HYSTERETIC LOSSES IN LUBRICATED SLIDING SOFT CONTACTS

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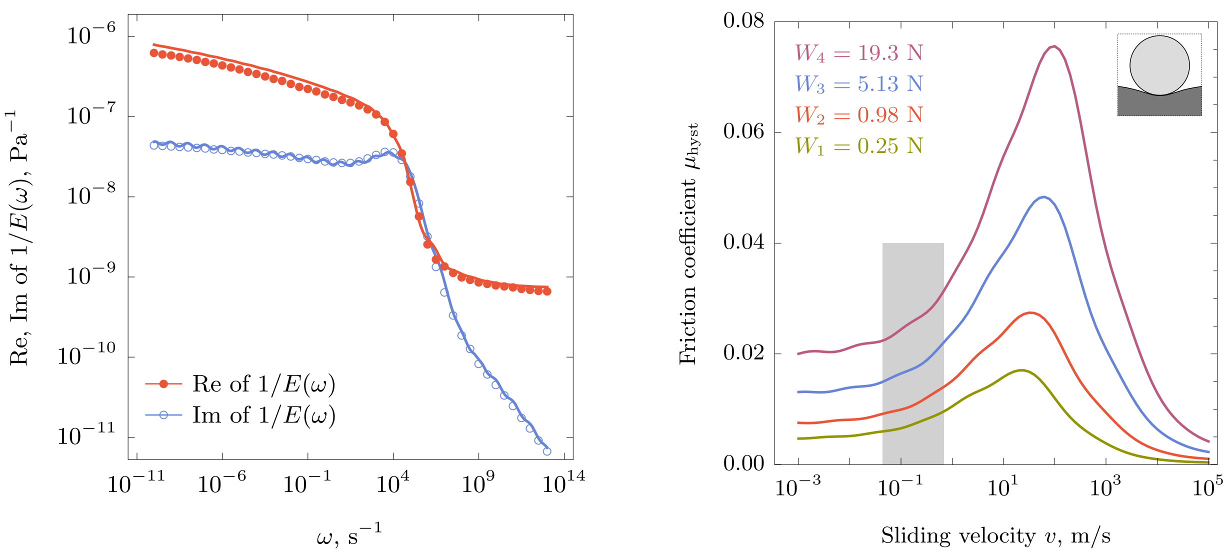
1. Introduction

The use of polymeric materials in various engineering applications, e.g., wipers, tyres, seals, has resulted in an increasing number of studies of their contact behaviour. The lubricated elastomeric contacts usually operate in special conditions which can be classified as the soft-elastohydrodynamic lubrication regime (soft-EHL). As one or both contacting bodies are highly compliant, relatively low contact pressures may lead to large deformations which in turn influence fluid flow. The soft-EHL regime is also characteristic for many biotrobological contacts, e.g., synovial joints, eye-eyelid contact, oral processing of food, which results in an increased interest in lubricated soft contacts.

Motivated by the applications mentioned above, we have performed a series of friction measurements using a home-made ball-on-disc tribometer [1]. NBR rubber and steel were used to produce elements of the tribo-pair. Three types of the ball-on-disc set-up, namely soft-on-hard (S/H), hard-on-soft (H/S) and soft-on-soft (S/S), have been examined. The friction coefficient has been investigated in lubricated contact conditions for varied sliding velocities and normal loads high enough to cause finite deformations, recently studied in soft-EHL [2].

