Proceedings of Asia International Conference on Tribology 2018, pp. 210-212, September 2018

Synergetic effects of a polymeric friction modifier and MoDTC on tribological properties under boundary lubrication

Hikaru Okubo[1], Mariko Isokane[1], Sumi Taro[2], Noriyoshi Tanaka[2], Shinya Sasaki[1,*]

[1)] Department of Mechanical engineering, Tokyo University of Science,
6-3-1 Niijuku, Katsushika-ku, Tokyo 125-8585, Japan.
[2)] ADEKA corporation 7-2-35 Higashiogu, Arakawa-ku, Tokyo 116-8554, Japan.

[*]Corresponding e-mail: sasaki@tribo-science.com

Keywords: Tribology; MoDTC; organic friction modified

ABSTRACT – The effects of organic friction modifier; GMO and PLA/HEA on lubricity of MoDTC were investigated using a reciprocating-type tribotester and several surface analyses. From the results of friction tests, the lubrication with PAO (poly-alpha olefin) + MoDTC + PLA/HEA exhibited lower friction coefficient than the lubrication with PAO + MoDTC, whereas the lubrication with PAO + MoDTC + GMO exhibited higher friction coefficient than the lubrication with PAO + MoDTC. The surface analysis results indicate that GMO inhibited the formation of MoS_2 tribofilms on the sliding surface.

1. INTRODUCTION

In an effort to solve various environmental issues, there is growing demand for improved fuel efficiency in the automotive industry. Reducing friction and wear in engine components is one of the wildly-recognized approach to meet the demand. To reduce the friction loss and wear of sliding components, the optimized design of engine lubricants that can give excellent tribological performance is required.

In a great deal of chemical compounds for engine lubricants, MoDTC is one of the great promised friction modifier commonly used in engine lubricants. It is well known that MoDTC can reduce boundary friction due to the formation of a MoS_2 tribofilm that is well known as a low frictional solid lubricant [1]. On the other hand, organic friction modifiers (OFMs) that can give low friction under especially mixed lubrication are also essential for engine lubricants since the sliding components in automotive engines are normally operated under boundary, mixed and hydromagnetic lubrication regimes. However, there is a serious problem that MoDTC and OFM inhibits their performance each other when they are used together in engine lubricants [2].

In order to achieve further low friction and wear, the synergetic effects of MoDTC and OFM is required. Therefore, we aim to reveal the interaction between OFM and MoDTC under boundary lubrication that can achieve a desired tribological performance. In this study, we investigated the effects of organic friction modifiers on lubricity of MoDTC.

2. EXPERIMENTAL DETAILS

Sliding tests were performed by using cylinder-on-disk type sliding tester (SRV, Optimol, GE), as shown in Figure 1. Test conditions are listed in Table 1. The test specimens used in this study were the 52100 bearing steel disk and cylinder. Poly-alpha-olefin (PAO4, VG16) was used as the base oil. MoDTC, glycerin monooleate (GMO), Poly-lauryl-acrylate-hydroxyethyl-acrylate (PLA/HEA) were used as lubricant additives. Their chemical structures are shown in Table 2. Lubricants used in this study were pure-PAO, PAO + MoDTC, PAO + GMO,PAO +PLA\HEA, PAO + MODTC + GMO and PAO + PLA/HEA + MoDTC. After the sliding test, Raman spectrometer (in Via spectrometer, Renishaw, ENG) and EDS (Energy Dispersive X-ray Spectroscopy) (SUPRA 40, Zeiss, DE) were used to evaluate the composition of tribofilms.

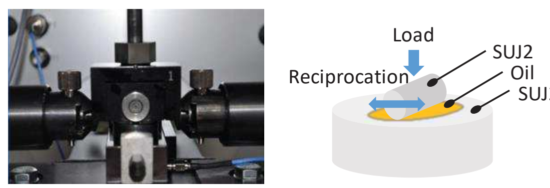
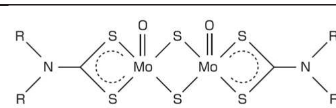
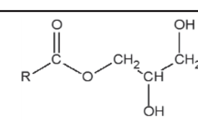
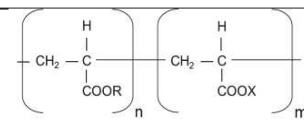


Figure 1 Schematic diagram of sliding tester.

Table 1 Test conditions.

Load	[N]	80
Temperature	[°C]	100
Stroke	[mm]	1.0
Frequency	[Hz]	50
Lubricant	[μl]	300
Test duration	[min.]	30

Table 2 Chemical structure.

MoDTC	
GMO	
PLA/HEA	 X=hydroxyethyl

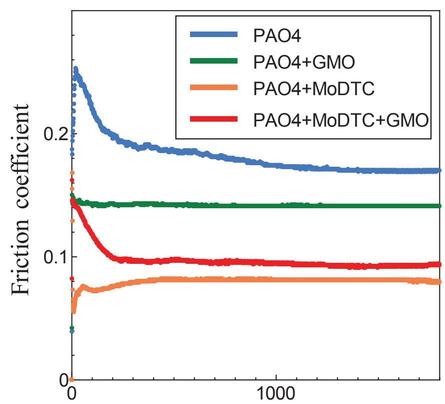
3. RESULTS AND DISCUSSION

3.1 Friction properties

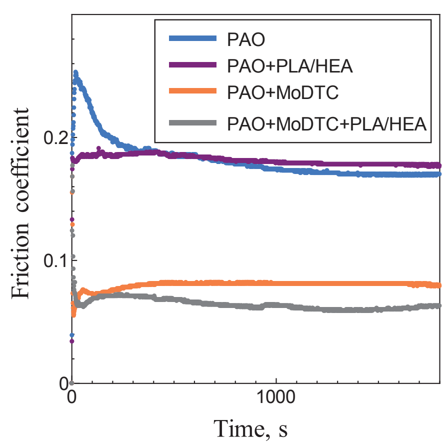
Figure 2 shows the friction behavior for each lubricant. For PAO + MoDTC, the friction coefficient was stable at 0.08. For PAO + MoDTC + GMO, the friction coefficient was 0.09. On the other hand, For PAO + MoDTC + PLA/HEA, the friction coefficient was stable at 0.06. This indicates that GMO inhibited the MoDTC-derived low frictional properties and the combination of PLA/HEA and MoDTC led the synergistic effects to achieve lower friction than MoDTC alone solution.

