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Oil-Compatible Polymer-Brush Coatings for Lubrication

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1. Introduction

The use of polymer brushes for lubrication in aqueous media is well documented [1], and to some extent bio-inspired [2]. The role of the brushes appears to be in separating the sliding surfaces, thanks to the osmotic effects resisting brush compression, and the entropic effects that withstand interdigitation of the polymer chains

While the use of water as a base fluid is in many ways very attractive, the fact remains that water is unsuitable for use at elevated temperatures, and can lead to corrosion problems in steel-based machinery. Moreover, the very low pressure-coefficient of viscosity for water means that lubricating systems relying on elastohydrodynamic lubrication need to be redesigned for use with water-based lubricants. In other words, for water to be used in practice, correspondingly modified concepts of machine design need to be developed. While this is clearly an interesting future possibility, the potential energy savings of using polymer brushes in existing oil-lubricated machinery are also worthy of investigation.

In the present work, we have extended the use of polymer-brush-based lubrication to an oil environment, and we show that the base-fluid properties play an important additional role in protecting the brushes from wear at low speeds.

2. Experimental

Poly(dodecyl methacrylate) brushes were grown on silicon surfaces and borosilicate glass spheres by means of atom-transfer radical polymerization [3]. Their dry thickness was characterized to be around 250 nm, by means of ellipsometry.

Tribological testing was carried out in reciprocating-arc, pin-on-disk geometry in a microtribometer between the coated spheres and flats in a wide variety of base fluids, including hexadecane (kinematic viscosity ca. 4 cSt), and commercial, additive-free lubricating fluids (kinematic viscosities ranging from 36 to 2,200 cSt at 20 °C) of two general types (petroleum fractions PF and ester oils EO).

3. Results and discussions

The frictional behavior of the bare and coated substrates was determined, and plotted as a "Stribeck-like" curve, as shown in Figure 1. It is to be noted that the bare-bare results show the typical shape of such a curve—normally explained in terms of the relationship between the roughness of the hard surfaces and the hydrodynamic film thickness. The coated-coated data, on the other hand, show far lower friction at low speeds, an extended hydrodynamic regime, and a significant lack of frictional increase at low speeds. This behavior can be interpreted as being due to the elimination of hard-hard contact in the presence of the brushes, meaning that lubrication at low speeds occurs within the fluid film at the brush-brush interface [4].

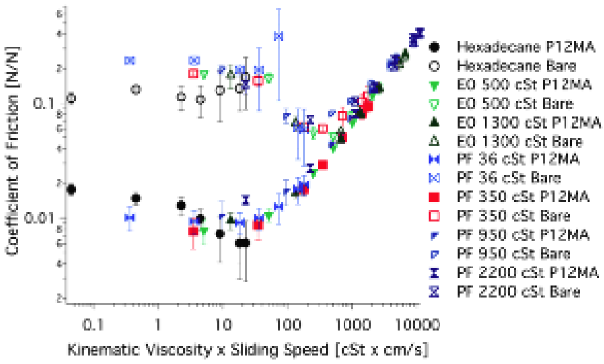

Figure 1: *Stribeck-like plots at constant load (20 mN) obtained for nine different base fluids for bare–bare SiO_2-borosilicate glass ball (empty markers) and for double-sided 250 nm (dry thickness) P12MA brush–brush functionalised tribological contacts (filled markers). Each marker represents the average COF of 20 reciprocating cycles [from 4]*

The viscosity of the lubricating oil appears to play a role in the wear-resistance of the brushes. This is thought to be due to the biphasic nature of the brush-viscous oil system, which is analogous to mechanisms that have been described for cartilage [5]. The resistance to movement of the viscous oil through the brush structure appears to provide a load-supporting effect, which in turn protects the brushes from wear. This behavior has been quantified by means of wear tests, as well as investigations by nanoindentation and the surface forces apparatus.

References

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