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EHL ANALYSIS (2) –GREASE'S FILM THICKENING MECHANISMS AT LOW SPEEDS–

Following our previous report on the permeability determinations that facilitate the analysis of the film thickening behavior of greases at low speeds in EHL(KYTB 17), this report focuses on the EHL analysis.

The non-Newtonian viscosity of grease is described by the Carreau-Yasuda model:

$$\eta_0 = (\mu_1 - \mu_0)[1 + (\lambda\dot{\gamma})^{a_Y}]^{(n-1)/a_Y} + \mu_0 \quad (1)$$

where it undergoes a transition from μ_1 to μ_0 as shear rate $\dot{\gamma}$ increases, and an exponential equation relating μ_1 and thickener volume concentration C is assumed. The constant is obtained by incorporating the values measured with a rheometer into Eq. (1).

An EHL analysis was performed using the Ertel-Grubin theory. Given that the grease has a two-phase flow associated with base oil and thickener, the continuity equation of a thickener can be written as follows:

$$[Q_C + Q_P/(1 + R)]C = \text{const.} \quad (2)$$

where Q_C is the shear flow rate and Q_P is the pressure flow rate. The square parentheses in Eq. (2) denote the flow rate of thickener network structure. The difference in flow rates between grease and thickener network structure is defined as Darcy's flow rate, and R is calculated as the ratio of Darcy's flow rate and the pressure flow rate of thickener network structure in the form:

$$R = (12K/h^2)(\eta/\mu - 1) \quad (3)$$

The thickener concentration is given by Eq. (2)

The central film thickness was measured by optical interferometry for a glass disk and a steel ball in pure rolling contact at room temp. and the max. Hertzian contact pressure of 0.51 GPa. The half contact width in the analysis was in line with the contact radius in the experiments.

In Figs. 1, 2 and 3, the central film thickness of the greases described in our previous report are plotted versus entrainment speed by thickener concentrations, base oil viscosities and thickener types, respectively. All measured and calculated values as represented by symbols and curves are in good agreement.

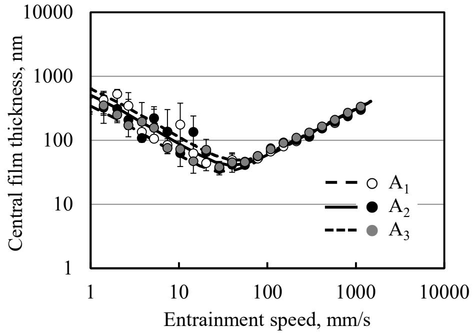

Fig. 1 Film thickness of greases with different thickener concentration; A_1, A_2, A_3

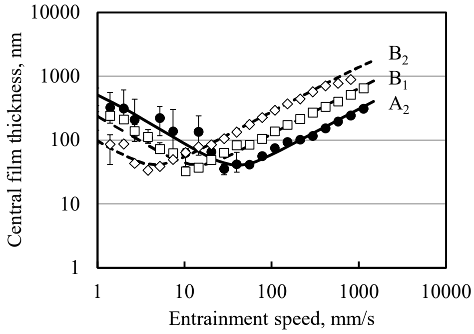

Fig. 2 Film thickness of greases with different base oils; A_2, B_1, B_2

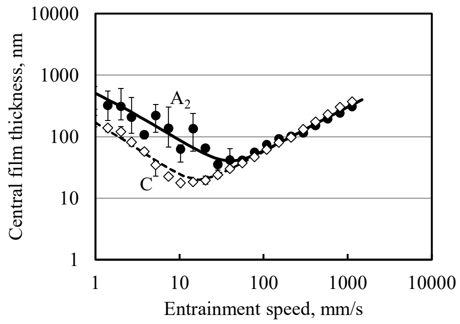

Fig. 3 Film thickness of greases with different thickeners; A_2, C

When the speed decreases, R becomes higher and the flow rate of thickener network structure decreases towards the contact region. Accordingly, the thickener concentration given by Eq. (2) increases leading to a higher apparent viscosity of grease to form a thicker film. As in Fig.1, the film thickness is little affected by the initial thickener concentration because the lower the initial concentration, the higher the permeability and the concentration rise rate. R becomes smaller with increasing base oil viscosity and decreasing permeability, and therefore film thickening starts to occur at a lower entrainment speed (Fig. 2, 3). As in Fig.3, grease C has a thinner film at low speeds compared to grease A_2 due to its lower apparent viscosity at high concentrations.

Soma, Nogi, Dong, Kimura. (2023). Changes in Permeability of Grease with Its Composition and Their Effect on Thick EHL Film Formation at Low Speeds. Tribologists, 68(3), 185-197