2. Hysteretic friction coefficient

In our experimental set-up, the ball, fixed in a grip and loaded by a normal force, slides on a lubricated flat disc, and the friction force is measured. In the H/S and S/S configurations, the contact zone is moving with respect to the rubber disc. The disc is thus repeatedly deformed, and this is associated with hysteretic losses in the viscoelastic rubber material. Accordingly, the measured friction force comprises then two components: the interfacial friction force and the hysteretic friction force. In the S/H configuration, there is no hysteretic friction because the rubber ball, once loaded by a constant load, does not deform any more. To estimate the



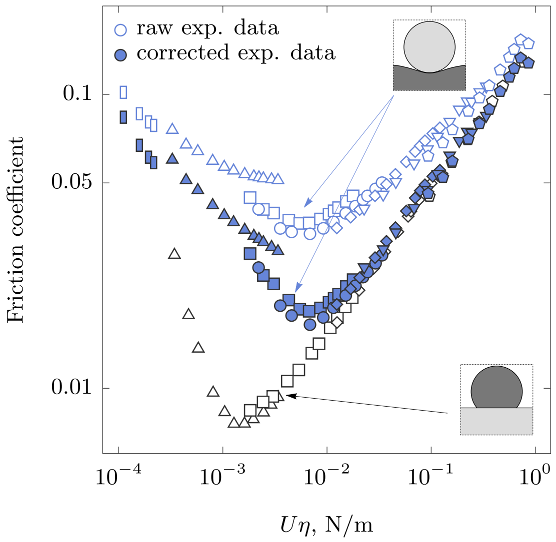
(a) (b)

Figure 1: (a) Real and imaginary part of the complex function $1/E(\omega)$ for NBR rubber: transformed DMA measurements (markers) have been fitted by the Prony series (solid lines). (b) Hysteretic friction coefficient $\mu_{\rm hyst}$ as a function of the sliding velocity v and load W for the H/S configuration.

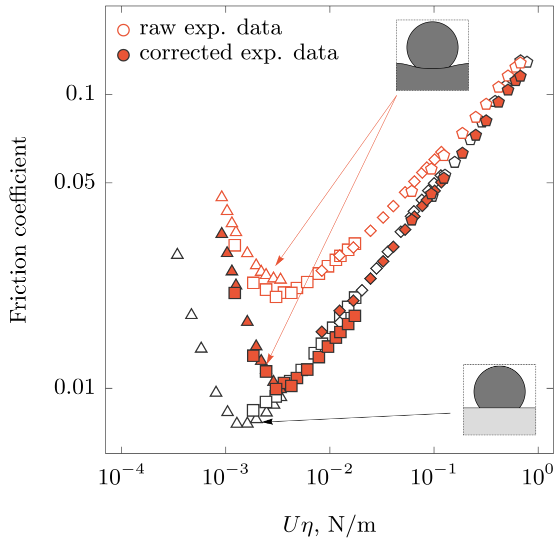
hysteretic friction coefficient μ_{hyst}, NBR rubber has been characterized via DMA measurements, cf. Fig. 1a. After extrapolating the experimental data with use of the Prony series, the Persson's model [3], see also [4], has been used. Results of μ_{hyst} as a function of the sliding velocity v for the H/S configuration and all loads W used in the experiment are shown in Fig. 1b. In the whole range of sliding velocities, the hysteretic friction coefficient increases with increasing load.

3. Correction for the hysteretic losses

Results of friction measurements in lubricated contact conditions are usually visualized via so-called Stribeck curves, representing the dependence of the friction coefficient on $U\eta$, the product of the entrainment speed U and lubricant viscosity η. Fig. 2 shows the experimental data for all considered configurations and for the normal load $W = 5.13\,\text{N}$. Transition from the full elastohydrodynamic to mixed lubrication regime is well captured. The estimated hysteretic friction coefficient characteristic for the H/S and S/S configurations has been used for extraction the interfacial friction, results of which are shown in Fig. 2 with filled markers. As a reference, the corresponding results for the S/H configuration are also included in Fig. 2. It can be seen that, upon correction for the hysteretic losses, the friction coefficient in the elastohydrodynamic regime (see the increasing branch corresponding to higher values of $U\eta$) does not depend on the configuration.



(a)



(b)

Figure 2: Friction coefficient as a function of $U\eta$: raw experimental data (empty markers) and friction coefficient corrected for hysteretic losses (filled markers) for the H/S configuration (a) and S/S configuration (b) for the load $W = 5.13\,\text{N}$. Results corresponding to the S/H configuration are provided as a reference.

References

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