A new film parameter with micro elasto-hydrodynamics

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A new semi-analytical model for estimating the lubrication quality in rough surface elasto-hydrodynamic lubricated (EHL) contacts is presented. The model was derived upon the basis of an idealized micro-EHL contact, and was subsequently extended to account for real engineering surfaces comprising isotropic and anisotropic roughness lay. Model validation was made against ball-on-disc experiments in which the true mixed and EHL regimes where identified by means of the electrical-contact-resistance signal (ECR). While, the conventional approach, the Λ-ratio, was found to grossly mispredict the transition to the EHL and mixed-lubrication (ML) regime boundary, the new film parameter was found to be surprisingly accurate.

Keywords (from 3 to 5 max): Λ-ratio, micro-EHL, mixed lubrication, running-in

1. Introduction

It is well established that surface roughness may deform under elasto-hydrodynamic lubrication (EHL), and that this occurrence may allow for an intermediate regime known as micro-EHL. Despite such knowledge, the most widely used approach in estimating the lubrication quality is still by means of the Λ-ratio (Λ=h/Sq). The deficiency of the Λ-ratio for EHL applications lies within the assumption of rigid roughness, which is a gross oversimplification that many times results in unrealistic estimates. E.g., we have through experimental measurements observed Λ<0.5, even when a fully separating EHL oil film was formed.

In this work, we have developed a new and much more accurate and realistic film parameter, Λ^*, that account for the micro-EHL film formed under surface irregularities of microscopic scale. The model is straightforward since only well-established EHL theory and surface metrology parameters are required. Thus, it can easily be employed by most professionals interested in a quick yet accurate assessment of the lubrication quality of rough surface EHL contacts.

2. Theoretical foundation

The new film parameter, Λ^*, was derived upon the basis of the idealized micro-EHL contact problem, depicted in Figure 1.

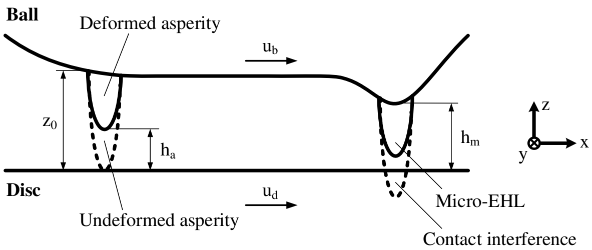

Figure 1: Schematic showing the essential features of the micro-EHL model.

The associated criterion for the transition between ML and EHL is based upon whether or not actual contact interference occurs, rather than a vaguely defined limit as in the classical approach (Λ=3).

3. Results and discussion

Fig. 2 shows electrical-contact-resistance signal (ECR) and coefficient of friction (CoF) running-in curves (EHL lift-off curves). The running-in sequence was terminated when the lubrication regime had shifted from ML (~0 % ECR) to full film EHL (~100 % ECR).

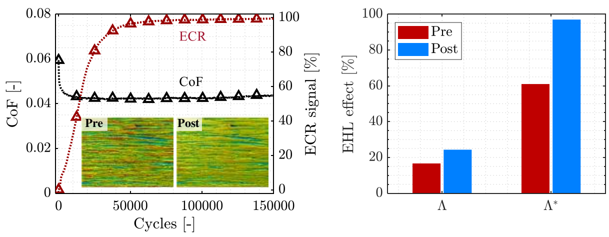

Figure 2: **Left:** Ball-on-disc running-in test of a transversely oriented rough ball surface (Sq=035μm), opposing surface nm smooth. **Right:** The pct. EHL effect, defined from each corresponding EHL limit (Λ=3 and Λ*=*undisclosed*).

Additionally, by employing a very precise surface topography tracing technique, we have been able to measure and re-identify the same surface area in great detail as it appeared under ML and EHL conditions. The bar chart shows the evaluation of this area by means of Λ^* and Λ. While it can be seen that the Λ-ratio is grossly mispredicting the full film EHL regime (24 % EHL effect post running-in), the Λ^* shows the contrary; a very good correspondence to the true measured EHL regime, with a 97 % EHL effect.

Furthermore, the Λ^*-parameter has been evaluated on longitudinal and isotropic surface structures as well (not shown), and the accuracy was found similar or even better. Hence, with Λ^*, it is possible to optimize the EHL/ML transition with respect to both the topographical structure, as well as e.g. the lubricant viscosity.

4. References

[1] Hansen J. et al., “A New Film Parameter for Rough Surface EHL Contacts with Anisotropic and Isotropic Structures”, Tribol. Lett., vol. 69, no. 37, pp. 1–17, 2021.