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# Synergistic Friction Reducing Effects between Surface Roughness and Adsorbed Molecular Film under Boundary Lubrication Regime

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## 1. Introduction

Active research regarding the effect of surface topography on tribological properties of mechanical components under boundary lubrication regime is currently in progress. In previous study by the authors, it has been reported that remarkable reduction in friction was observed at transvers direction of anisotropic roughness under low speed region where hydrodynamic action of the fluid is believed ineffective[1]. This is thought to be caused by generation of some additional pressure of the fluids at transverse roughness, called as microscopic elastohydrodynamic lubrication (micro EHL) effect, to support a load-carrying capability of an adsorption film formed from fatty acid-formulated oil. This also indicates that the friction reducing effect was premised on the existence of the adsorption film. However, fundamental research regarding the function of the adsorption film in generation of the additional pressure has been still lacking. In this study, friction characteristics of steel roughened with an anisotropic striped ground scar were investigated under the lubrication with several types of organic polymer-formulated oil to focus on difference of adsorption performance among multiple adsorptive polymers and existing oiliness agents.

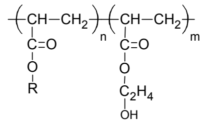
## 2. Experimental procedure

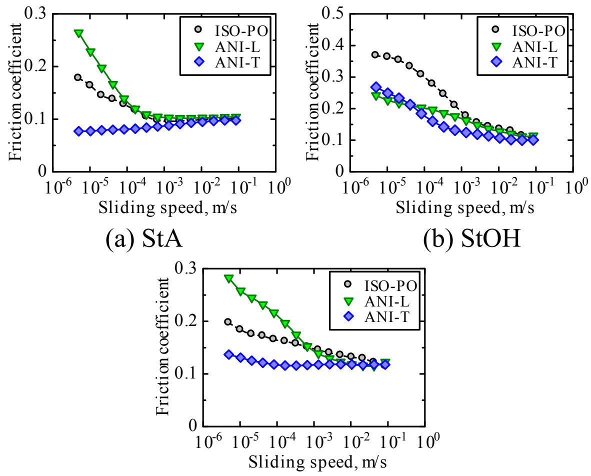
The friction measurements were carried out using the self-developed tribometer, following a running-in. For the measurement, the sliding speeds were changed stepwise from 5 µm/s to 8.5 cm/s. Two types of surface finishes were applied to the disk specimens. One is an isotropic polished surface (ISO-PO), and the other is an anisotropic striped surface (ANI) by a surface grinder with reciprocating motion. Two different roughness orientation were applied; the direction of the striped ground scar varied transverse (ANI-T) and longitudinal (ANI-L) with the sliding direction of the counter surface. Polyalphaolefin was used as additive-free base oil. Table 1 shows the lubricating additives used in this study.

## 3. Results and discussion

Figure 1 compared friction-speed characteristics among three different kinds of lubricating oils. Remarkable reduction in friction appeared at ANI-T in case of StA and PMA-OH1.2, while no marked differences were observed regardless of the roughness in case of StOH. Fatty acids such as StA usually form high-oriented molecular adsorption films on the friction surface, while StOH physically-adsorbs on the surface because hydroxyl groups have less adsorbability than carboxyl group does, and eventually it may easily desorbed in the low speed region. On the other hand, PMA-OH1.2 contains many hydroxyl groups that may act as adsorption sites and then multiple adsorptions of the groups to the surfaces promoted the formation of more homogeneous and hard-to-remove adsorption films than the single adsorption did. In Fig. 1, the differences in friction reducing effect among the additives may be ascribed to the differences in both the adsorbability and the density of the films. It is expected that the higher-density adsorption film formed, the higher osmotic pressure might be produced between the bulk fluids and the films. This thus suggests that reduction in friction resulted from the synergistic effects between micro EHL effects caused by roughness and the osmotic pressure derived from the high-density adsorption films.

Table 1 Sample additives

| CODE | Additives | Concentration |
|---|---|---|
| StA | Stearic acid | 10 mmol/kg |
| StOH | Stearyl alcohol | 1 mass% |
| DMODA | N,N-Dimethyloctadecylamine | 1 mass% |
| PMA-OH0 | Polymethacrylate functionalized with hydroxyl group | 0 mass%OH (Mw: 20000) |
| PMA-OH0.6 |  | 0.6 mass%OH (Mw: 20000) |
| PMA-OH1.2 | | 1.2 mass%OH (Mw: 20000) |




(a) StA (b) StOH (c) PMA-OH1.2

Figure 1 Comparison of friction characteristics among three different kinds of lubricating oils

## 4. Reference

[1] Masuko, M., Aoki, S. and Suzuki, A., "Influence of Lubricant Additive and Surface Texture on the Sliding Friction Characteristics of Steel under Varying Speeds Ranging from Ultralow to Moderate," Tribol. Trans., 48, 2005, 289-298.