Tribofilm composition of dialkyl phosphonoacetic acid in Ester base oil and PAO

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Antiwear performance (AW) of dialkyl phosphonoacetic acid (DAPA) in ester base oil (Ester) and poly-a-olefin (PAO) were evaluated, and their tribofilm compositions were analyzed using X-ray Photoelectron Spectroscopy (XPS). DAPA in Ester showed better AW performance than DAPA in PAO especially at high loads. XPS results revealed the difference between the compositions of the tribofilms obtained by DAPA in Ester and DAPA in PAO.

Keywords: Antiwear additives, Synthetic esters, DAPA, XPS

1. Introduction

Environmentally adapted lubricants (EAL) have been widely used for many applications. Ester base oils are often used for EAL because they have good biodegradability. Yet, few studies exist on the AW additives for ester oils, and it is often difficult to improve AW performance with classical lubricant additives generally used in mineral base oils or PAOs. In our previous study, DAPA showed superior AW performance in ester base oils compared to PAO [1]. However, it is still unclear why DAPA performs better in ester base oil than in PAO. This research focused on the characterization of tribofilm using XPS in order to understand this difference of behavior between the two base fluids.

2. Methods

2.1. Materials

The chemical structure of DAPA is presented in Figure 1. Trimethylolpropane trioleate (Ester) and PAO8 were used as base oils in this study. The concentration of DAPA in the base oils is 3.3 mmol/kg.

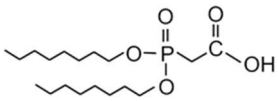

Figure 1: Chemical structures of DAPA

2.2. Four-ball tests and XPS analyses

Four-ball tests were carried out with AISI 52100 steel balls at room temperature for 30 minutes. The worn surfaces after the four-ball tests were analyzed by XPS.

2.3. Results

Figure 2 illustrates the wear scar diameters after the four-ball tests. DAPA in PAO prevents wear up to 196 N, but significant wear is observed at 294 N and 392 N. DAPA in Ester improves AW performance of the lubricant at all tested loads compared to Ester alone.

The curve fitting results of O1s spectra on the worn surfaces at 98 – 392 N are shown in Figure 3. Regarding DAPA in PAO, the peaks assigned to BO (Bridging Oxygen) and NBO (Non-Bridging Oxygen) are detected at all tested loads. In the case of DAPA in Ester, in addition to BO and NBO, the peaks assigned to Ester (C-O and C=O) are observed.

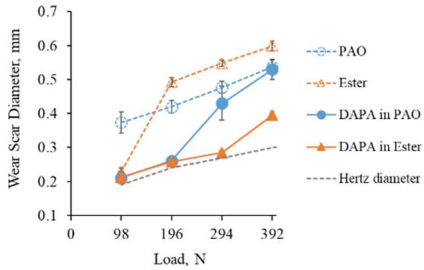

Figure 2: Effect of DAPA in Ester and PAO on four-ball tests with varying load

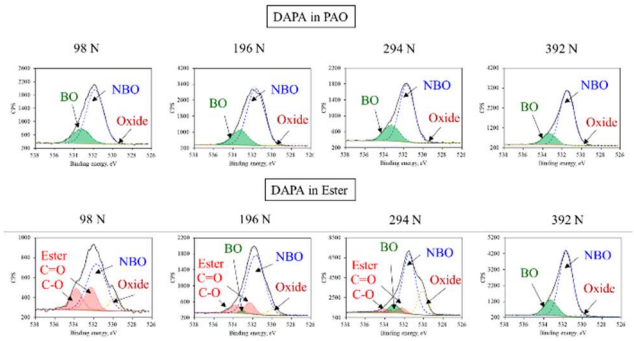

Figure 3: Curve fitting results of O1s spectra on the worn surfaces at 98–392 N

3. Discussion

DAPA in PAO forms a phosphorus film including BO and NBO at all tested loads, nevertheless, this reduces wear only at 98 and 196 N, suggesting that no effective tribofilm was formed at 294 and 392 N.

DAPA in Ester reduces wear at all tested loads. At 98 N, significant peaks from Ester are observed; their intensities decrease with the load. Conversely, BO and NBO peaks appear with increasing load. These results indicate that Ester is efficient at lower loads; DAPA at higher loads. Therefore, Ester helps to reduce wear with DAPA up to 294 N.

4. References

[1] T.Oshio, et al.:46th Leeds-Lyon Symposium on TRIBOLOGY, Lyon: 2019.