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

Transition between mixed lubrication and elastohydrodynamic lubrication with cavity-textured surfaces

Yann Alexandre[1)*], Denis Mazuyer[1)] and Juliette Cayer-Barrioz[1)]

[1)] Laboratoire de Tribologie et Dynamique des Systèmes, Ecole Centrale de Lyon, CNRS UMR5513, France
*Corresponding author: yann.alexandre@ec-lyon.fr

The friction in passenger car engines plays a crucial role in fuel overconsumption. One way to reduce friction is to use textured surfaces with low viscosity lubricants. In this framework, we were interested in understanding the effect of cavity texturing on friction in mixed and elastohydrodynamic lubrication. Friction level obtained from Stribeck experiments were compared with data for a smooth surface. Friction mechanisms in each regime and the transition between the regimes were analyzed and discussed.

Keywords: EHL, Low viscosity lubricants, Mixed lubrication, Surface texturing, Surface topography

1. Introduction

The presence of texturing such as cavity, affects the pressure field and induces local film thickness variations which can be used to improve the lubricant efficiency in the contact [1]. The aim of our work was to deepen the understanding of the role of cavity texturing on the friction force in mixed and EHL regimes. We focused in particular, on the cavity pattern induced-shift of the transition between these regimes.

2. Methods

2.1. Friction tests

Traction and Stribeck experiments were performed on a ball-on-disc MTM tribometer with simultaneous tangential and normal force measurements. Balls of radius 9.525 mm and discs were made of steel. To avoid any additive chemical effect, we used a classical Group III base oil with a viscosity of 22mPa.s at room temperature. The theoretical viscous friction under pressure was identified using several traction experiments. In our experiments, we chose a representative contact pressure of the piston-ring/cylinder contact, such as 310 MPa. Finally, we used a moderate entrainment speed for the Traction (0.2 m/s) and moderate SRR for the Stribeck (25%) to minimize the temperature increase and the surface wear at low speed.

2.2. Surface topographies

The surface topographies were measured using a Brüker interferometer. The RMS roughness of smooth surfaces was around 15 nm. Six cavity patterns were manufactured on the balls by Femtosecond Laser Surface Texturing. The cavity diameters ϕ_{cav} ranged from 20 to 40 µm, the cavity depths h_{cav} from 0.15 to 4 µm and the dimple density T_S from 2 to 25 %. Typical topography characterization is illustrated in the inset in Figure 1.

2.3. Results

The shear stress of the Stribeck experiments and the viscous friction were plotted versus the entrainment product $\eta_0 U_e$ to take into account the effect of the room temperature fluctuations on the viscosity. The mixed/EHL regime transition were identified according to a friction based definition of the mixed lubrication [2,3]. An example of the results is reported in Figure 1.

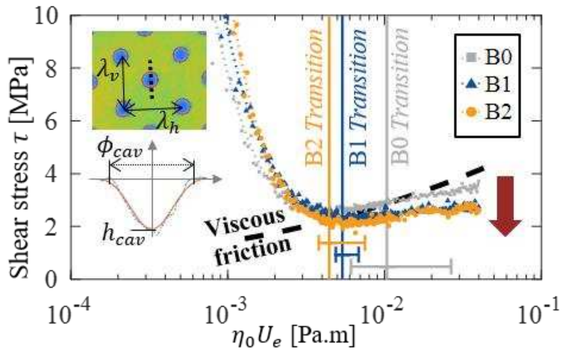

Figure 1: Stribeck curves for the smooth surface (B0) and two cavity patterns with diameter of 40 µm, depth of 0.15 µm and dimple densities of 25% (B1) and 7%. (B2). The inset shows the B1 topography characterization.

3. Discussion

Figure 1 shows that the two textured surfaces present a similar friction response as the smooth surface. However, a detailed analysis showed that in mixed regime, with a slightly higher roughness at the edge of the cavities, the number of asperity contacts increase leading to an increase in friction in this regime. In contrast, the EHL friction was lower in the case of the textured surfaces: the shallow cavities induce a local increase in the film thickness [1], inducing a decrease in viscous friction. This seemed to be validated by traction results.

In addition, the shift in the transitions to lower $\eta_0 U_e$ also confirmed this interpretation.

4. References

[1] Mourier, L et al., Proceedings of the Institution of Mechanical Engineers, Part J: Journal of Engineering Tribology, 2010, 224(8), 697-711.

[2] Touche, T. et al., Tribology letters, 2016, 63(2), 25.

[3] Bonaventure, J. et al., Tribology letters, 2016, 64(3), 44.