Proceedings of Asia International Conference on Tribology 2018, pp. 348-349, September 2018

The effect of molybdenum carbide (Mo_2C) particles on wear properties of diamond-like carbon under boundary lubrication

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Keywords: MoDTC; Mo_2C; DLC

ABSTRACT – Molybdenum dithiocarbamate (MoDTC) has received notable attention as an anti-friction additive in engine oil. However, it has wear accelerating effects on the sliding contact of DLC and steel under boundary lubrication condition. MoDTC is a degradable material and can change its structure into MoS_2, MoO_3, Mo_2C and Mo during friction test. Whether MoDTC itself enhances the wear or its by-products materials has still been unknown. Therefore, it is important to clarify which elements actually give severe effects on the wear acceleration. This paper focuses on the wear properties of Si-DLC coatings and SUJ2 ball with MoDTC and Mo_2C particles as additives in engine oil under boundary lubrication condition. It shows that Mo_2C gave severe effect on the wear properties of Si-DLC coatings.

1. INTRODUCTION

Since decades ago, the control of friction and wear in the automotive engine system has been captured attention by many researchers. Low friction coefficient under boundary lubrication that leads to a vital decrement of fuel consumption, and also increment of life expectancy and durability are the main goals of those researches.

Diamond-Like Carbon (DLC) coatings is one of the potential candidates to give low friction and long life span due to its high hardness and chemical inert properties [1]. It is now being prominently used in industry as coating materials and also as lubricant additives. Its resistance to friction and wear, chemically inertness and high hardness make it very suitable to use both in sliding and rolling contact condition. The low friction property of DLC under boundary lubrication is a paramount factor on the sliding parts of automobile engine especially on piston ring and cylinder liner.

In automotive industry, the effect of lubricant additives to DLC coatings on the contact parts is extensively being studied in order to get the optimum operating condition under lubrication regimes. These recent years, molybdenum dithiocarbamate (MoDTC) has received noticeable attention as an anti-friction additive in automobile lubrication.

MoDTC is very proficient in reducing friction coefficient between steel-DLC contact surfaces under boundary lubrication [2]. However, the MoDTC lubrication resulted in wear rate's increment of DLC [3]. MoDTC is an easy degradable material. Therefore, it can simply change its physical and chemical structures.

It is often assumed that intermediate and final products from the degradation of MoDTC as the wear acceleration material. These elements increase the wear and scratch both DLC and the counterpart surfaces. There are several by-products elements from the MoDTC degradation has been discovered; which are MoO_3, Mo_2C and Mo. However, which sub-element mainly accelerates the wear has still been unknown.

Thus, it is very essential to have concrete clarification on each sub-element behavior and which of them affect the most on the DLC wear. This complex condition is quite critical especially in automotive components as the wear will shorten the lifetime of DLC. Therefore, further analyses are required.

This paper focused on the clarification of the wear acceleration mechanism of MoDTC and its sub-element, Mo_2C between steel-DLC contact surfaces under boundary lubrication.

2. METHODOLOGY

The friction test was conducted using Ball-on-Disc friction tester as shown in Figure 1. It has leaf springs with strain gauge as the load and friction force sensor. The counter materials being used are Si-DLC disc against 8mm stainless steel SUJ2 ball. The oil additives are MoDTC and Mo_2C particles, being dispersed into poly-alpha-olefin (PAO) base oil with several weight percentages. The experimental parameters are listed in Table 1.

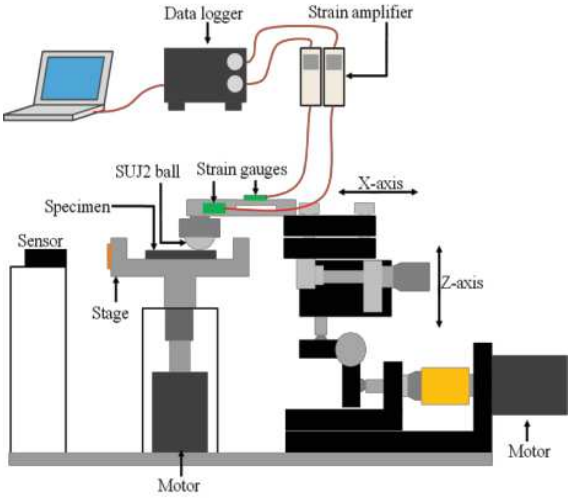

Figure 1 The schematic image of Ball-on-Disc friction tester.

