Influence of Hydrogen Bond Network Formation on Lubrication Performance of Hydrophilic–Hydrophobic Surface Combinations: Analysis and Hypotheses

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1. Introduction

According to previous studies[1-3], researchers suggest that interfaces with different wetting abilities have varying impacts on friction performance. Regarding to our past experiments[4-5] , by pairing a rotating hydrophobic surface with a fixed hydrophilic counterpart, we observed remarkably low friction coefficients under full lubrication condition using polar liquids (specifically, water around 0.03, while ethanol, hexanol, and octanol ranged around 0.02–0.03), highlighting the effectiveness of polar functional groups in this interfacial configuration.

In this study, the effects of different combinations of hydrophilic and hydrophobic interfaces under lubrication of polar and non-polar liquids will be discussed to investigate the influence of polar functional groups and hydrogen bonding on friction performance.

2. Experimental procedure

Figure 1 shows the schematic diagram of the test rig used in this study. A point contact area was created between a stationary convex glass lens with a rotating disc. The experiment was carried out under 10N pressure and room temperature. All samples used in the experiment were cleaned with Hexane and Acetone prior to experiments. Deionized pure water, alkanes, and fatty alcohols were used as lubricants shown by Table 1. 2

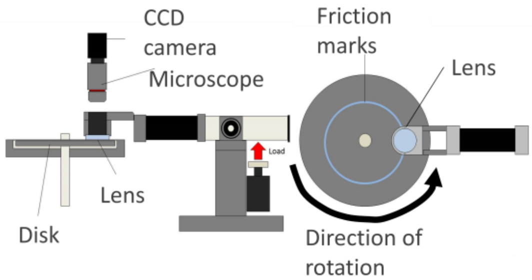

Fig. 1 Schematic diagram of test rig

Figure 2 presents the combinations of different hydrophilic and hydrophobic surface types, a 1-μm-thick PTFE-coated metal disc was used as the hydrophobic surface. PTFE-coated lenses and uncoated lenses were provided to serve as hydrophobic and hydrophilic surfaces, respectively.

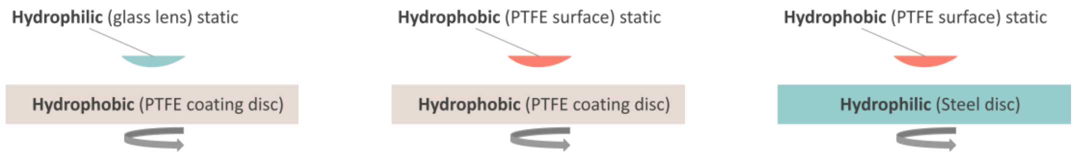

Fig. 2 Schematic diagram of contact configuration

Table 1 Molecular weights and molecular formula of lubricants

	Molecular weight, g/mol	Molecular Formula
Water	18.0	H_2O
Hexane	86.1	C_6H_{14}
Octane	114.2	C_8H_{18}
Dodecane	170.3	$C_{12}H_{26}$
1-Hexanol	102.2	$C_6H_{13}OH$
1-Octanol	130.2	$C_8H_{17}OH$
1-Dodecanol	186.3	$C_{12}H_{25}OH$

3. Results and discussion

Figures 2 and 3 show the friction coefficients obtained when using two hydrophobic surfaces in combination (Group 2) with alkanes or fatty alcohols as lubricants. When alkanes were used, the friction coefficient ranged between 0.04 and 0.06, which is clearly better than the results from our previous experiments using a fixed hydrophilic surface and a rotating hydrophobic surface (Group 1, where the stabilized friction coefficient for alkanes ranges above 0.06[4]). For the experiments with fatty alcohols, the friction coefficient tended to stabilize in the high-speed region, and we obtained extremely low friction coefficient values similar to those in our previous experiments (approximately around 0.02–0.03).

Figure 5 presents a comparison of two groups with different hydrophilic and hydrophobic surface combinations under dry and water-lubricated conditions. Under dry conditions, although the friction coefficient quickly increased to over 0.1 due to surface wear, we believe that the friction coefficient of the PTFE surface without lubrication should originally be around 0.05. However, when water was used as a lubricant, both groups exhibited extremely low friction coefficients, approximately in the range of 0.02–0.03.

