Tribological Performance of Palm Olein with Additive Using Linear Reciprocating Tribotester

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Abstract. As engine oil supplies deplete and prices rise, study on alternative vegetable oil bases is becoming one of the most important studies in applying green technology. However, due to the lack performance of the vegetable oil as lubricant, previous researcher indicates that additives is needed in order to provide excellent lubricity efficiency. This research is aim to use a linear reciprocating tribometer to study the effect of the coefficient of friction (COF) and wear behaviour of Palm Oil with the addition of Molybdenum Disulfide (MoS2). The sample of 2 cm diameter plate material used in this experiment is steel SKD-11, and the material for the ball bearing is tool steel with a diameter of 10 mm. For each load, the tribological properties of PO + 0.05wt% MoS2 will be compared to RBD Palm Olein (PO) and benchmark lubricant Engine Oil SAE10W-30 (EO). According to the findings of this study, the COF for PO + 0.05wt% MoS2 increases from 0.055 to 0.069 at loads ranging from 50 N to 150 N, but decreases marginally to 0.063 at loads above 150 N due to wear debris that serves as a defensive layer on surfaces. At load 200 N, PO + 0.05wt% MoS2 has a 4.5% COF and a 5.5% smaller wear scar diameter than PO.

Keywords: Tribology · Palm oil · Friction · Wear · Biodegradable material

1 Introduction

Using palm oil as a lubricant requires a high load-carrying capability and good lubrication over a wide range of speeds, temperatures, and contact geometries. Several researchers have investigated the use of palm oil in various engineering applications such as proposed by Yahaya et al. [1] and Hasan et al. [2] that study the performance of palm olein that been blended with mineral oil. Palm oil has also been studied by applying additives, as demonstrated by Sapawe et al. [3] where the result shows that different type of additives has a significant impact depend on type and application (Load, speed and temperature) improvement of lubricant that been used. Kiu et al. [4] investigated the use of additives in vegetable oil using a four-ball tribotester, and found that the vegetable oil's tribological performance had improved. The effect of lubricant as a nanofluid also investigated in simulation works [5].

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Because of its low friction and robustness, MoS_2 is commonly used as a dry lubricant. Although it has a low friction coefficient, it not behaves like graphite because it does not rely on adsorbed vapours or moisture [5–7]. In fact, adsorbed vapors might result in a slight increase in the friction coefficient. Besides that, molybdenum sulfide is a diamagnetic which can be repelled by a magnetic field. The indirect bandgap semiconductor for MoS_2 also was similar to silicon, which is 1.23 eV. MoS_2 is naturally found as either molybdenite, a crystalline mineral and low-temperature form of molybdenite. Molybdenite ore is processed by flotation, which is a process for separating the different minerals in a mass of powdered metal based on their tendency to sink in, or float on, which will result to a relatively pure MoS_2. The primary contaminant for MoS_2 is a carbon [6]. In other words, MoS_2 is a mixture that can be applied to a lube oil to enhance lubricant performance. This can be the best way to reduce friction in lubricant to help in maintaining the industrial factory, especially in the manufacturing sector which involved in high load operating a machine that uses a lubricant to manage its maintenance.

As a promoting the use of palm oil as a lubricant, this research is aiming to use the additive in order to improve the lubrication performance of palm olein. The experiment is been tested by benchmarking with RBD palm olein (PO) and commercial engine oil (EO) using linear reciprocating tribometer to evaluate the coefficients of friction, to analyse the wear scar diameter and to observe the wear formation of all sample.

2 Methodology

2.1 Sample Lubricant

Table 1 shows the physicochemical properties of palm olein and engine oil. Until the mixing phase begins, the weight of the palm oil and MoS_2 nanoparticles is determined using a weighing machine. The ratio of the mixture is been mixed using Eq. 1.

$$\frac{MoS_2(g)}{Palmolein(g) + MoS_2(g)} \times 100\% = 0.05wt\% \tag{1}$$

Table 1. Physicochemical properties of sample lubricant

Physicochemical test	Palm olein	Engine oil
Iodine value (mg Koh/g oil)	61.7	–
Cloud point (°C)	7 (±1)	–
Pour point (°C)	5 (±1)	−12 (±1)
Flash point (°C)	>320 (±5)	>200
Density at 25 °C (kg/m^3)	915.5	897.1
Kinematic viscosity at 40 °C (cSt)	45.9	128.8
Kinematic viscosity at 100 °C (cSt)	9.4	15.2
Viscosity index	195	96

2.2 Experimental Set up

A linear reciprocating tribometer is one tool for experimenting with friction and wear scar. The load applied to the mounting bearing ball, the slipping speed or frequency of the balls, the time for testing the experiment, and the stroke length of the ball are the four major parameters conditions that must be regulated for the linear reciprocating tribometer. Table 2 shows the specification of the linear reciprocating tribometer (Fig. 1).

