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WHY GREASE FORMS THICK ELASTOHYDRODYNAMIC LUBRICATION FILM AT LOW SPEEDS? — A SIMPLIFIED ANALYSIS

Analysis has been made of the mechanism of forming thick elastohydrodynamic(EHL) film of grease by using "Carreau-Yasuda equation", which depicts a transition of a generalized viscosity from high Newtonian viscosity at low shear rates to low Newtonian viscosity at high shear rates. It has been concluded that, while thick EHL film is formed by high entrainment rates at high speed, increased viscosity at low shear rates causes it at low speeds.

To express non-Newtonian viscosity of grease, a generalized viscosity η^* is introduced, which is defined by the ratio of the amplitudes of the shear stress and the shear strain when grease is sheared in an oscillation manner.

$$\eta^* = (\mu_1-\mu_2)\{1+(\lambda\dot{\gamma})^a\}^{(n-1)/a}+\mu_2$$

where μ_1 is the first Newtonian viscosity, μ_2 is the second Newtonian viscosity and $\dot{\gamma}$ is the shear rate. This equation represents a transition of η^* from μ_1 at low shear rates to μ_2 at high shear rates, and λ and a are the parameters characterizing the transition. Examples of the change in η^* with shear rate are illustrated in Fig.1.

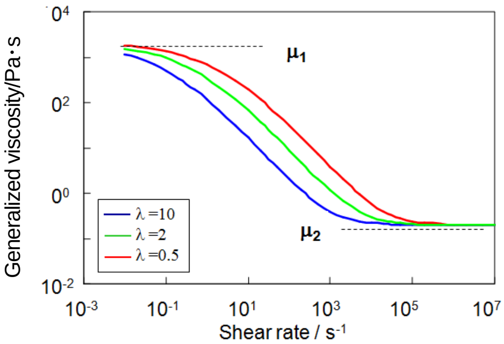

Fig.1 Change in the generalized viscosity with $\dot{\gamma}$

The generalized viscosity was determined for a grease prepared with synthetic hydrocarbon as the base oil and lithium stearate as the thickener (grease A in KYTB No.1) on a cone-on-plate rheometer giving shear in a sinusoidal angular oscillation manner. Results are shown in Fig.2 as a function of the shear rate and the oscillation frequency.

By using this generalized viscosity, a simplified EHL analysis has been made based on the 2-dimensional Ertel-Grubin theory. The dependence of μ_1 and μ_2 on pressure is assumed to be represented by two viscosity-pressure coefficients, α and β, such that $\mu_1 = \mu_{10}(1+\beta p)$ and $\mu_2 = \mu_{20}\exp(\alpha p)$, where μ_{10} and μ_{10} are the values of μ_1 and μ_2 at atmospheric pressure. Since the generalized viscosity depends on the oscillation frequency, certain "interpretation" has been necessary to use it in the EHL calculations.

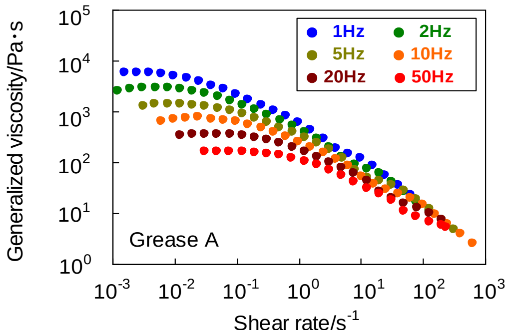

Fig.2 Generalized viscosity determined by rheometry

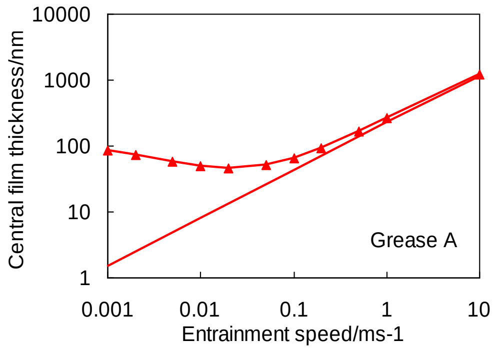

Fig.3 Film thickness calculated with η^*

The result is given in Fig.3. Though direct comparison with the experimental results of point contact is inadequate, Fig.3 shows that the film thickness follows the general EHL theory at high speeds, but at low speeds it deviates from the theory and increases again as speed is further reduced. This reproduces the peculiar behavior of grease observed in the optical interferometry.

Y. Kimura, T. Endo and D. Dong, "EHL with grease at low speeds", Jianbin Luo, Yonggang Meng, Tianmin Shao and Qian Zhao (eds.), Advanced Tribology - Proceedings of CIST2008 & ITS-IFToMM2008 Beijing, China (2009) pp.15-19.