Relationship between Nano / Macro Friction Behaviour and Mechanical Properties of Tribo-Film by Multi-Dimensional Nano-Indentation Equipment

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Continuously variable transmission (CVT) which transmits torque by friction force requires high friction coefficient and low wear. To achieve such tribological properties, the tribo-film formed by CVT fluid (CVTF) plays an important role. However, the relationship between the mechanical and frictional properties of CVTF tribo-film has yet to be clarified. In this study, we evaluated the tribo-films formed by CVTF additives in terms of the mechanical and frictional properties in both nano and macro scales. The results indicate an apparent correlation between frictional properties in nano and macro scales.

Keywords (from 3 to 5 max): CVT, Tribo-film, Multi-dimensional nano-indentation

1. Introduction

Tribo-film, which is formed by chemical reaction between lubricant additives and sliding surface, dominantly affects friction and wear properties under boundary lubrication. Continuously Variable Transmission (CVT) is one of the automobile transmissions which transmit torque by friction force [1]. In order to ensure the high efficiency and long lifetime of CVT, the tribo-film formed by CVT fluid (CVTF) is expected to exhibit high friction and low wear [2]. However, the relationship between the mechanical and frictional properties of the tribo-film has yet to be clarified due to the difficulty in accurate detection of such nanothick film. Multi-dimensional nano-indentation equipment (Gemini, KLA, US) has two actuator heads pointing in vertical and lateral directions, enabling simultaneous measurement of both vertical and lateral forces during nano-indentation process. By utilising this function, the frictional property of thin film can be accurately measured. In this study, the mechanical and frictional properties of the tribo-film which is formed by macro friction tests were evaluated by multi-dimensional nano-indentation equipment. Comparing the results of friction tests in both nano and macro scales, the relationship between mechanical and frictional properties of tribo-film is discussed.

2. Experimental

Poly-alpha-olefin (PAO 4) was used as a base oil, and Tricresylphosphate (TCP), Dibenzyldisulfide (DBDS) and Overbased Calciumsulfonate (OBCS), which are contained in typical CVTF, were used as lubricant additives. Cylinder-on-disk type macro sliding tests were conducted using SRV4 (Optimol, DE). Mechanical properties of the tribo-film, which had been formed by macro sliding tests, were evaluated by the nano-indenter (iMicro, KLA, US). Also, by the nano-indenter, nano sliding tests on the tribo-film were performed at a load of 1 mN with spherical sapphire indenter.

3. Results and Discussion

Figure 1 shows the time varication of friction coefficient of sliding tests in macro scale. The results indicate clear difference in friction behaviours among each oil. Figure 2 shows the summary of friction coefficient by nano sliding tests. Tribo-film derived from OBCS showed the lowest friction, whereas tribo-film derived from DBDS showed the highest friction coefficient. Figure 3 shows the relationship between macro and nano friction behaviour. The results indicate an apparent correlation between frictional properties in nano and macro scales.

4. References

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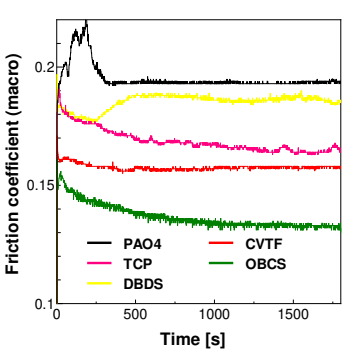

Figure1: Macro friction behaviour under lubrication with each oil

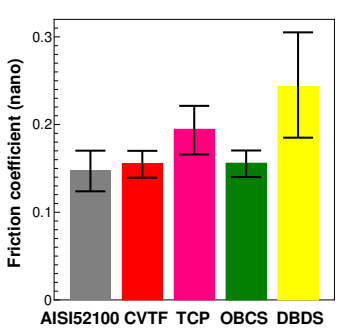

Figure 2: Nano friction coefficient on AISI 52100 surface and the sliding surfaces under lubrication with each oil

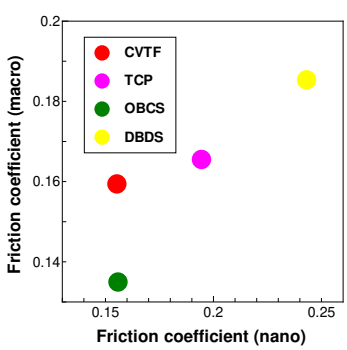

Figure 3: Relationship between macro and nano friction coefficient