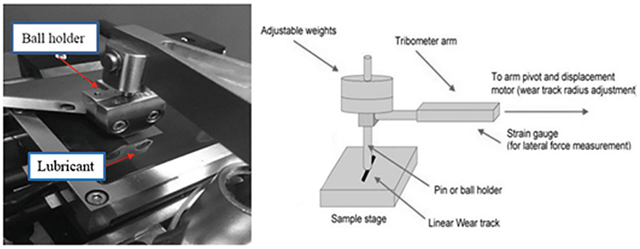

Fig. 1. Linear reciprocating tribotester.

Table 2. Experimental condition

Load	50 N, 100 N, 150 N, and 200 N
Lubricant temperature	100 °C
Sample lubricant	Commercial engine oil (EO), RBD palm olein, and palm olein mix with additives
Duration	10 min
Frequency	2 Hz
Volume sample	18 ml

3 Result and Discussion

3.1 Coefficient of Friction

Figure 2 illustrates the variation of COF values with load for Engine Oil 10W30, Palm Olein, and Palm Olein with nanoparticle additives PO + 0.05 wt percent MoS_2. PO + 0.05wt% MoS_2 has a lower COF than Engine Oil 10W30 and Palm Olein. The maximum friction coefficients for Palm Olein and PO + 0.05wt% MoS_2 are obtained at load 150 N, where the COF value for Palm Olein is 0.073 and the COF value for PO + 0.05wt% MoS_2 is 0.069. Engine oil has the highest COF value at 100 N, which is 0.098, whereas PO + 0.05 wt% MoS_2 has the lowest COF value at 50 N, which is 0.055.

In general, as the applied load increases, so will the COF values. As the load approaches 150 N, the COF seems to be slightly raised from range 0.057 to 0.073 for Palm Olein and 0.055 to 0.069 for PO + 0.05 wt% MoS_2. According to Maleque

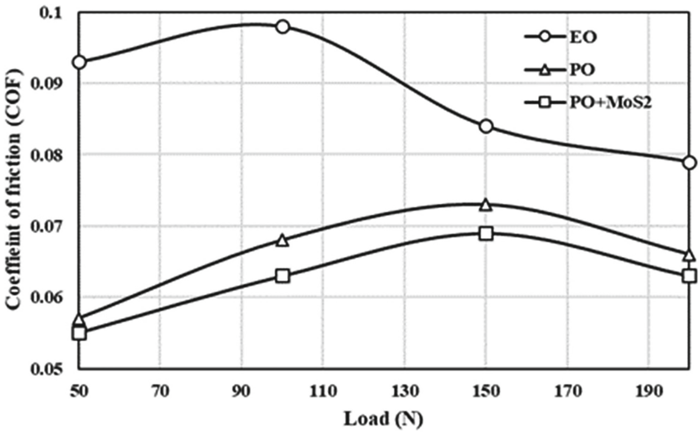

Fig. 2. Coefficient of friction for all sample lubricants

et al. [6], higher loads and temperatures result in more metal-to-metal interaction due to the destruction of the protective film. However, as reaching 200 N, the COF values are reversed and marginally reduced. Palm olein has a low coefficient of friction since its molecular structure contains a fatty acid structure that serves as a film layer on the material's structure, as discussed by previous researchers [8, 9]. The presence of fatty acid aids lubricant molecules in adhering to ball bearing surfaces and maintaining the lubricant layer. This finding is confirmed by Lawal et al. [10], who claim that long chain fatty acids can help to reduce the coefficient of friction. It could be said that a significant amount of wear debris is thought to be responsible for the decrease in friction with increasing normal load, where the wear debris generated can interfere with the metal surface and serve as a protective layer to resolve high frictional force and metal to metal direct contact, resulting in a lower value of COF [11, 12, 13, 14].

PO + 0.05 wt% MoS_2 has the lowest COF value as compared to Engine Oil and Palm Olein. These good lubricity properties are due to the inclusion of molybdenum disulfide nanoparticles in Palm Olein, where Molybdenum disulfide serves as anti-wear additives. As stated by Asrul et al. [15], the anti-wear mechanism of molybdenum disulfide nanoparticle can be clarified when the lubricant film becomes thinner and boundary lubrication occurs, the nanoparticle can carry a proportion of load and separate the two surfaces to prevent adhesion, thus benefiting the anti-wear properties. Besides that, Choi et al. [16] also addressed that the value of COF for PO + 0.05 wt% MoS_2 is low because of the hexagonal structure of the MoS_2, the layers of MoS_2 shear off by the application of load and these layers formed a protective layer on the surface.

