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Surface Chemistry and Friction of Organic Friction Modifiers as Self-Assembled Boundary Layers

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Interactions between organic friction modifiers and surface chemistry influence lubricated interface tribological behavior. The formation and the friction response of self-assembled Glyceryl Oleate boundary layers, on Cobalt and Carbon surfaces, were investigated using the SFA-ATLAS Molecular tribometer. Results showed a higher surface coverage ratio on Carbon surfaces (≈1 vs ≈0.63 on Cobalt surfaces). Friction response obeyed Amontons-Coulomb law on Carbon surfaces, while for Cobalt surfaces, friction increased non-linearly with the normal force. Friction dynamics with the sliding velocity also differed as a function of the surfaces. These friction variations were discussed in terms of molecular organization and surface affinity.

Keywords boundary regime, nanotribology, surface forces, organic friction modifiers

1. Introduction

Chemically-controlled surfaces are known to have a drastic impact on organic friction modifiers (OFMs) surface coverage and friction performance, especially in a predominant boundary lubrication regime [1][2]. The aim of this study was to highlight the effect of Carbon surface vs metallic Cobalt surface at iso-roughness on the molecular organization and the friction response of Glyceryl Oleate self-assembled boundary layers.

2. Methods

2.1. Liquids and Surfaces

A solution of 3%$_{w/w}$ of Glyceryl Oleate in a Group III base oil, with a bulk viscosity of 28 ± 1 mPa.s at 24° C was provided by Total. Fused silicate glass spheres with a radius of about 2.1 ± 0.05 mm were prepared prior to the tests. Planes were made of <111> polished silicon wafers. Both spheres and planes were coated with a 3 nm thick Cobalt layer, which made **Cobalt Surfaces**. Adding a 3 nm thin sputtered Carbon layer to the Cobalt covered surfaces made the **Carbon Surfaces**. AFM and Brüker interferometry profilometer scanning gave a root mean square roughness less than 0.5 nm on both types of surfaces tested.

2.2. Experimental Setup

A detailed description of the Surface Force Apparatus – ATLAS molecular tribometer and of the dynamic and quasi-static protocols can be found in [3]. Squeeze and friction experiments were carried out at room temperature, up to a contact pressure of 40 MPa, for sliding velocities ranging from 0.5 to 500 × 10^{-10} m /s.

3. Results and Discussion

The boundary films were thicker on Carbon surfaces: initial squeeze measurements showed a self-assembled adsorbed layer thickness of ≈ 4.5 × 10^{-9} m on Carbon surfaces and ≈ 3.1 × 10^{-9} m on Cobalt surfaces. This resulted in a higher coverage rate on Carbon surfaces, indicating the existence of a higher affinity between the Glyceryl Oleate molecules and the Carbon sputtered surfaces.

Friction history figures showed that, after running-in cycles, friction level continually increased on Cobalt surfaces while it decreased and then remained stable on Carbon surfaces, confirming the relatively higher affinity hypothesis. This friction evolution was correlated with the film thickness variation. Friction laws as a function of the sliding speed exhibited opposite trends: on Carbon surfaces, the sheared interface established an increasing friction with speed, while the friction response for the Cobalt surfaces case decreased with increasing speed, as shown on figure 1.

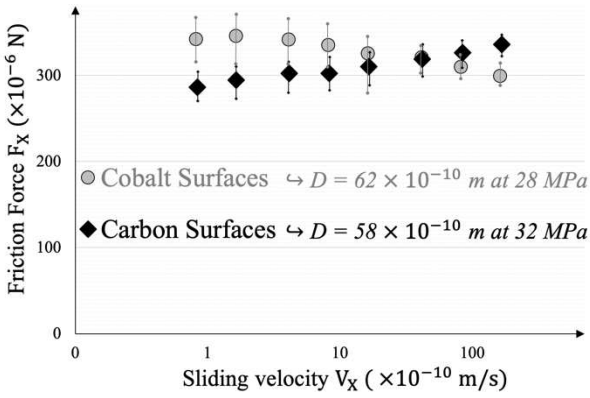

Figure 1 : *The friction force* F_X *against the sliding velocity* V_X *for the Glyceryl Oleate adsorbed boundary layers on both surfaces, after running-in friction cycles.* D *= Interface thickness.*

In response to increasing load, the friction response of squeezed boundary layers formed on Cobalt surfaces increased non-linearly, due to a molecular disorganization caused by the shear stress. Contrarily, the friction response in respect to increasing load on Carbon surfaces followed Amontons-Coulomb law. The shear mechanisms were correlated to the boundary layer thickness and thus governed by the molecular organization and affinity on each surface.

4. References

[1] Fry, B. M. et al., Langmuir 36, 5 (2020).
[2] Ratoi, M. et al., RSC Advances 4, 4278 (2014).
[3] Crespo, A. et al., Tribology Letters 65, 138 (2017).