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Comparison of Tribological Properties Between Canola Oil+ZDDP and SAE 40 Lubricants

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Abstract: The needs of replacing mineral based lubricants with a renewable, biodegradable and low toxicity lubricant is essential as to curb the environmental issues imposed by mineral based lubricants. This study reports the development or a new bio-lubricant using canola oil with the addition of Zinc Dialkyldithiophosphate (ZDDP) as anti-wear and anti-friction additive. It also presents the comparison data of tribological properties of the newly developed bio-lubricant against the commercially available SAE 40 mineral oil. From the data, it is evident that canola oil added with 2 wt% ZDDP is the most desirable addition as it gives the lowest coefficient of friction at 0.081 and the lowest wear scar diameter at 34.72 μ. These values are even lower than a commercialized mineral based lubricant SAE40. It can be concluded that canola oil with the addition of ZDDP at 2 wt% has a wide prospect in becoming an alternative green lubricant replacing the commercially available SAE40 lubricant oil.

Key words: Bio-lubricants, canola oil, ZDDP, anti-wear, friction

INTRODUCTION

Lubricants are substances that are used to facilitate two moving parts in contacting. Apart from that, it is also used as a friction reducer, reducing wear agent and dissipating friction heat (Bannister, 1996). For many years, starting from the ages of industrial revolution era, mineral based oil from petroleum produce has been used as the base stocks of liquid lubricants. The revolution of mineral based lubricants continues with the development of new semi-synthetic and fully synthetic lubricants for industrial and machinery use. However with the increasing concerns on environmental issues which includes the toxicity, biodegradability and renewability of mineral based lubricants, studies have being conducted in order to search for an alternative which is more environmental friendly but at the same time possess the same lubricity effect that is required by a lubricant.

Biodegradable oil based on animal and vegetable has been widely used as lubricants dated way back in 1400 BC (Pirro and Wessol, 2001). The use of animal fats added with mineral additives was used as lubricants to lubricate chariot wheels. However, with the emergence of petroleum based products, these biodegradable substances had been replaced. But, with the new emerging trends, vegetable oils are back in the limelight and studies have been conducted to investigate the probability and feasibility as replacement to mineral based oil. Vegetable oil is chosen as base stocks by many researchers to date as they possess high lubricity (Azhari *et al*., 2014; Mahipal *et al*., 2014). Apart from that, vegetable oil has higher flash and fire points, high thermal stability and high biodegradability compared to mineral based oil. These are the leading factors for choosing vegetable oil as base stocks for the development of lubricants. However, the addition of additives into lubricants could enhance the properties and performance of a lubricant. Organophosphorous and organosulphur compounds such dithiophosphate and dithiocarbamate are normally added into lubricant base stocks as to improve the property of lubricity. The addition of these compounds is to facilitate the lubricant performance by reducing wear and friction between 2 contacting surfaces. As such, anti-wear and anti-friction additive is to be added to vegetable oil to investigate if it will increase the performance as a lubricant compared to the commercial SAE 40 mineral based oil. This will later determine if the newly developed oil are suitable to be a replacement alternative to the commercialized SAE 40 mineral based lubricant oil.

MATERIALS AND METHODS

Commercialized cooking canola oil was purchased from local store and used as is. Zinc Dialkyldithiophosphate was added into canola oil at

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0-3 wt% using direct introduction method to see the effect of ZDDP concentration upon tribological properties of canola oil added with ZDDP. The solutions were then heated in a water bath at 50°C for 2 min to facilitate miscibility between the two substances. SAE 40 mineral based lubricant oil purchased from a local store was used as is without any addition of additives. Upon completion of sample preparation, the samples were tested using a Spectroil Rotating Disc Electrode-Atomic Emission Spectrometer (RDE_AES) to investigate the concentration of Phosphorous and Zinc elements in the prepared samples as well as SAE 40 mineral based lubricant oil. Ducom Four Ball Tribometer was used to investigate the coefficient of friction and wear scar diameter of all samples including the SAE 40 mineral based lubricant oil.