3.2 Wear Scar Diameter

Figure 3 represents the relationship between the wear scar diameter (WSD) for three different varieties of sample lubricant oil and the increment value of the applied load. The obtained results show that all of the wear scar diameters for each lubricant show the same increasing trend. The range of wear scar diameter obtained from 50 N to 200 N for Engine Oil is between 596.2 μm to 770.3 μm, Palm Olein is between 569.4 μm to 777.5 μm and PO + 0.05 wt% MoS_2 is between 561.9 μm to 734.7 μm. At loads between 50 N and 100 N, Engine Oil has a larger wear scar diameter than Palm Olein and PO + 0.05wt% MoS_2, but as it gets up to 150 N, it has almost same wear scar diameter as Palm Olein, which is 723.2 m and 725.4 m.

Based on the graph's trend, it can be inferred that as the applied load increased, the wear scar diameter increased slowly and gradually. The formation of shear stress on the metal-metal interface surface can be explained as the cause of this. According to Choi et al. [1], as the wear scar diameter increases due to an increase in applied load, there will be higher shear stress due to frictional contact, and the mild wear will gradually turn into extreme wear. We can also see that the WSD for Palm Olein is greater than of Engine Oil at high load. These findings are close to those obtained by Fazal et al. [6], who discovered that the film stability of vegetable oils varies based on operating conditions such as temperature, speed, and viscosity.

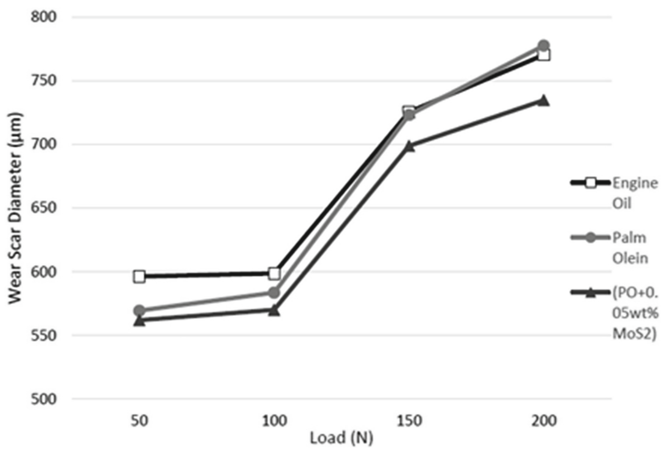

Fig. 3. Wear scar on ball bearing

Figure 4 shows that all of the wear scar diameters for each lubricant increase in the same direction. The wear scar diameter pattern for Palm Olein and Engine Oil has slightly changed over the load increment of 50 N to 200 N. According to the graph, at low loads of 50 N, the value of wear scar diameter for Palm Olein is greater than of Engine Oil, but when the load is increased to 200 N, the effect is the same, with the value of wear scar diameter for Engine Oil being greater than the Palm Olein, but the difference seems to be minor since both patterns are similar to each other.

According to the result obtain, the addition of molybdenum disulfide nanoparticles to vegetable oil results in the smallest wear scar diameter. It can be concluded that the excellent lubricating properties of MoS_2 are due to its strong covalent bonding, which results in strong polarization of the sulfur atoms. He also claims that MoS_2 is unique among layer lattice materials due to the strong polarization properties of two atoms, which provides excellent metal adhesion and film-forming properties. As a result, MoS_2 nanoparticles can minimize friction and wear in any high-load operating machine.

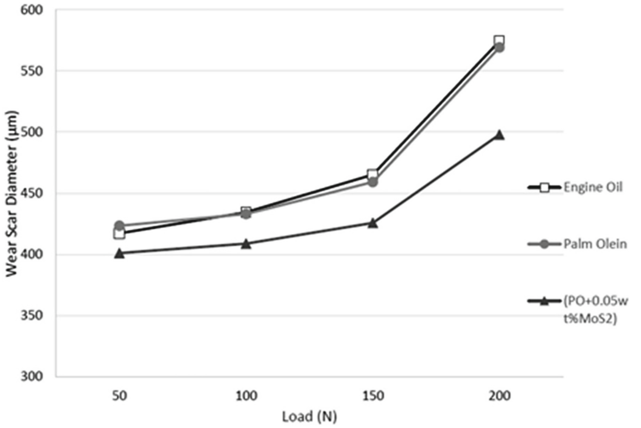

Fig. 4. Wear scar on plate surface

4 Conclusion

After doing the data analysis of test, it can be concluded that wear resistance characteristics of Palm Oil with 0.05 wt% of Molybdenum Disulfide (PO + 0.05 wt% MoS_2) are as follows:

1. PO + 0.05wt% MoS_2 is a better friction reducer at lower and higher load compared to Palm Oil alone and Engine Oil based on the lower value of friction coefficient due to the addition of nanoparticles additive that give better lubricity performance thus provide extra protective layer on the surfaces.
2. The wear scar diameter of the ball specimens and plate surfaces increases as the applied load increase but the present of additive has led to much lower compared to Engine Oil and Palm Olein (PO).

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