7th World Tribology Congress, WTC 2022
July 10-15, 2022, Lyon, France

Interfacial Structure and Nanotribological Property of Adsorption Layer Formed by Ashless Antiwear Agent Composed of Dibasic Acid Ester Derivative

Naoki Yamashita[1)*], Tomoko Hirayama[1)]
Yutaro Shimizu[2)], Kazuhiro Oda[2)], Hideki Kawamoto[2)]

[1)] Department of Mechanical Engineering and Science, Graduate School of Engineering, Kyoto University, Japan
[2)] NOF CORPORATION, Japan.
*Corresponding author: tomoko@me.kyoto-u.ac.jp

An interfacial structure of adsorption layer formed by an ashless antiwear agent composed of dibasic acid ester derivative was investigated by neutron reflectometry. The thickness of the adsorbed layer formed by the antiware agent on iron surface was estimated to be over its monolayer-thickness. Nanoscale friction test using atomic force microscopy (AFM) revealed the antiwear agent has both characteristics of two molecules that compose the antiware agent. The antiware agent exhibited excellent tribological performance.

Keywords (from 3 to 5 max): antiware agent, nanotribology, neutron reflectometry

1. Introduction

The viscosity of lubricating oil has been reduced to improve a fuel efficiency of engine oil. However, low-viscosity-oil possibility causes wears of sliding surface due to the oil film shortage under high temperature environment. Although zinc-dialkyldithiophosphates (ZDDP) is an antiwear agent that has been used for a long time, it may generate zinc-derived sludge and reduce the efficiency of the emission gas system. Therefore, we have developed an ashless antiwear agent, which can exhibit similar performance to ZDDP and phosphate ester under high temperature keeping lower friction [1]. In this study, we report the results of evaluating the interfacial structure of the adsorption layer formed by the antiwear agent and its nanotribological properties.

2. Methods

2.1. Sample
The newly developed antiwear agent named AW-11 (0.1% in PAO) is a dibasic acid ester derivative, which has a carboxyl group and an ester group, and the carboxyl group is neutralized with a tertiary amine. In this research, monooleyl succinate (C18-SA; 0.05% in PAO) and dimethyl lauryl amine (C12-DA; 0.05% in PAO), which are the components of AW-11, were used. Palmitic acid (PA; 0.1% in PAO) was also used for comparison.

2.2. Neutron reflectometry
To evaluate interfacial structure of adsorption layer formed by antiwear agent on iron surface, neutron reflectivities was measured and analyzed. In this experiment, for convenience of synthesis, C18-SA in AW-11 was changed to deuterated-monooctane succinate (d-C8-SA), which has short alkyl chain. For comparison, deuterated-palmitic acid was also used.

2.3. Nanoscale friction test
To realize high-sensitive detection of tribological properties and in-situ observation of wear depth, an AFM was used. First, each lubricant was applied on iron surface prepared by sputtering on silicon chip. Second, friction test on 2 × 2 μm area for 100 times (256 lines per image) was performed at a scanning speed of 20 μm/s under 7000 nN load. Finally, 10 × 10 μm area including the 2 × 2 μm area was observed under 700 nN load to evaluate a wear depth.

3. Results and Discussion

Neutron reflectometry revealed the thickness of AW-11 (with C8 alkyl chain) was 2.0 nm which is larger than that of palmitic acid (1.8 nm), even though it was composed of shorter alkyl chain. This result indicates that AW-11 form a thicker adsorption layer, and its thickness is more than monolayer-thickness.
The CoF values obtained in nanoscale friction test are subitized in Fig.1. In the experiment with palmitic acid, 100-times-friction was not sufficient to stabilize CoF at a lower level. On the other hand, in the friction measurement with AW-11, CoF values obtained in 1st scan was lowest than other additives and exhibit lower value within 20th scan. Although C18-SA exhibit low friction, more frictions were required to stabilize CoF at a sufficiently low value. On the other hand, C12-DA has slightly high CoF in 1st scan, but several-times-friction is enough to stabilize CoF value at lower level. These results revealed AW-11 has the characteristics of both C18-SA and C12-DA. The wear depth measured without any additive was 4.6 nm while 3.2 nm in the measurement using AW-11. These results indicate AW-11 can form thicker adsorption layer and protect iron surface from wear, providing lower friction.

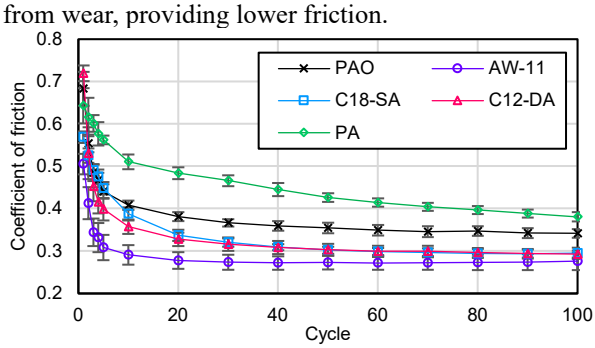

Fig. 1 Friction measurements using AFM.

4. References

[1] Shimizu, Y et al., "Development of new ashless antiwear agent composed of dibasic acid ester derivative," Tribology conference 2020 Beppu, Japan, Nov. 11-13th 2020.