RESULTS AND DISCUSSION

Zinc and phosphorous concentrations: Table 1 exhibits the concentration of zinc and phosphorus in the newly developed bio-lubricant as well as SAE 40 mineral oil. It can be seen that, for pure canola oil without any addition of ZDDP, there were no zinc particle detected and 28 ppm of phosphorus was detected. With the addition of 1 wt% of ZDDP, the concentration of zinc and phosphorus increased to 508 and 563 ppm respectively. Further addition of ZDDP to 2 and 3 wt% into canola oil showed that zinc concentration has increased to 1113 and 1834 ppm while the concentration of phosphorus was recorded at 1253 and 2170 ppm. This shows that, there were increment of zinc and phosphorus concentration as the ZDDP addition into canola oil is increased. This condition can be suggested that the ZDDP was successfully dissolved into the canola oil since according to Azhari *et al*. (2006) positive increment of zinc and phosphorus concentration with increment of ZDDP addition proved that ZDDP has completely dissolved in the parent base oil. On the other hand, concentration of zinc and phosphorus for SAE 40 mineral oil was observed which zinc was found at 1130 ppm while phosphorus at 1217 ppm. This zinc and phosphorus concentration is found similar to the concentration of zinc and phosphorus of canola oil with 2 wt% of ZDDP. Thus, it can be suggested that the SAE 40 mineral oil also was added with 2 wt% of ZDDP during production of the oil. On the other hand, with similar concentration of ZDDP additive addition, it is expected both oil will show similar performance in the characterization process due to similar type and concentration of additive contain.

Effect of zddp on coefficient of friction: Figure 1 displays the coefficient of friction of canola oil added with ZDDP and SAE 40 mineral based lubricant oil. From Fig. 1, it is evident that canola oil added with 0wt% of ZDDP reads at 0.140. With the addition of 1 wt% of ZDDP, the coefficient of friction reduces to 0.084. Further addition of ZDDP to 2 wt% causes the coefficient of friction to continue reducing to 0.081. However, with 3 wt% of ZDDP added into the canola oil, the coefficient of friction increases to 0.121. This condition can be explained that at 1 and 2 wt% of ZDDP addition, the amount of zinc and phosphorus particles produced a boundary film that could reduce the friction between two surfaces contacting (Azhari *et al*., 2006). This condition was also proved by Mahipal *et al*. (2014) in which the study found that 2 wt% of ZDDP is the optimum amount to be added in karanja oil in order to have a boundary film layer that act as friction modifier for the bio-lubricant. Thus, this also explained that at 3 wt% of ZDDP, the amount of zinc and phosphorus was exceeded and multiple layer of boundary film is formed (Minfray *et al*., 2003). With multiple layer of film formed, the friction will be increased due to the collision between the layers and the coefficient of friction will also be higher (Minfray *et al*., 2003). This explained why coefficient of friction reduces when 1 and 2 wt% of ZDDP addition and increases at 3 wt% of ZDDP addition into the canola oil.

Table 1: Zn and Phosphorus concentration of newly developed bio-lubricant and SAE 40 mineral oil

Type of oil	Element: Zn	p
Pure canola	<1	28
Oil canola oil with 1 (wt% ZDDP)	508	563
Canola oil with 2 (wt% ZDDP)	1113	1253
Canola oil with 3 (wt% ZDDP)	1834	2170
SAE 40	1130	1217

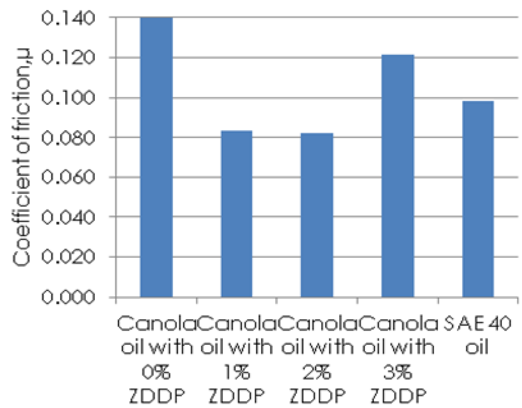

Fig. 1: Coefficient of friction of newly developed bio-lubricant and SAE 40 mineral oil

Besides that, coefficient of friction of SAE 40 mineral oil was observed at 0.098 in Fig. 1 which is higher than

