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Influence of lubricant polarity on friction performance between hydrophobic and hydrophilic surfaces

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1. Introduction

In the previous studies, researchers suggest that interfaces with different wetting abilities have varying impacts on friction performance[1-3]. In our experiments[4] using polytetrafluoroethylene (PTFE) as the hydrophobic layer and glass lenses as the hydrophilic layer, we found that the combination of a moving hydrophobic layer and a stationary hydrophilic layer exhibited the lowest and most stable friction coefficient performance under the pure water full lubricant conditions.

In this study, the unique lubrication characteristics that develop in contact areas between a hydrophilic surface and a hydrophobic surface are further investigated with changing polarity of lubricant.

2. Experiment procedure

Figure 1 shows the schematic of the test rig used in this study. Figure 2 shows the schematic of the contact configuration. A point contact area was created between a stationary convex glass lens with a curvature of 77.85 mm with a hydrophilic surface and a rotating PTFE coated disc. The film thickness between the lens and disc was measured using white light optical interferometry, and was captured by CCD camera.

All samples used in the experiment were cleaned with acetone prior to the experiment, Table 1 shows some other experimental conditions.

Deionized pure water, alkanes, and fatty alcohols were used as lubricant to investigate the effect of lubricant polarity. Table 2 shows the contact angles of all these various liquids on hydrophobic surfaces. Experiments were conducted with varying sliding speeds, moisture content and so on.

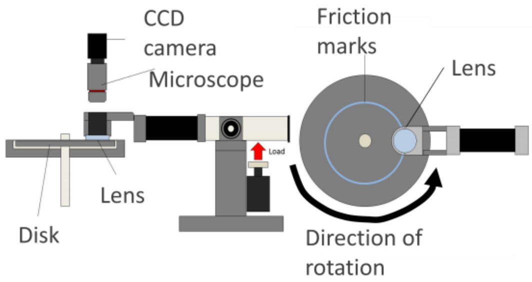

Fig. 1 Schematic diagram of test rig

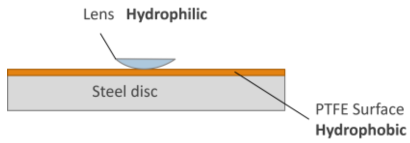

Fig. 2 Schematic diagram of contact configuration

Table 1 Experiment conditions

Disk		Lens Curvature Radius, mm	Load, N	Contest Radius, mm	Maximum Hertzian Pressure, MPa	Sliding Speed, mm/s	Temperature, °C
Diameter, mm	Surface roughness, µm						
70	0.14	77.85	10	0.21	72.2	10 to 400	27

Table 2 Molecular weights and contact angles of lubricants on hydrophobic surfaces

	Molecular weight	Contact angle, deg
Water	18.0	94.3
Octane	114.2	11.0
Dodecane	170.3	26.8
Ethanol	46.1	20.8
Hexanol	102.2	36.3
Octanol	130.2	43.4

3. Experiment Results

3.1 Effect of polarity on lubrication performance

Figure 3 shows variations in friction coefficient at different sliding speeds for alkanes. When alkanes of non-polar liquids were used, the friction coefficients were even higher than those in dry conditions with around 0.04 shown as the gray line. However, it was found that the friction coefficient decreased with increasing molecule length. The friction coefficients were 0.1 for octane (C_8H_{18}) and 0.07 for dodecane ($C_{12}H_{26}$).

Figure 4 shows variations in friction coefficient at different sliding speeds for fatty alcohols. When fatty alcohols of polar liquids were used, although the friction coefficient was high in a low sliding speed regime from 10 to 100 mm/s, the friction coefficient had similar low results as water lubricant condition in a high sliding speed regime from 150 to 500 mm/s.

3.2 Effect of water content in polar liquids on lubrication performance

To investigate further the influence of water on friction performance, we take ethanol as an example, as it can be mixed with water in any proportions. Pure ethanol of 30 ml was mixed with water of 30 ml, 60 ml, and 90 ml respectively. Figure 5 shows variations in the friction coefficient and contact angles of these solutions. As the water content in the solution increased, the contact angle of ethanol gradually increased. Compared to pure ethanol, ethanol-water mixtures exhibit smaller friction coefficient at a low sliding speed area regime from 10 to 100 mm/s. Although it was hard to directly measure the film thickness using optical interferometry as shown in Fig. 5, in which optical interferograms were shown for pure ethanol, these three solutions demonstrated smaller friction coefficient of around 0.01 to 0.02 in a high sliding speed regime from 200 to 500 mm/s than those for pure water and pure ethanol.

