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Elastohydrodynamic lubrication in soft-on-hard, hard-on-soft and soft-on-soft point contacts at high loads

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Friction in lubricated soft contacts is examined using a ball-on-disc tribometer. The contact-pair members are either soft or hard and the effect of the respective configuration is investigated. For a soft polymeric disc, the time-dependent viscoelastic deformations contribute to friction. After the correction of the hysteretic losses, estimated using a theoretical model, the friction coefficient in the full-film regime does not depend on the configuration. This holds also true for high normal loads inducing finite deformations.

Keywords: soft-EHL, mixed lubrication, finite deformation, surface roughness

1. Introduction

This work is concerned with the soft-elastohydrodynamic lubrication (soft-EHL) regime. When one or both bodies in contact are highly compliant, relatively low contact pressures may cause large deformations, thus affecting fluid flow. These specific conditions are present in various engineering applications, e.g., wipers, tyres, seals, or biotribological contacts, e.g., synovial joints, eye-eyelid contact, oral processing of food, hence an increased interest in lubricated soft contacts.

A number of friction measurements have been performed with the use of a home-made ball-on-disc tribometer [1]. Contacting bodies were produced from steel and NBR rubber, and three types of the ball-on-disc set-up have been examined, namely soft-on-hard (S/H), hard-on-soft (H/S) and soft-on-soft (S/S) configurations. The friction coefficient has been measured in lubricated contact conditions for varied sliding speed, surface roughness, lubricant viscosity and load. High loads have been employed in order to induce finite deformations, cf. [2].

2. Estimation of the hysteretic losses

In the ball-on-disc tribometer, the disc made of rubber (in H/S and S/S configurations) is repeatedly deformed, and this is associated with hysteretic losses in the viscoelastic material. Consequently, the measured friction force consists of the interfacial friction force and the hysteretic friction force. This is not the case for the S/H configuration, where the rubber ball, once loaded by a constant load, does not deform any more. The estimated hysteretic friction coefficient increases with increasing load in the whole range of considered sliding velocities [1].

Sample results are presented in Fig. 1. The interfacial friction coefficient (corrected for the hysteretic losses) is shown as a function of $U\eta$, the product of sliding speed and viscosity, for the H/S configuration together with the raw experimental data and the reference results corresponding to the S/H configuration. Transition from the full-film EHL to the mixed lubrication regime is well captured.

3. Main outcomes

Upon correction for the hysteretic losses, the friction coefficient in the full-film EHL regime (the increasing branch corresponding to higher values of $U\eta$) does not depend on the configuration.

The transition from the full-film EHL to the mixed lubrication regime has been found to be governed by surface roughness, in agreement with the previous studies. With an increasing surface roughness, the transition is shifted to higher values of $U\eta$. Additionally, the roughness does not influence the friction coefficient in the full-film EHL regime.

4. References

[1] Sadowski, P., Stupkiewicz, S., "Friction in lubricated soft-on-hard, hard-on-soft and soft-on-soft sliding contacts", Tribol. Int., 129, 2019, 246-256.

[2] Stupkiewicz, S. et al., "Finite deformation effects in soft elastohydrodynamic lubrication problems", Tribol. Int., 93, 2016, 511-522.

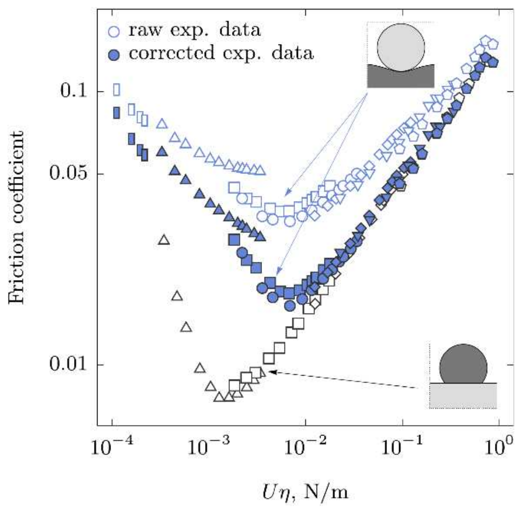

Figure 1: Friction coefficient as a function of $U\eta$: raw experimental data (empty markers) and data corrected for hysteretic losses (filled markers) for the H/S configuration for the load $W = 5.13$ N. The results corresponding to the S/H configuration are provided as a reference (black empty markers).