Analysis of the Effect of ZDPP and MODTC Additives to Wear Protection of Castor Oil

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Abstract. Application of castor oil as an alternative lubricant already knowledge since years ago due to its good lubricating characteristics. Most lubricant formulation are made of base oil and addtives. Molybdenum-Dithiocarbamates (MoDTC) and ZincDialkyl- dithiophosphates (ZDDP) are well-known additives for lubricant formulation. Although already possess good lubricity properties, it is believed that wear preventive properties of castor oil can be enhanced again by ZDDP and MoDTC additives. This work is meant to investigate the effects of ZDPP and MoDTC to wear prevention of Castor oil. Wear testing was performed by using a cylinder on disc apparatus adopting the ASTM G77 standard testing. A cylindrical SS 201 steel of 6 mm diameter and 25 mm length was employed as block sample slid against a 52 mm of diameter mild steel rotor. The pin was loaded with 150 kg load and slid at sliding speed of 600 rpm at room temperature for 30 min testing period. Wear prevention properties of the lubricant sample were determined from weight loss of pin sample measured after the test. Optimum concentration of ZDPP to wear preventive properties of castor oil is at 1.75 wt% and for MoDTC is at 1.5 wt.%. Not only related to the additive loading, wear prevention of castor oil also related to surface interaction between the pin and disc. Wear mechanism and surface interaction also play a role on the wear of the sample.

Keywords: Castor Oil · ZDDP · MoDTC · Wear prevention

1 Introduction

Lubrication plays a vital role in machines and equipment in which components rub against each other, such as protection from surface failure. Petroleum mineral and synthetic based oil (derived from petroleum) are typical lubricant used globally today. With global awareness to environment sustainability, consideration on the further use of mineral based lubricant oil in the future is getting high. This because mineral oil-based

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lubricants are typically difficult to decompose in the environment and toxic [1]. Eco friendly lubricants based on vegetable oils animal fats was found able to meet all basic functional of lubricant compound alongside their renewable resource.

Molybdenum-Dithiocarbamates (MoDTC) and ZincDialkyl- dithiophosphates (ZDDP) are well-known additives for lubricant formulation. Molybdenum-Dithiocarbamates (MoDTC) mainly added as friction modifier and ZDDP primarily function as anti-wear enhancer for lubricant base oil [3]–[7]. The MoDTC typically provide low friction at the tribological contacts in boundary lubrication conditions and ZDDP provide wear protection by forming sulphide-and phosphate-containing tribofilms at the surfaces [4, 8].

Application of castor oil as an alternative lubricant already knowledge since years ago. Castor oil characteristics such as high lubricity, high viscosity index, and insolubility in aliphatic petrochemical fuels and solvents, make it suitable to be used as lubricant [2]. This oil also finds their use for several other purposes from cosmetics to polymer raw materials. Thus, since their demand always high, the availability of this oil also high which economically strategic to use it as lubricant base. Although already possess good lubricity properties, it is believed that wear preventive properties of castor oil can be enhanced again by ZDDP and MoDTC additives. Therefore, this work is meant to investigate the effects of ZDPP and MoDTC to wear prevention of Castor oil.

2 Method

Commercially available castor oil was employed as base oil. ZincDialkyl-dithiophospates (ZDDP) and Molybdenum-Dithiocarbamates (MoDTC) additives were employed as anti-wear additives. Prior to wear testing, lubricant sample was prepared by mixing the additives with the base oil at different content level, i.e. 1wt.% – 2.5 wt.% at room temperature by a magnetic stirrer.

Wear testing was performed by using a cylinder on disc apparatus adopting "ASTM G77: Standard Test Method for Ranking Resistance of Materials to Sliding Wear Using Block-on-Ring Wear Test". The test configuration is shown in Fig. 1. A cylindrical SS 201 steel of 6 mm diameter and 25 mm length was employed as pin sample. This pin was slid against a 52-mm of diameter mild steel rotor and loaded with 150 kg load at sliding speed of 600 rpm at room temperature for 30 min testing period. Schematic view of the test is shown in Fig. 1. In this work, the wear prevention characteristic was determined by weight loss method. Furthermore, surface morphology of the wear track occurred on the contact region after test was examined by an Optical microscope. Typical wear scar was formed on the pin sample after wear test is shown in Fig. 2.

