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EHL ANALYSIS (1) –MEASUREMENTS OF PERMEABILITY OF GREASE BASED ON CENTRIFUGAL OIL SEPARATION TESTING–

Greases in rolling contact have been found to exhibit unique film thickening behavior and form a much thicker lubrication film than lubricating oils at low speeds. It was shown in preceding works that the film thickness increases due to increased apparent viscosity of grease triggered by the base oil being squeezed out of the inlet region to increase thickener concentration and when the shear rate decreases. Analysis of this behavior observed in elastohydrodynamic lubrication (EHL) requires understanding of the permeability that represents how easily the base oil passes through thickener network. Thus, the permeability of various greases was determined as shown in Table 1.

By applying Darcy's law to the flow of base oil through thickener network, the flow velocity of base oil u is given as:

$$u = (K/\mu_0)(\Delta P/L) \quad (1)$$

where K is the permeability, $\Delta P/L$ is the pressure gradient, and μ_0 is the viscosity of base oil. An assumption is made that the relation between the permeability and the mass concentration of thickener f is expressed by a modified form of the Kozeny-Carman equation:

$$K = \delta(1-f)^3/f^m \quad (2)$$

where the permeability decreases with increasing thickener concentration. δ and m were taken as constants dependent on the shape of thickener and determined by fitting oil separation calculated from Eq. (1), the flow velocity of base oil, to that measured with a centrifuge. Here, the pressure gradient in Eq. (1) was obtained from the centrifugal force subtracted by the capillary force acting on the base oil in grease.

Figures 1 and 2 show the results for greases A_2 and C, respectively. The capillary force increases with increasing thickener concentration. Oil separation becomes constant when the centrifugal force and the capillary force are balanced. Comparing A_2 with other greases, it was revealed that a grease with higher thickener concentration and higher base oil viscosity has lower oil separation. The calculated and measured values correspond well with each other, and so Eq. (2) can provide an accurate description of permeability. Table 1 shows the permeability of each grease in its initial state.

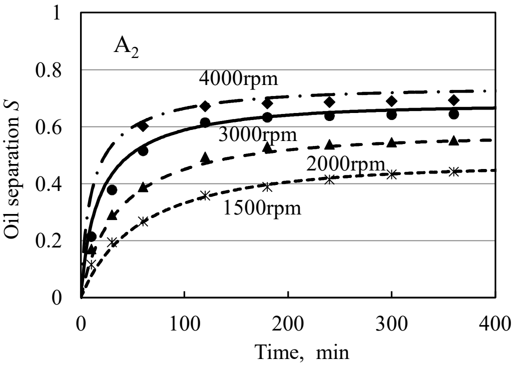

Fig. 1 Oil separation of grease A_2 under different rotational speeds

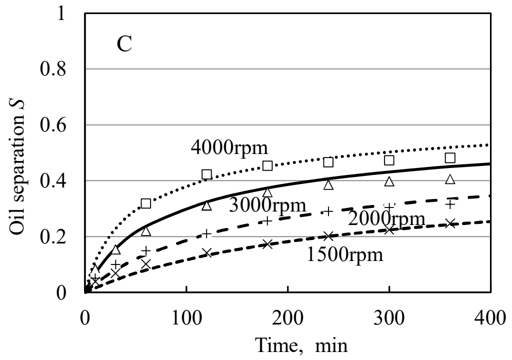

Fig. 2 Oil separation of grease C under different rotational speeds

Soma M, Nogi T, Dong D, Kimura Y. Changes in Permeability of Grease with Its Composition and Their Effect on Thick EHL Film Formation at Low Speeds. J Japanese Soc Tribol. 2023;68(3): 185-197 (in Japanese).

Table 1 Sample greases

Sample grease	A_1	A_2	A_3	B_1	B_2	C
Thickener type	Li(12OH)St					LiSt
Initial concentration of thickener f, mass%	6.0	9.5	12.5	9.5		17.0
Base oil type	PAO					
Base oil viscosity μ_0 @25°C, mPa·s	50			144	440	50
Worked penetration	356	302	261	268	256	294
Permeability K at initial concentration, 10^{-14} m^2	9.5	2.2	0.88	2.2		0.41