Friction and Wear Characteristic of DLC Coatings with Different Hydrogen content Lubricated with Several Mo-containing Compounds and Their Related Compounds

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1. Introduction

Although MoDTC additive brings superior friction-reducing performance both for steel and DLC surfaces, it sometimes causes wear acceleration of the DLC surface [1,2,3]. This study confirms the wear acceleration of DLC surface by the MoDTC-formulated oil, and the friction and wear characteristic of DLCs lubricated with the other Mo-containing compounds and the related compounds are compared to understand the wear acceleration by MoDTC.

2. Experimental

2.1. Tribometer and test specimens

Three-ball on disk tribometer consisting of a DLC-coated disk and three 3/8" steel balls (JIS SUJ2) was used. Tribotests were carried out under 500 N for 6 h or 250 N for 3 h at 50°C.

Three types of DLCs with different hydrogen content were used. Nominal hydrogen content of DLCs were hydrogen-free, 10 at% and 30 at%; and they were named ta-C, a-C:10H, and a-C:30H, respectively. The DLC coatings were deposited on a tool steel (JIS SK85) with interlayers by a filtered-arc deposition for ta-C, an unbalanced magnetron sputtering for a-C:10H, and a plasma-enhanced chemical vapor deposition for a-C:30H. As a reference, tribology of non-coated tool steel specimen was also examined.

2.2. Base oil and additives

Poly-alpha-olefin (16.89 mm^2/s @ 40°C) was used for a base oil. Mo-containing additives used were molybdenum dioctyl dithiocarbamate (MoDTC), molybdenum dioctyl dithiophosphate (MoDTP), amine molybdate (MoAMN), and molybdenum phosphate (MoP). In addition, zinc dioctyl dithiophosphate (ZnDTP), zinc dibutyl dithiocarbamate (ZnDTC), dioctyl dithiophosphoric disulfide ($(DTP)_2$), and tricresylphosphate (TCP) were used as the related compounds for references.

3. Results and Discussion

Tribological properties of DLCs lubricated with oils containing MoDTC, ZnDTP and MoDTC+ZnDTP were examined to confirm the tribological characteristic of MoDTC. Although formulation of MoDTC showed good friction-reducing performance for every specimen, it accelerated the wear volumes of both hydrogen-containing DLCs. Formulation of MoDTC+ ZnDTP did not accelerate the wear.

To confirm the tribological characteristic of other Mo-containing compounds for DLCs, friction tests with several types of Mo-containing additives and their related compounds were carried out, and the results were compared (Fig. 1).

DLC surfaces after friction test were analyzed by Auger electron spectroscopy and X-ray photoelectron spectroscopy. When hydrogen-containing DLCs were lubricated with MoDTC, MoDTP, and MoDTC+ZnDTP, it was observed that wear of hydrogen-containing DLCs increased with increase in the formation ratio of MoO_3/MoS_2 on the friction surface. Since the formation of MoO_3 did not always bring wear acceleration, it could not be confirmed that the formation of MoO_3 directly related to the wear acceleration of hydrogenated DLCs.

The action of the other effects, such as the formation of phosphorous-containing protective layer and adsorbed molecular layer, etc. should be taken into consideration.

4. References

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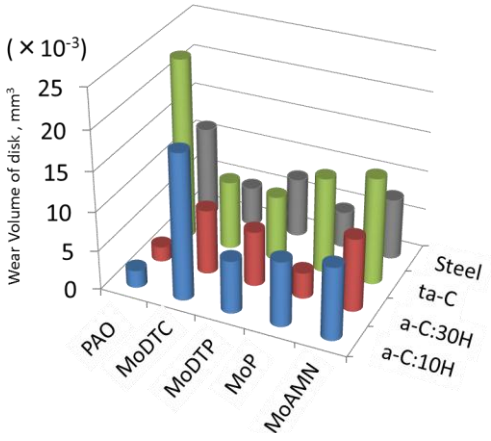

Fig. 1 Wear volume of disks