Figure 6 shows the surface images before (left) and after (right) experiments when using Dodecanol, which involving extremely low friction coefficients. Typically, noticeable friction tracks appear on the PTFE surface after testing. However, when Dodecanol was used and an extremely low friction coefficient was achieved, this track was almost invisible to the naked eye. Similar results (approximately 0.01 or even lower) were previously observed in our experiments when varying the water content in ethanol[5].

According to some previous studies[6-7], under boundary lubrication conditions—especially in nanoscale contact environments—the influence of molecular structure may be amplified. In such cases, the layered stacking of molecular structures may play a positive role in the formation of hydroxyl group interactions and hydrogen-bond networks, which in turn may contribute to improved friction performance. During the presentation, some more experiment results and details for understanding the underlying mechanisms will be discussed.

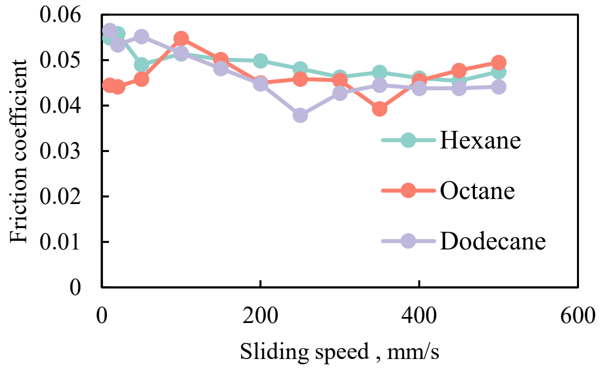

Fig. 3 Variations in friction coefficient for alkanes

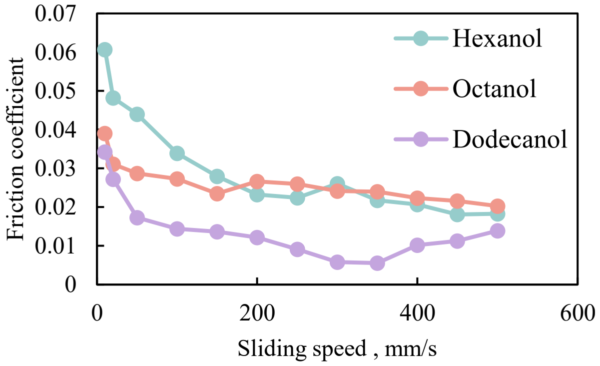

Fig. 4 Variations in friction coefficient for fatty alcohols

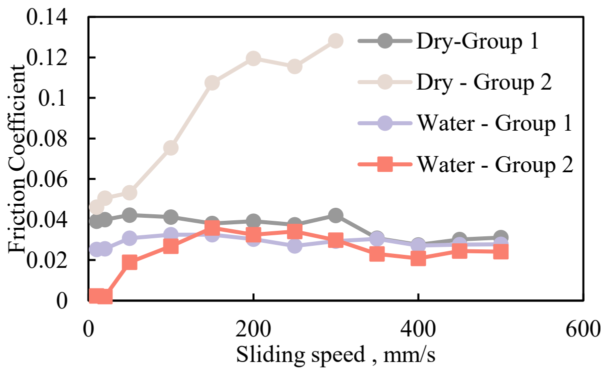

Fig. 5 Variations in friction coefficient for dry and water

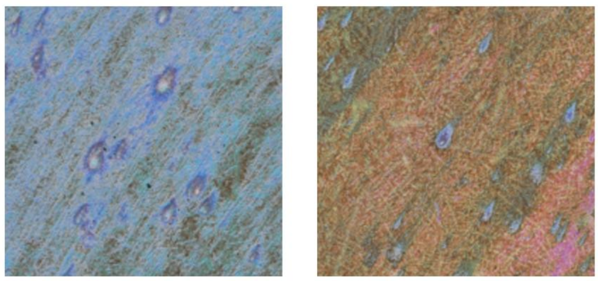

Fig. 6 Variations in surface roughness for Dodecanol

Acknowledgment

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