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

Lubricated Friction and Mixed-EHL Transition in Patterned Soft Surfaces

Anand Jagota[1,2,*], Nichole Moyle[2], Hao Dong[2], Haibin Wu[3], Constantine Khripin[4], Chung-Yuen Hui[3]

[1]Department of Bioengineering, [2]Department of Chemical and Biomolecular Engineering, Lehigh University,
[3]Department of Mechanical and Aerospace Engineering, Cornell University
[4]Michelin North America Inc.
* Corresponding author, anj6@lehigh.edu

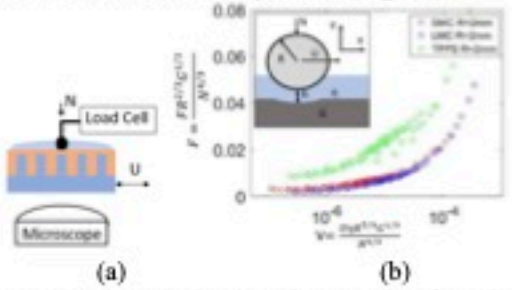
We will describe recent work on lubricated friction of two types of near-surface patterned soft solids. In the first, the surface is patterned by stripes of stiff and compliant regions. We show strong enhancement of sliding friction in the patterned samples compared to homogeneous controls. We interpret extra dissipation to be due to periodic vertical motion of the indenter as it slides over regions with periodically varying contact stiffness; this is supported by transient EHL simulations. The second set of samples contain an embedded subsurface mesh. In this case we also observe sliding friction enhancement but due to a different mechanism – we propose it is because of early transition from EHL to mixed regimes. We will conclude with a discussion of ongoing work on what controls transition from EHL to mixed lubrication in soft solids.

Keywords (from 3 to 5 max): tribology, soft solids, EHL-mixed transition

1. Introduction & Discussion

The ability to alter and control lubricated sliding behavior in compliant materials can benefit a number of mechanical and biological systems. Mechanical systems include anti-slip safety shoes[1], tires sliding on a wet road[2], and elastomeric seals[3] while biological systems include contact lenses[4] and wet skin contact applications.

Recently, a two-phase periodic structure (TPPS) was developed using two elastomers with varied modulus to obtain enhancements (where by enhancement we mean increases) in the lubricated sliding friction of the system [5]. This structure (Fig. 1a) produced enhancements in the elastohydrodynamic lubrication (EHL) regime through an additional mechanism for dissipation of energy as the system alternated between sliding on regions of two different compliances (Fig. 1b).

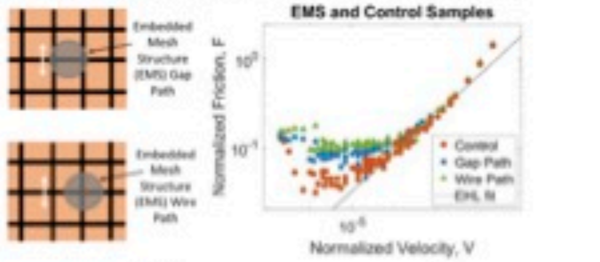


(a) (b)

Figure 1. (a) Schematic drawing of patterned surface. (b) Plot of normalized friction force and normalized velocity for experiments with R=2mm indenter using EHL theory for scaling. The data show how the structured surface has systematically larger sliding friction.

There are several ways in which a structure could be developed to produce a spatially varying contact compliance, raising the question if similar behavior would be observed for such alternate structures. In subsequent work, an embedded mesh structure (EMS) was developed which also produced enhancements in the lubricated sliding friction of the system; however, the mechanism of enhancement appears to be different[6].

Typically, at low loads and high velocities and viscosities, a soft solid system operates in the elastohydrodynamic lubrication regime. As load is increased and the velocity and/or viscosity are decreased, a system will next enter the mixed lubrication regime. We show that in the EMS structure the transition from EHL to mixed regime occurs at higher velocity (Fig.2).



(a) (b)

Figure 2. (a) Schematic drawing of embedded mesh structure. (b) Normalized sliding friction as a function of normalized velocity showing the transition from EHL to mixed regime.

2. Acknowledgements This work was supported by the National Science Foundation of the USA through the grant LEAP-HI: CMMI-1854572.

3. References

1. Manning, D. P.; Jones, C.; Rowland, F. J.; Roff, M. The Surface Roughness of a Rubber Soling Material Determines the Coefficient of Friction on Water-Lubricated Surfaces. *J. Safety Res.* **1998**, *29* (4), 275–283.

2. Harrin, E. Low Tire Friction and Cornering Forces on a Wet Surface. *Wear* **1959**, *2* (6), 492.

3. Muller, H. K. *Fluid Sealing Technology: Principles and Applications*; Routledge, 1998.

4. Sawyer, W. G.; Dunn, A. C.; Tichy, J. A.; Uruen, J. M. Lubrication Regimes in Contact Lens Wear during a Blink. *Tribol. Int.* **2013**, *63*, 45–50.

5. Moyle, N.; Wu, H.; Khripin, C.; Bremond, F.; Hui, C.-Y.; Jagota, A. Enhancement of Elastohydrodynamic Friction by Elastic Hysteresis in a Periodic Structure. *Soft Matter* **2020**, *16*, 1627–1635.

6. Moyle, Nichole, Hao Dong, Haibin Wu, Constantine Y. Khripin, Chung-Yuen Hui, and Anand Jagota. "Increased Sliding Friction of a Lubricated Soft Solid Using an Embedded Structure." *Tribology Letters* 70, no. 1 (2022): 1-12.