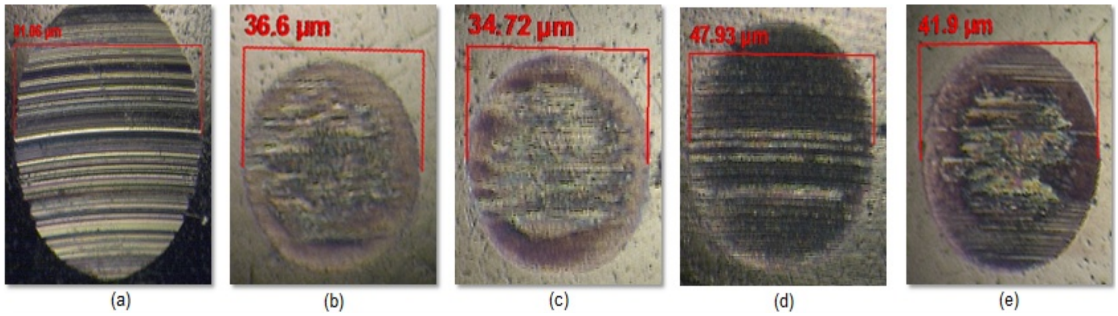

Fig. 2: Wear Scar Diameter Image Under Light Microscope: a) Wear scar diameter for pure canola oil; b) Wear scar diameter for canola oil with 1 wt% of ZDDP; c) Wear scar diameter for canola oil with 2 wt% of ZDDP; d) Wear scar diameter for canola oil with 3 wt% of ZDDP; e) Wear scar diameter for SAE 40 mineral oil

canola oil with 2 wt% of ZDDP. Although the amount of zinc and phosphorus particle inside the SAE 40 mineral oil is similar, however the coefficient of friction of both oils is different. This condition can be explained that the coefficient of friction of SAE 40 mineral oil is higher because of the type of oil is different. It was found that fatty oil from canola oil will gives strong absorption onto the metal surfaces thus the lubrication film formed by canola oil will adheres more strongly to the surface than mineral oil (Applewhite, 1993). Therefore, less friction will occur and low of coefficient of friction resulted by canola oil with 2 wt% of ZDDP.

Effect of zddp on wear scar diameter: Figure 2 indicates the wear scar diameter of newly developed bio-lubricant and SAE 40 mineral oil. It is observed that wear scar diameter for pure canola oil is at 81.06 μm. Then, with addition of 1 wt% of ZDDP, the wear scar diameter decreased to 36.6 μm. Further addition of ZDDP to 2 wt%, the wear scar diameter continues to decrease to 34.72 μm. However with 3 wt% of ZDDP added into the canola oil, the wear scar diameter observed is increased to 47.93 μm. This trend of decrement and increment of wear scar diameter is found to have a clear correlation with coefficient of friction whereby the result decreased as ZDDP added up to 2 wt% and then increases at 3 wt% of ZDDP addition. This proved that there was a correlation between wear scar diameters, coefficient of friction and amount of zinc and phosphorus particle as at 2 wt% of ZDDP, the right amount of zinc and phosphorus will form a boundary film layer and resulted in reducing the coefficient of friction. Thus wear scar diameter should be decreased as well as less friction was occurred (Azhari *et al*., 2014). On the other hand, at 3 wt% of ZDDP, the zinc and phosphorus particle has exceeded and multiple layer films were formed and this resulted to increment of the coefficient of friction and wear scar diameter since thickness of lubrication film increased makes the performance of the bio-lubricant as anti-wear reduces (Burkinshaw *et al*., 2014).

Other than that, the wear scar diameter of SAE 40 oil is observed at 41.9 μm which is higher than canola oil with 2 wt% of ZDDP at 34.72 μm in the Fig. 2. This condition can be explained that there were correlation between the type of oil, coefficient of friction and wear scar diameter whereby vegetable oil was found can adheres more to the surface than mineral oil (Applewhite, 1993). This will lead to low of coefficient of friction and then resulted to low of the wear scar diameter since as less friction produced makes less wear to be occurred (Azhari *et al*., 2014). Therefore this proved that wear scar diameter is correlated with the coefficient of friction and the type of oil as canola oil with 2 wt% of ZDDP give low coefficient of friction and wear scar diameter than SAE 40 mineral oil. From this result, it can be suggested that canola oil with the addition of 2 wt% ZDDP is more desirable as it exhibits a lower coefficient of friction and wear scar diameter compared to the commercial SAE 40.

CONCLUSION

The new bio-lubricant using canola oil with the addition of ZDDP additive was successfully developed. From the testing of coefficient of friction and wear scar diameter upon all newly developed bio-lubricants, it is evident that the most desirable concentration of ZDDP addition into canola oil is at 2 wt%. It is proven that, at 2 wt% ZDDP addition, the coefficient of friction and wear scar diameter of the bio-lubricant is the lowest compared to the other ZDDP concentrations. It is also evident that the coefficient of friction and wear scar diameter of canola oil added with 2 wt% ZDDP is lower compared to commercial SAE 40 mineral based lubricant oil. This shows that there is a possibility for canola oil added with

ZDDP to be proposed as an alternative lubricant to replace the commercial mineral based lubricant oil based on the better tribological properties that was portrayed by canola oil compared to SAE 40.

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