3.2 Raman results

The Raman spectra were obtained using a 532-nm laser, with a maximum power output of 5 mW. The radius of the laser spots was 6 μm. Figure 3 shows Raman analysis was conducted on the rubbed surface of the disk for PAO + GMO + MoDTC and PAO + PLA/HEA + MoDTC. They all show the C-H bond peak of PAO (840-895, 1081, 1303, 1442 cm-1) [3]. For PAO + MoDTC + PLA/HEA, a peak derived from MoS_2 (378, 412 cm^{-1}) was also confirmed although these peaks were not observed for PAO + GMO + MoDTC [4].



(a)

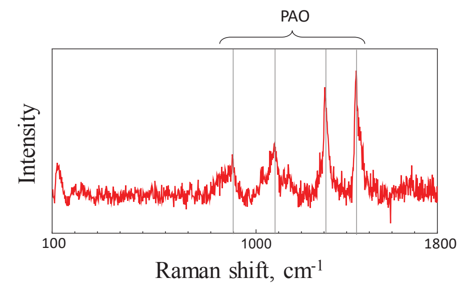


(b)

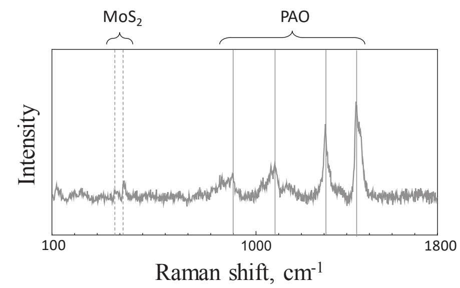
Figure 2 Frictional behavior of (a) GMO added oil and (b) PLA/HEA added oil.

3.3 EDX results

Figure 4 shows the atomic concentration of MoS_2-derived elements (iron, oxide, carbon, sulfur) calculated from EDS element mappings of the worn surfaces on the steel disk after the friction test. For PAO + MoDTC and PAO + MoDTC + PLA/HEA, the sulfur concentration was almost 4.9 %. On the other hand, for PAO + MoDTC + GMO, the sulfur concentrationwas 1.6 %, which was significantly lower than the other cases.



(a) PAO+MoDTC+ GMO



(b) PAO+MoDTC+PLA/HEA

Figure 3 Raman spectra

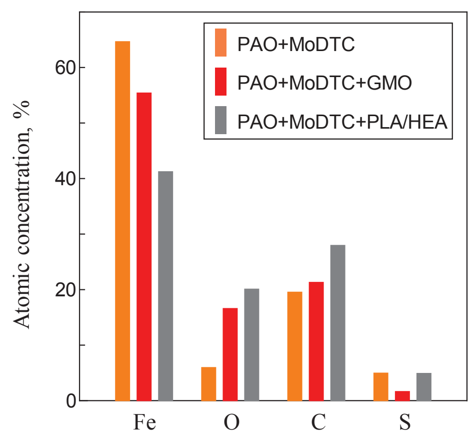


Figure 4 Concentration of Fe, O, S.

PAO + MoDTC + PLA / HEA exhibited the lowest value than the other MoDTC solutions. The results of the Raman and SEM analysis showed the formation rate of MoS_2 for PAO + MoDTC + PLA / HEA was higher than the case of PAO + GMO + MoDTC. This strongly reletd to the low frictional behavior of the combination of mODTC and PLA/HEA. The details will be shown in the presentation.

4. SUMMARY

The effect of organic friction modifiers on lubricity of MoDTC in the presence of organic friction modifiers and MoDTC was investigated. The main conclusions are as follows:

(a) For lubrication with PAO + MoDTC + PLA/HEA, it is confirmed that friction reduction effect exceeding that of MoDTC alone added oil.

(b) For lubrication with PAO + MoDTC + GMO, GMO inhibited the formation of MoS_2 tribofilm, therefore friction coefficient increased.

REFERENCES

[1] Grossiord, C. K. J. M. T. C. K., Varlot, K., Martin, J. M., Le Mogne, T., Esnouf, C., & Inoue, K. (1998). MoS2 single sheet lubrication by molybdenum dithiocarbamate. *Tribology international*, *31*(12), 737-743.

[2] Idemitsu Kosan Corporation, Lubricating oil composition and friction reducing method for internal combustion engine, Japan Patent 193995, 2016-11-17.

[3] Nakase, S., Kato, H., Woydt, M., & Sasaki, S. (2015). Lubricities of Environmentally Acceptable Lubricants with Zinc Dialkyldithiophosphate and Dibenzyl Disulfide on Tribological Properties of Plasma Electrolytic Oxidation Coated A6061-T6 Alloy under Mixed/Boundary Lubrication. *Tribology Online*, *10*(1), 56-63.

[4] Khaemba, D. N., Neville, A., & Morina, A. (2015). A methodology for Raman characterisation of MoDTC tribofilms and its application in investigating the influence of surface chemistry on friction performance of MoDTC lubricants. *Tribology letters*, *59*(3), 1-17.