3 Result and Discussion

Figure 3 shows the effect of additive loading to wear of SS201 pin. Low concentration of the ZDDP additive wear prevention characteristics. This results is not surprising since ZDDP is a typical additives added in most lubricant formulation to enhance the wear preventive properties of base lubricant [9, 10]. However, it is observed that the wear prevention characteristics of the ZDDP additive is reduced after the 1.75 wt% of

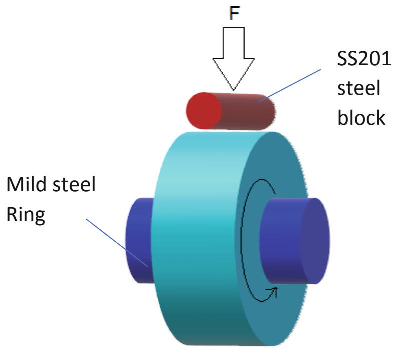


Fig. 1. Wear Test Configurationssssss

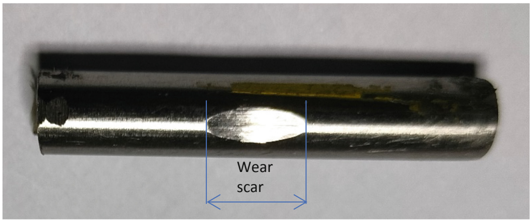


Fig. 2. Wear scar after test

concentrations. It is believed that this result is related to on the rates of recovery and growth of effective surface films by the ZDDP additive [11]. At a low sliding speed and temperatures below 50 °C, the surface film generated at contact area is mainly formed by physisorbed film. When the load of ZDDP additives increases in castor oil, the formation of this film was possibly not well maintained thus reduce the surface protection from wear. Figure 3 also shows the wear prevention characteristic of MoDTC. MoDTC is typically added into lubricant base oil as friction modifier substance, however it is believed that this compound also shows wear prevention characteristics. It can be observed that wear prevention characteristics shown at higher concentration of MoDTC. The wear prevention characteristic started to occur at more than 1.5 wt.% MoDTC loading, and the lowest specimen wear is observed at highest content of MoDTC. This result is in agreement with *Trindade et.al* [3] which were found that the presence of MoDTC can reduce wear rates. Therefore, it is concluded that optimum value of ZDPP wear preventive properties for this base oil is at 1.75 wt% and for MoDTC is at 1.5 wt.%

Figure 4 – Fig. 7 shows the surface morphology of the worn-out surfaces of the specimens. Figure 4 shows the surface morphology of worn pin surface lubricated with castor oil and 1.75 wt.% ZDDP at 50 × and 100 × magnification. This sample shows lowest wear compared to other ZDDP loading samples. It is observed that in general this sample experience mild adhesive wear. Furthermore, magnification to 100 × (Fig. 4(b)) reveals some trace of absorbed lubricant film although the sample already cleaned with solvent. It is also observed occurrence of micro-pitting which indicate fatigue also taken a role during the wear process. Figure 5 shows the surface morphology of worn pin

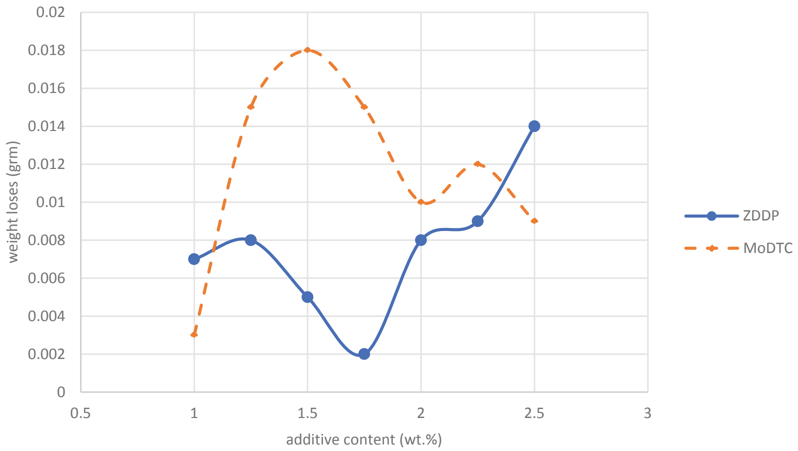
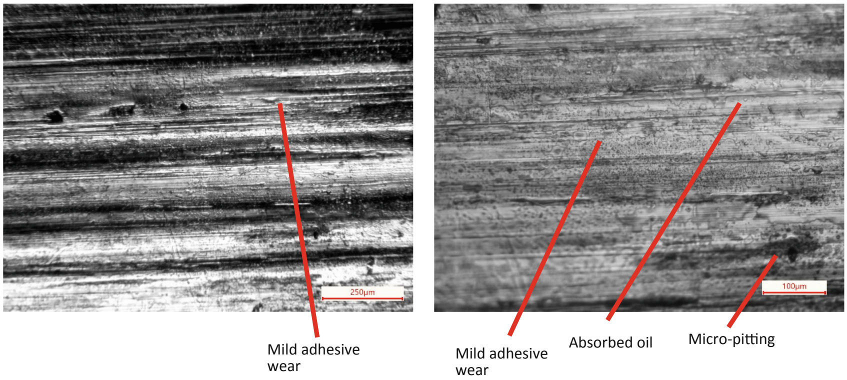


Fig. 3. Effect of Additive loading to wear of the SS201 specimen.