4. Conclusion

Some polar liquids exhibited low friction coefficients around 0.03 over the combination of hydrophobic and hydrophilic surfaces, whereas nonpolar liquids did not show such results. We believe that this low friction performance is related to the polarity of these liquids. Mixtures of ethanol and water decreased more the friction coefficient than those for pure ethanol and water.

Acknowledgment

PTFE coating on steel discs was conducted by Sumitomo Electric Industries, Ltd.

Reference

[1] A. Borruto, G. Crivellone, F. Marani: Influence of surface wettability on friction and wear tests, Wear, 222, 1 (1998) 57.

[2] K. Fukuda, S. L. Sheng, Z. A. Subhi: Tribological behavior of hydrophilic and hydrophobic surfaces in atmosphere with different relative humidity, Tribology Online, 14, 5 (2019) 353.

[3] J. Zhang, J. Tan, R. Pei, S. Ye, Y. Luo: Ordered water layer on the macroscopically hydrophobic fluorinated polymer surface and its ultrafast vibrational dynamics, Journal of the American Chemical Society, 143, 33 (2021) 13074.

[4] Zeyu Wang, Kota Kuga, Kazuyuki Yagi: Lubrication Characteristics of Water between Surfaces between Hydrophobic and Hydrophilic Surfaces, 9th International Tribology Conference, 26-PO-07 (2023).

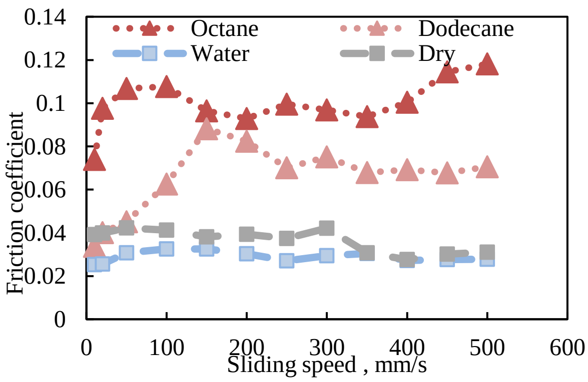

Fig. 3 Variations in friction coefficient for alkanes

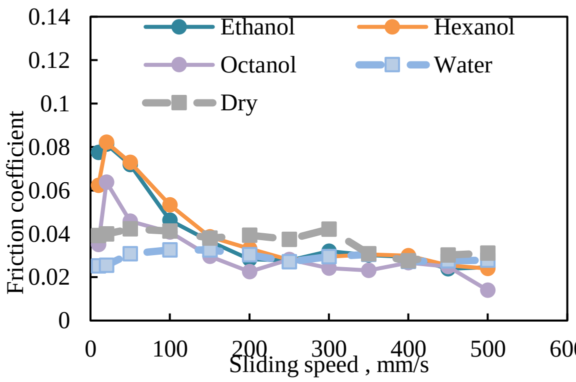

Fig. 4 Variations in friction coefficient for fatty alcohols

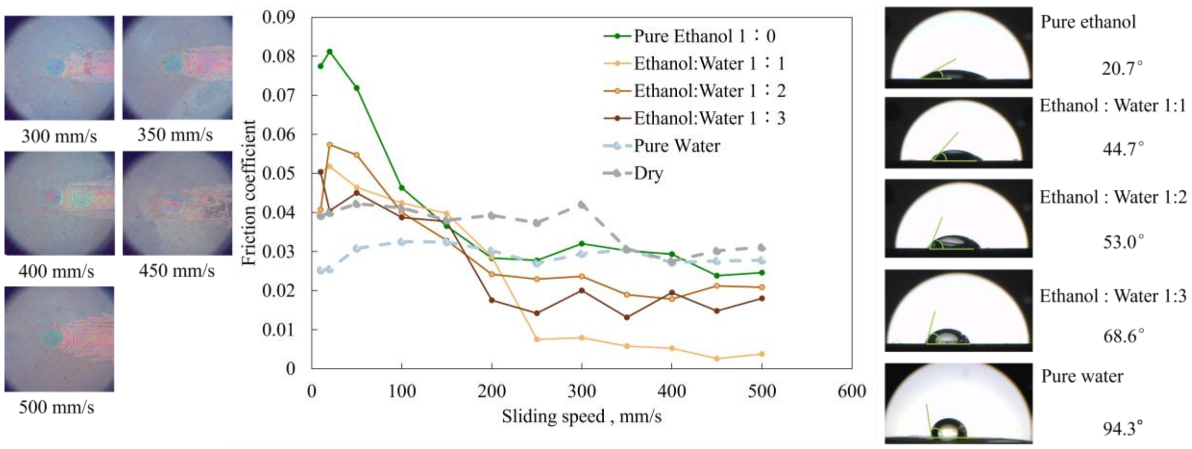

Fig. 5 The effect of water content in ethanol on variations in friction coefficient