7th World Tribology Congress, WTC 2022
July 10-15, 2022, Lyon, France

Transient effects of squeeze and starvation on EHL Film Forming Capability under forced oscillation

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This work provides new insights on the EHL regime in time-varying conditions, here forced oscillations, using a full-analytical resolution of the Reynolds equation combined with experimental measurements. The analytical film thickness equations provided perfect modeling of the film forming mechanisms as confirmed by experimental validations. The results highlighted the film thickness transient evolutions in the oscillating contact, by the combination of squeeze and transport effects. In addition, the inlet flow modulation in the analytical equations gave an accurate prediction of the effects induced by the starvation resulting from the change in direction (i.e., as the original outlet zone becomes the next inlet zone).

Keywords: Elastohydrodynamic lubrication, Film thickness, Reynolds equation, Reciprocating sliding, Time-varying conditions

1. Introduction

Lubrication mechanisms under transient contact kinematics are still poorly understood despite their importance in everyday life contacts (knee, piston/rings/cylinder contacts, etc). In this work, the film-forming mechanisms in a smooth EHL contact subject to forced oscillating velocities (succession of acceleration/deceleration cycles) were analyzed considering the contributions of both squeeze and starvation. Thanks to an extension of a recent theoretical work [1], an analytical solution of Reynolds equation was presented and experimentally validated to get a better understanding of the lubrication mechanisms under these time-varying conditions [2].

2. Modeling of transient EHL line contact

The Reynolds equation was analytically solved using the method described in [1] and three main film thickness equations were used to describe the first deceleration, the following accelerations and decelerations.

For instance, the dimensionless contact film thickness during the first deceleration $H_1(X, S)$ can be expressed by the equations system (1) with S the dimensionless time and X the dimensionless position, $H_0[X]$ corresponding to the initial thickness profile (i.e., in pure rolling before the first deceleration).

$$H_1(X,S) = H_0(X) \cdot \frac{e^{-\frac{\sigma}{4} \cdot S^{*2}}}{\left[e^{\frac{-\sigma}{3}} + \sqrt{\frac{\sigma\pi}{3}}\left[\operatorname{erf}\left(\sqrt{\frac{\sigma}{3}}\right) - \operatorname{erf}\left(\sqrt{\frac{\sigma}{3}} \cdot S^*\right)\right]\right]^{3/4}} \qquad (1)$$

3. Results and Discussion

The central film thickness of lubricated contacts in time-varying conditions was accurately calculated (Fig. 1).

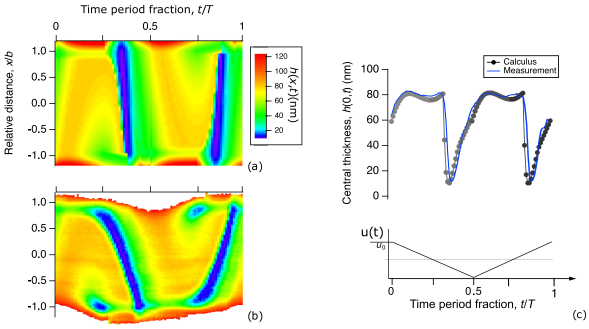

Figure 1: Lubricant film thickness for a viscosity of 0.8 Pa·s and sliding frequency of 10 Hz under a load of 10 N: (a) waterfall of calculated thickness profiles; (b) waterfall of measured thickness profiles; (c) calculated and measured central lubricant film thickness for the velocity profile U(t) indicated in (c).

The main contributions to the film establishment i.e., the squeeze and the transport effect, were well retrieved by the calculation, which confirmed and explained several observations: film thickness hysteresis, transient squeeze and residence time effect and starvation effects. The influence of the oscillating frequency and stroke, governing the feeding capability, was also investigated.

4. References

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