STERIC EFFECT OF THICKENING AGENTS
IN INTERFACIALLY CONFINED LIQUID LUBRICANTS

CATEGORY
Nanotribology

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INTRODUCTION
Recent trend towards tightening environmental regulations raises demands on development of low-viscosity lubricants that can reduce hydrodynamic viscous friction. Generally, formulation of low-viscosity lubricants require improved anti-wear performance since lowering viscosity decreases fluid film thickness in principal, eventually accelerating wear. Chemically-reactive anti-wear additives such as zinc dialkyldithiophosphate (ZDDP) exhibit superior anti-wear performance by forming protective tribofilms on rubbed surfaces, though their application is limited due to their corrosiveness on some materials [1]. Thickeners, which consist of hydrocarbons with a molecular weight higher than base oils, are also known to prevent wear [2]. Unlike ZDDP, thickening agents can prolong the life of mechanical components without corrosion. However, the origins of the anti-wear performance of thickening agents have been unknown. In this work, we studied the influences of thickening agents on surface force in confined liquid lubricants to examine anti-wear mechanisms of thickening agents at asperity contact.

METHODS
Using a surface force apparatus (SFA), we analyzed surface force between the two curved ultra-smooth mica surfaces confining liquid lubricants containing thickening agents. We measured distance of two opposed mica surfaces by the method called fringes of equal chromatic order (FECO) method [3,4]. Our SFA was equipped with resonance shear measurement system to evaluate viscoelastic properties of confined media. We also evaluated macroscopic dynamic viscoelasticity, elastohydrodynamic fluid film pressure, and surface tension to characterize bulk physical properties.

We used two types of ethylene-propylene copolymers (EPCs) as thickening agents: Oligomer-type EPC with relatively low molecular weight and polymer-type EPC with relatively high molecular weight. The oligomer-type EPCs used in this study were reported to extend fatigue life of ball bearings [5]. We mixed these EPCs with paraffinic mineral oils. Both oligomer-containing and polymer-containing oils were formulated into identical viscosities. A mineral oil with a viscosity identical to these EPC-containing oils was used as control.

RESULTS AND DISCUSSION
SFA experiments revealed that the oligomer-containing oils generated repulsive force at submicron surface separation (Fig. 1). The repulsive force increases with the decreasing distance between the mica surfaces, implying the steric response to compression. Existence of such steric response was not observed in the bulk physical properties. Thus, this repulsive force emerged
locally in microscopic asperity, and might be due to the concentration of thickener molecules in confined lubricants. The steric response of polymer-type EPC was not as significant as oligomer-type one. This is consistent with the literature showing that high-molecular-weight thickeners lack anti-wear performance [2]. Therefore, the steric effect might contribute to wear protection performance of thickeners.

![Graph showing surface force (F/R) vs distance (D) profiles of interaction between mica surfaces. An arrow shows the onset of increase of F/R during approach.]

**Figure 1:** Surface force (F/R) vs distance (D) profiles of interaction between mica surfaces. An arrow shows the onset of increase of F/R during approach.

**ACKNOWLEDGMENTS**
We thank Mr. Masaya Hino (Tohoku University) for his valuable technical support for the SFA experiments.

**REFERENCES**

**KEYWORDS**
Additives:Antifatigue Additives, Lubricant Chemical Analysis:Spectroscopy