Tribological Properties of tetrahedral amorphous-Carbon(ta-C) in Lubricants Containing Phosphonate Ester Additive

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Diamond-like carbon (DLC) films provide low friction and high wear resistance. In particular, tetrahedral amorphous-Carbon (ta-C) film has shown ultralow friction behavior under boundary lubrication with an organic friction modifier (FM), such as glycerol mono-oleate (GMO). Also, phosphate esters are widely used as anti-wear additives under boundary lubrication. In this research, we attempted to achieve coexistence of low-friction and anti-wear properties by using additives with GMO-derived structure and phosphonate ester structure. The results of roller-on-disk friction tests in ta-C/ta-C tribo-pair showed that phosphonate ester additive provided ultralow friction, comparable to GMO, and better anti-wear properties than GMO.

Keywords (from 3 to 5 max): DLC, ta-C, additive, boundary lubrication, ultralow friction

1. Introduction

Diamond-like carbon (DLC) films provide low friction and high wear resistance. In particular, tetrahedral amorphous-Carbon (ta-C) film has shown ultralow friction behavior under boundary lubrication with an organic friction modifier (FM), such as glycerol mono-oleate (GMO) [1]. Also, phosphate esters are widely used as anti-wear additives under boundary lubrication. However, when FM is used in combination with phosphorus-based anti-wear additives, it has been found that its original performance is not achieved due to competitive adsorption [2]. In this research, we attempted to achieve coexistence of low-friction and anti-wear properties by using additives with GMO-derived structure and phosphonate ester structure.

2. Methods

In order to clarify tribological properties of ta-C in lubricants containing phosphonate ester additive, Roller-on-Disk friction tests were conducted.

2.1. Materials and lubricants

Steel roller (φ=5 mm and l=4.2 mm, AISI52100) and disk (φ=22.5 mm and t=4 mm, AISI52100) coated with ta-C films were used as the test specimens. The base oil used in this research was poly alpha olefin (PAO). GMO and three types of phosphonate ester additives (primary dialkyl dihydroxypropyl phosphonate (pri-DDHP), secondary dialkyl dihydroxypropyl phosphonate (sec-DDHP), and secondary dialkyl monohydroxypropyl phosphonate (sec-DMHP)) were added to the base oil. The structure of these additives is shown in Fig. 1.

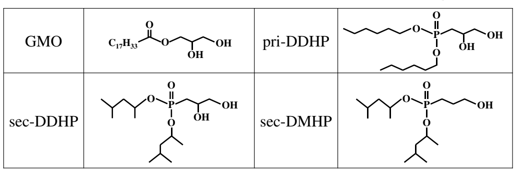

Fig. 1 Structural formula of additives

2.2. Friction test conditions

The test conditions were a normal load of 5 N (corresponding to a maximum Hertzian contact pressure of 200 MPa), a sliding speed of 0.099 m/s, a temperature of 80 ºC, and a test duration of 3600 s. The calculated lambda ratio was 0.12 for the test conditions. This means that operating lubrication regime was boundary lubrication.

3. Results and Discussion

The friction behavior of ta-C film lubricated with PAO and PAO+additives are shown in Fig. 2. For the pure PAO, the friction coefficient decreased only to approximately 0.05, whereas the PAO+additives showed ultralow friction of approximately 0.01-0.02. It is considered that the additives formed molecular layers on ta-C surface that led to ultralow friction [1]. Fig. 3 shows wear behavior of ta-C film lubricated with PAO and PAO+additives. The specific wear rate for lubrication with PAO +GMO was slightly lower than with pure PAO. On the other hand, PAO+phosphonate ester showed high performance with regard to anti-wear properties. These results suggest that the phosphonate ester additives exhibit ultralow friction and high wear resistance in ta-C lubrication.

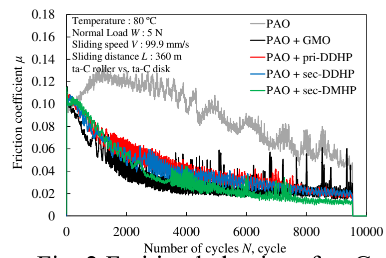

Fig. 2 Frcition behavior of ta-C

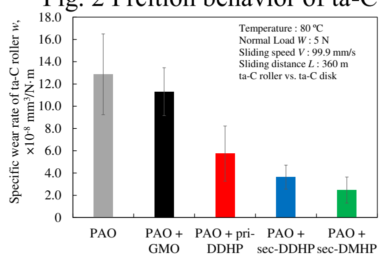

Fig. 3 Wear behavior of ta-C

4. References

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