Table 1 Experimental parameters.

Parameter	Value
Normal load *W,* N	1
Sliding speed *V,* m/s	0.05
Duration time *t,* min	15
Additives	MoDTC, Mo_2C
Ball	SUJ2 (Ø8mm)
Disc	Si-DLC
Additives amount wt.%	0, 0.005, 0.01, 0.05, 0.1
Temperature *T,* ºC	23

3. RESULTS AND DISCUSSION

The specific wear rate results of Si-DLC with MODTC and Mo_2C particles under PAO lubrication are shown in Fig. 2. Both additives showed increment of specific wear rate proportionally to the particles amount. This result showed that Mo_2C, as the intermediate product of MoDTC, contributes to the wear acceleration of DLC.

This statement was also proven by the SEM images of Si-DLC disc and counter material SUJ2 ball surfaces. As shown in Fig. 3, the DLC coating peeled-off from the disc surface after the friction test with PAO and 0.1 wt.% MoDTC. On the other hand, there was wear debris on the ball surface.

Meanwhile, Fig.4 showed the friction test effect of PAO with 0.1 wt.% Mo_2C. Spalling and scratches took place on the Si-DLC surface while transfer film was assumed to be occurred on the SUJ2 ball.

Therefore, these images showed that Mo_2C particles gave severe abrasive effect to the Si-DLC disc and SUJ2 ball compared to MoDTC particles.

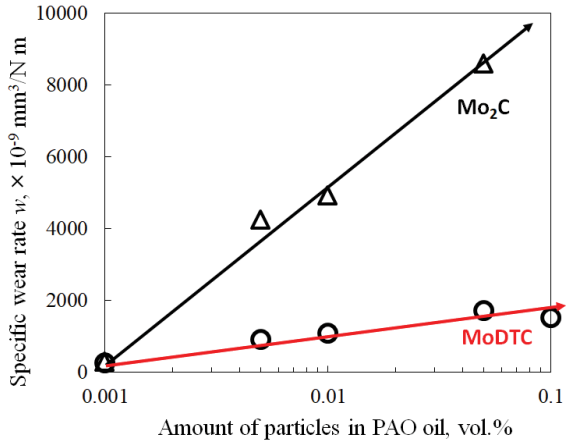

Figure 2 Specific wear rate of Si-DLC against SUJ2 ball in PAO with MoDTC or Mo_2C.

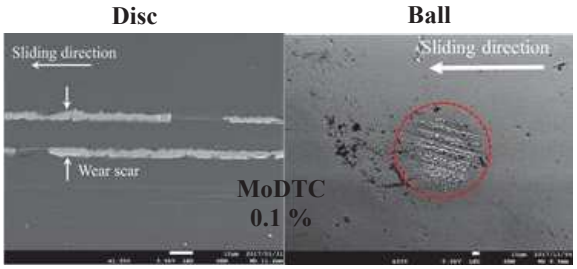

Figure 3 SEM image of Si-DLC and SUJ2 ball surface after friction test in PAO with 0.1 wt.% of MoDTC.

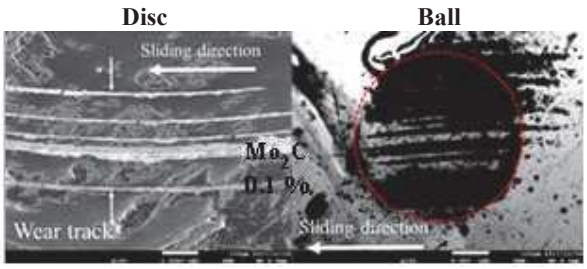

Figure 4 SEM image of Si-DLC and SUJ2 ball surface after friction test in PAO with 0.1 wt.% of Mo_2C.

4. CONCLUSION

Both MoDTC and Mo_2C accelerate wear on Si-DLC coatings in the PAO base oil under boundary lubrication condition. Mo_2C showed more severe wear effect compared to MoDTC. It was proven by the increment of specific wear rate which proportional to the dispersion of particles amount. This analysis was also supported by the formation of wider wear track, spalling and scratches took place on the DLC surface and transfer film covered the SUJ2 ball surface. It was interesting that MoDTC was not the main factor of wear acceleration in Si-DLC coating, but its by-product Mo_2C from the degradation resumes the wear ability effect.

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