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XANES study of tribofilms generated from belt-drive continuously variable transmission fluid

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Introduction

Belt-drive continuously variable transmissions (CVTs) have attracted attention because they give better fuel efficiency than conventional automatic transmissions (ATs). Belt-drive CVT fluids (belt-drive CVTFs) must have not only the same physical properties as ATs, such as low temperature fluidity, oxidation stability, but also high friction coefficients between the belt and pulley in the transmission system to convey forces efficiently[1]. The friction coefficient of a belt-drive CVTF is governed by its composition. The additives in CVTFs react with metal surfaces to form tribofilms. However, it is very difficult to predict the properties of the films only by analysis of the additives in fluids. In order to design high performance belt-drive CVTFs, it is necessary to investigate the nature of the tribofilms that directly govern friction coefficients.

In this paper, we report relationship between chemistry of the S species in the films and friction coefficient when extra additives are added to CVTFs[2].

Experimental

The block-on-ring friction test[3] was employed to prepare tribofilms and measure the friction coefficients of 4 test fluids at the 30-minute duration point (Table1). The test conditions are described elsewhere [3]. The concentrations of S, P, and Ca in CVTF-1 are 5000, 600 and 1300ppm; and those in CVTF-2 are 900, 200 and 500ppm, respectively. Tribofilms at 30-minute point of the friction test were then subjected to XANES measurement.

The S K-edge XANES measurements were carried out at BL-9A. The samples were placed in a flowing helium environment, and the spectra were collected using a fluorescent ion chamber in the fluorescence yield mode.

Table1: Friction coefficients of test fluids

Test fluid	Friction coefficient
CVTF-1	0.141
CVTF-1+Friction Modifier(FM)	0.120
CVTF-2	0.138
CVTF-2+Detergent(Det)	0.119

Results and Discussion

The friction coefficients of both CVTF-1 and CVTF-2 decrease when additives such as a friction modifier and a detergent were added (Table1). Sulfur-containing compounds in CVTFs are thought to react readily with metal surface and play an important role in the formation of tribofilms. So, in order to clarify whether additives affect the chemistry of the S species in the tribofilms, the S K-edge XANES spectra were examined. In both CVTF-1 and CVTF-2, the shape of the XANES spectra changed after the additives were added (Fig.1). This indicates that the chemistry of the S species in the films changed after the addition of additives. In order to estimate the ratio of the S species in the films, the XANES spectra of films were pattern-fitted with those of sulfur-containing model compounds expected to be in the tribofilms. As a result of pattern-fitting, it was found that the ratios of sulfides with the exception of iron disulfide decrease in the films when the additives are added to both CVTF-1 and CVTF-2 (Fig. 2). Thus, additives such as friction modifiers affect the ratio of sulfur compounds in the tribofilms.

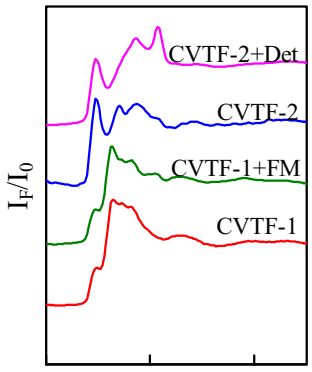

Fig. 1 S K-edge XANES

This suggests the following: the decrease in the friction coefficient by adding additives such as friction modifiers and detergents to CVTFs is the result of decrease in the ratio of sulfides (except iron disulfide) in the tribofilms.

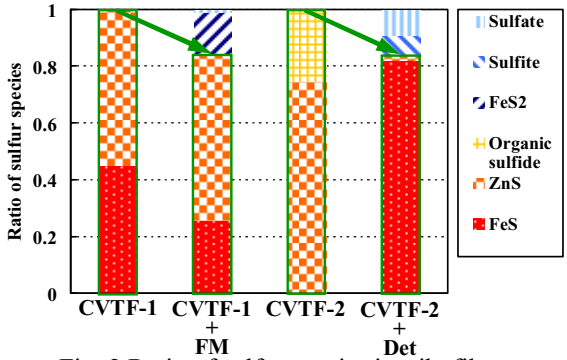

Fig. 2 Ratio of sulfur species in tribofilms

References

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