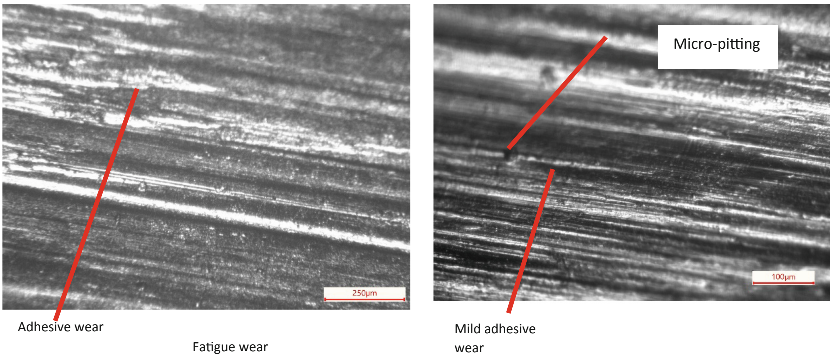


(a) 50× mag. (b) 100× mag.

Fig. 4. Surface morphology of worn SS201 pin lubricated with castor oil and 1.75 wt.% ZDDP.

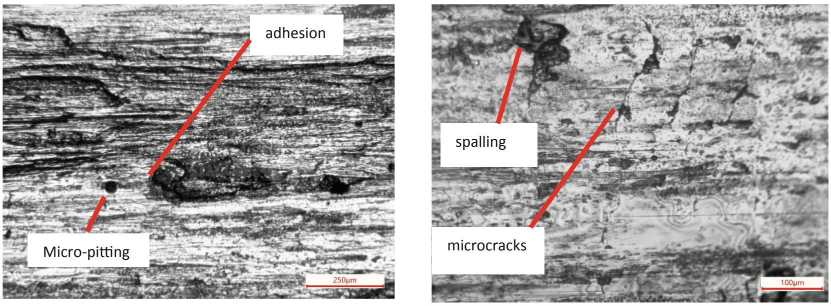
surface lubricated with castor oil and 2 wt.% ZDDP. This composition is the starting point of incremental of wear again. It can be observed that fatigue wear and adhesive wear getting strong on the worn surface and trace of oil physisorption not clearly expose. Thus, it can be concluded that physisorption of ZDPP to the steel surface was reduced, resulting in a stronger adhesive and fatigue wear to the surface.

Figure 6 shows the surface morphology of SS201 pin wear lubricated with 1.5 wt.% MoDTC. This oil sample shows the highest wear compared to other MoDTC added oil. Adhesion wear accompanied by spalling clearly observed on the wear surface. Several microcracks due to surface fatigue also clearly observed on the wear surface. This wear mechanism is believed to be main reason for high wear observed at this sample. Figure 7 shows the Surface morphology of worn SS201 pin lubricated with castor oil and 2.25 wt.% MoDTC. Several marks of adhesion and fatigue wear were observed on this pin



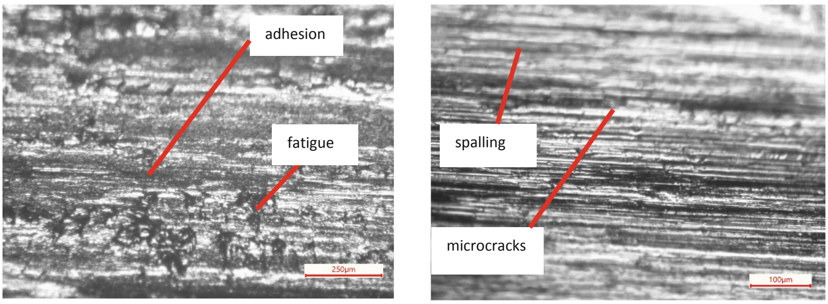
(a) 50× mag. (b) 100× mag.

Fig. 5. Surface morphology of worn SS201 pin lubricated with castor oil and 2.5 wt.% ZDDP.



(a) 50× mag. (b) 100× mag.

Fig. 6. Surface morphology of worn SS201 pin lubricated with castor oil and 1.5 wt.% MoDTC.



(a) 50× mag. (b) 100× mag.

Fig. 7. Surface morphology of worn SS201 pin lubricated with castor oil and 2.25 wt.% MoDTC.

surface although this oil sample shows low wear. No trace of absorbed lubricant on the steel surface observed which possibly broken during cleaning up procedure after the testing.

4 Conclusion

ZDDP and MoDTC are typical additives added to enhance tribological properties of mineral and synthetic lubricant base oil. Based on the results of wear testing, it can be concluded that addition of small amount of ZDDP into castor oil can enhance wear prevention of the oil with optimal value obtained at 1.75 wt.% ZDDP. In contrast adding more MoDTC to castor oil increase wear prevention of the castor oil with optimal value obtained at 1.5 wt.% MoDTC. Not only related to the additive loading, wear prevention of castor oil also related to surface interaction between the pin and disc. Wear mechanism also play a role on the wear of the sample.

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