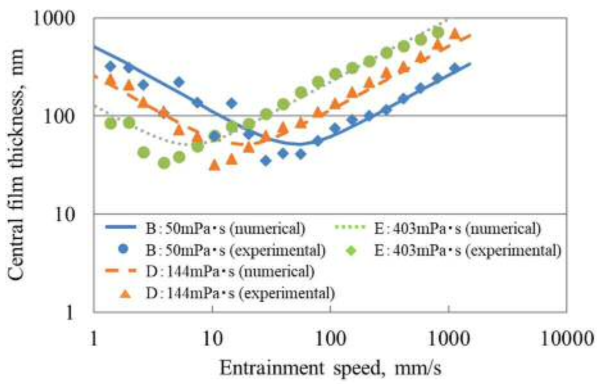

Figure 1: Film thickness of greases with different base oil viscosity

4. References

[1] G. E. Morales-Espejel, et al., "Film Thickness in Grease Lubricated Slow Rotating Rolling Bearings," Tribol. Int., 74 (2014) 7.

[2] T. Kochi, et al., "Experimental Study on the Physics of Thick EHL Film Formation with Grease at Low Speeds," Tribol. Lett., 67 (2019) 55.

[3] T. Nogi, et al., "Numerical Analysis of Grease Film Thickness and Thickener Concentration in Elastohydrodynamic Lubrication of Point Contacts," Tribol. Trans., DOI: 10.1080/10402004.2020.1778147.

[4] M. Soma, et al., "Determination of Permeability of Grease with Centrifugation," Int. Tribol. Conf., Sendai 2019, 18-E-10.