

## EFFECTS OF TRIBOFILM DERIVED FROM SULFUR/PHOSPHORUS-BASED ADDITIVES ON PITTING/WEAR RESISTANCE OF BEARING STEEL DURING ROLLING FRICTION

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### KEYWORDS

*Rolling contact fatigue; Lubricant additives; Wear, Tribofilms*

### ABSTRACT

According to the development of lubricants, there is a growing tendency to lower the viscosity of oil to enhance power efficiency. This trend towards lower viscosity is increasing the risk of wear and fatigue damage on sliding components. To address these issues, lubricant additives are one of the important technologies. Therefore, the purpose of this study is to investigate how the phosphorus/sulfur additives influence anti-wear and anti-pitting properties.

We used ball-on-disc type MTM for fatigue friction tests of nine million cycles. The results have indicated that sulfur-based oil exhibited higher anti-wear properties compared to phosphorus-based oil, and sulfur/phosphorus-based oil showed further improvement of anti-wear performance. Additionally, the results were inversely proportional to surface hardness except PAO4 (Fig. 1). Furthermore, phosphorus-based and sulfur/phosphorus-based oils showed higher damaged area percentage (DAP) compared to sulfur-based oil. DAP also tended to be inversely proportional to hardness. Therefore, it can be considered that sulfur-based additives protected steel surfaces against wear by forming hard tribofilm. However,

sulfur/phosphorus-based additives showed high DAP despite of forming high hardness tribofilm derived from sulfur/phosphorus-based additives (Fig. 1).

To investigate the mechanisms of these results, XPS measurement and FIB-TEM observation were conducted. By XPS measurement, iron phosphate and iron sulfate were found on the wear track of phosphorus-based and sulfur-based oils, respectively. Both of iron phosphate and iron sulfate tribofilm were found on the wear track of sulfur/phosphorus-based oil. In the case of sulfur-based oil, the multilayer tribofilm was found: iron sulfate was first layer, and iron sulfide was second layer (Fig. 2). A multi-layered structure of this sulfur-based tribofilm was also found in the cross-sectional observation of the tribofilm through FIB-TEM (Fig. 2). We will report tribofilm structures formed in phosphate additive and sulfur/phosphate-based oils observed by FIB-TEM and discuss the pitting/wear resistance of sulfur/phosphorus-based additives.

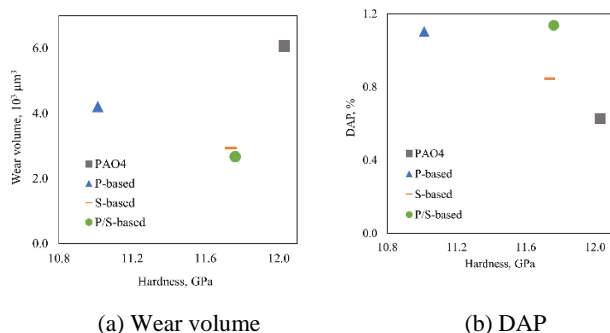


Fig.1 Relation between wear volume/DAP and surface hardness

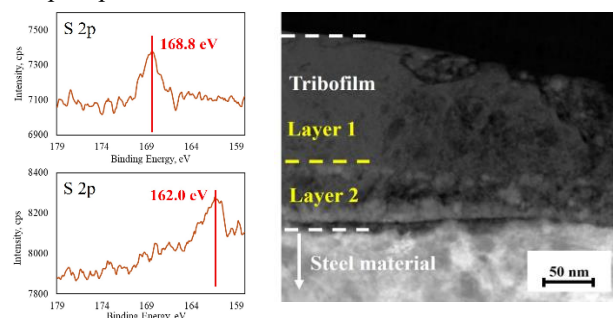


Fig.2 XPS peaks after and before Ar etching and FIB-TEM observation result of sulfur-based tribofilm

### REFERENCES

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