Simulation of Rubber Friction: Influence of Surface Texture

Fabian Kaiser[1)*], Andreas Gropp[1)], Yohei Sakai[2)], and Ravindrakumar Bactavatchalou[1)]

[1)] Freudenberg Technology Innovation SE & Co. KG, Höhnerweg 2-4, 69469 Weinheim, Germany
[2)] NOK Corporation, 4-3-1 Tsujido-shinmachi, Fujisawa-shi, Kanagawa, Japan
*Corresponding author: fabian.kaiser@freudenberg.com

In the last two decades, several models for the simulation of rubber friction have been developed. Similarly, contact mechanics methods, required to calculate the load sharing between the surface roughness asperities and the fluid film, have been established as well as experimentally validated. By coupling these models with a soft-EHL approach, the Stribeck-curve of lubricated rubber contacts can be simulated. Using this model, an analysis of the effect of surface texture and rubber material is presented.

Keywords (from 3 to 5 max): tribology, friction, simulation, rubber, lubrication

1. Introduction

Understanding the tribological behavior of rubber sliding against steel surfaces in lubricated condition is essential for many products, like elastomer seals in machinery. Figuring out which phenomena contribute to friction and wear in the different ranges of sliding velocities is crucial for improving the tribological properties of parts.

However, these phenomena can rarely be isolated in real parts like seals. This is where a carefully validated simulation model can be used to gain additional insight into the underlying mechanisms and thus help improving the friction or wear behavior of a rubber seal.

2. Methods

For the simulation of lubricated tribological contacts, one needs to cover all relevant lubrication regimes: elasto-hydrodynamics, mixed lubrication and boundary lubrication.

The contact mechanics (interfacial separation between the rubber and the counter face) are described using Perssons's theory [1]:

$$\bar{u} = \sqrt{\pi} \int_{q_0}^{q_1} dq\, q^2 C(q) w(q) \times \int_{p}^{\infty} dp' \frac{1}{p'} \left[\gamma + 3(1-\gamma) P_{p'}^2(q)\right] e^{-[w(q)p'/E^*]^2} \quad (1)$$

This method are coupled with an in-house EHL solver for rubber materials including flow factors according to Almqvist [2].

To couple the EHL model with the contact model for mixed friction, the normal load L_{total} is split in to a fluid and solid contribution:

$$L_{total} = L_{solid} + L_{fluid} \quad (2)$$

This model allows the simulation of the complete Stribeck curve of rubber steel contacts with only one free parameter: the friction coefficient $\mu_{boundary}$ of the boundary regime at very low sliding speeds which needs to be fitted to the experiments.

$$F_{friction} = \mu_{boundary} * L_{solid} + F_{friction,fluid} \quad (3)$$

3. Discussion

Three different NBR rubber materials (50, 70 & 90 ShA) are used with three different surface textures (Sq from 0.5 µm to 5.3 µm). These are sliding against a smooth steel disc in a pin-on-disc configuration lubricated with PAO oil.

It is shown that the material has only little influence on the sliding friction in any regime (boundary, mixed or hydrodynamic) for the analyzed system.

The rubber surface, however, shows a significant influence on the friction: The onset of mixed friction happens at much lower speeds for increasing roughness, in very good agreement with experimental results. Furthermore, no benefits of surface texturing are observed in the purely hydrodynamic regime at high speeds, contradicting the findings of simple hydrodynamic simulations without surface deformation.

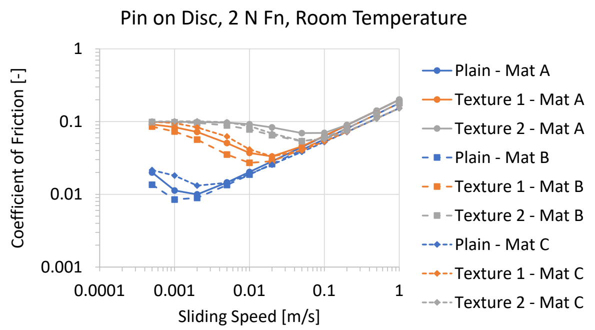

Figure 1: Simulated friction for three materials with three different surfaces

Our results show that lubricated rubber friction can be simulated very well, but the model needs to take into account the contact mechanics between rubber and the counter-face to correctly predict the experimental results.

4. References

[1] Yang, C., Persson, B.N.J., “Contact mechanics: contact area and interfacial separation from small contact to full contact”, J. Phys.: Condens. Matter, 2008 (20).

[2] Almqvist, A., “ On the effects of surface roughness in lubrication”, PhD-Thesis, Luleå University of Technology, 2006