Lubricant Rheology Effect on Roughness Behavior in EHL Contacts

P. Sperka[1*], I. Krupka[1], M. Hartl[1]

[1)]Faculty of Mechanical Engineering, Brno University of Technology, Technicka 2896/2, Brno, Czech Republic.

[*]Corresponding author sperka@fme.vutbr.cz

1. Introduction

The trend of decreasing of lubricant film thickness in tribological systems is one of the important features of current tribology stirred up by the quest for higher efficiency and energy saving. As a result, the influence of the surface micro geometry on the contact performance and machine component life increases steadily.

Roughness features are elastically or plastically deformed during EHL contact passage. The elastic deformation is connected with pressure variations and effectively decreases the actual roughness height. The pressure variations are related to subsurface stress field and affecting surface fatigue life. The surface height has a role on severity of asperity contacts in mixed regime. Therefore, the effects of surface roughness and topography on lubrication film thickness and pressure have been a subject of a number of numerical and experimental studies.

Systematic study of a low-amplitude surface roughness passing through a rolling EHD contact has led to general model called amplitude attenuation theory. It was found that the elastic deformation of roughness features is wavelength dependent, where short wavelengths are deformed less than the long wavelengths. The effect of operational conditions can be expressed by relation for non-dimensional wavelength.

It was found that the cases of pure rolling and rolling-sliding show different behavior. In pure rolling case the model with one component is sufficient for the film thickness description. However, in rolling-sliding case two components model is necessary to explain the film variations. It is roughness deformation and so called complementary wave, the first moves at rough surface speed and the second is drift by mean entrainment speed. Recently, it was shown that the amplitude of complementary wave is related to the conditions in contact inlet contrary to roughness deformation which is influenced by conditions inside the contact. Unlike the contact inlet where lubricant often behaves as Newtonian fluid, inside the contact the flow is governed by non-Newtonian phenomenon. The current amplitude attenuation model for rolling-sliding conditions is based on Ree-Eyring shear thinning theory and parameter τ_0 with in the form [1]:

$$\frac{h_a}{A_0} = \frac{1 - \mathrm{i}CQ}{1 - \mathrm{i}Q - \mathrm{i}CQ}, \quad Q = sign(\Delta u)\frac{6\tau_0\lambda^2}{\pi^2 E' h^2} \qquad (1)$$

where h_a/A_0 is the complex amplitude ratio representing the modified amplitude and phase, λ is roughness wavelength, E' is reduced elastic modulus, h is mean film thickness, $C = hE'\omega / 4B$ implies the fluid compressibility effect.

2. Material and methods

The experimental results were obtained by using ball-on-disk optical tribometer. Thin film colorimetric interferometry was used for the film thickness evaluation. Experiments conditions are in Tab 1.

Table 1 Operational conditions and lubricants

Load F		50 N
Reduced modulus elasticity E'		123.8 GPa
Mean film thickness, h		220 nm
Lubricant	min. oil SR600	synth. oil PAO650
Viscosity, η	0.22 Pa.s	~6Pa.s
Pressure-viscosity	24 GPa^{-1}	~20 GPa^{-1}
Eyring stress, τ_0	5 MPa	~0.06MPa

3. Results

Fig. 1 shows measured profile of transverse ridge with initial height 200 nm. For both lubricants deformation for same mean film thickness is very similar. However, this does not correspond to Eq. 1 since the both lubricant has significantly different τ_0 value.

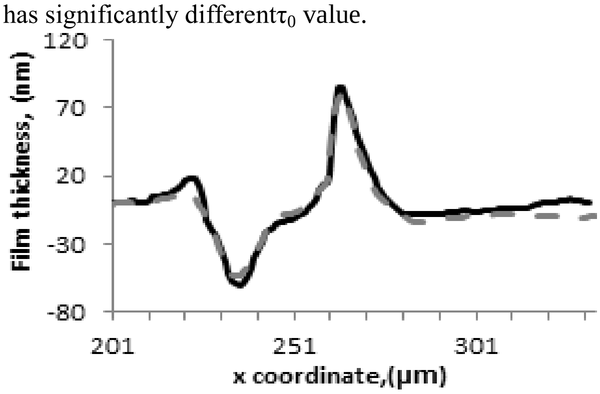

Fig 1Measured film thickness profile;black solid line PAO650, gray dashed line SR600 oil.

4. Conclusions

The experiments with artificial roughness features and two lubricants withvarious $\tau_0$stress exhibit similar deformation which cannot be explain by current theory. In this study the effect of lubricant rheology will examine to extend the present amplitude attenuation theory.

References

[1] Hooke. CJ, Roughness in rolling-sliding elastohydro-dynamic lubricated contacts. Proc. Instn. Mech. Engrs. Part J: J. Eng. Tribol., 2006; 220: 259-271.