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TRIBOLOGICAL FEATURES OF REFINED, BLEACHED AND DEODOURISED (RBD) PALM OLEIN BLENDS WITH MINERAL OIL

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ABSTRACT

Vegetable oil has been investigated to replace petroleum-based products due to its environment-friendly characteristics and has become a vital source of bio-lubricants. The usefulness of vegetable oil is its availability as one of the renewable sources. Additionally, the vegetable oils based lubricant has indicated the potentials for reducing carbon dioxide and hydrocarbon emission while operating in internal combustion engines and in industrial process. There are two ways for using vegetable oils as bio-lubricants, either by directly using the neat vegetable oils without blending or using certain blending ratio of the vegetable oils along with the commercial lubricants. In this paper, the influences of the blending ratio of mineral oil with one type of vegetable oil was investigated on the tribological characteristics and compared with commercial lubricant oil using the four ball tribotester. Refined, bleached and deodorized (RBD) palm olein was blended at volumetric ratio ranging from 20 to 80 % with commercial mineral oil. All experimental works were conforming to ASTM D4172. The results exhibit that some blends of RBD palm olein with commercial lubricant oil have lower the wear scar diameter compared to mineral oil. Blends exhibit lower the wear scar diameter and coefficient of friction compared to commercial lubricant oil. As conclusion, the blends of RBD palm olein with commercial lubricant oil has better tribological performance compared to commercial mineral oil or neat RBD palm olein.

Keywords: *Refined, bleached and deodorized palm olein, blending ratio, wear scar diameter, coefficient of friction*

1.0 INTRODUCTION

Starting in the early 19th century, engineers and researchers found effective solution to increase the production of petroleum. This has led to the production of low-priced petroleum-based lubricants, which brought into society, the greenhouse effect and the issues of global warming. The increase of worldwide concerns about health, the environment and limited petroleum resources has promoted the use of biodegradable products. Special attention has been paid to protect the environment against pollution caused by the petroleum based lubricants. A survey study found out that nearly 12 million tons of lubricant wastes were deposited into the environment every year [1].

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Consequently, the increased knowledge about the ecological pollutions and the biodegradable oil products has also become one of the vital alternatives to the petroleum based lubricants. Animal fats and vegetable oils are considered as substitutes for the mineral-based oil as bio-lubricants. Bio-lubricants, also known as bio-based lubricants are made from a variety of edible oils such as rapeseed, canola, sunflower, soybean, palm and coconut oils and the non-edible oils from jatropha, jojoba oils. The usage of bio-lubricants from non-edible oils can overcome the problems of food verse fuels, lubricants, environmental and economic issues related to edible vegetable. Non-edible oils are not suitable for human food due to the presence of some toxic components in the oils. The selection of non-edible oils as lubricants requires extensive characterisation works. Moreover, non-edible seed crops are expected to use lands that are largely unproductive and those that are located in poverty-stricken areas and in degraded forests [2].

The advantages of choosing vegetable oils rather than mineral lubricants sources are the fact that they are biodegradable and are less toxic as compared to petroleum-based oil. They are easy to produce from renewable source. In addition, during an investigation on the tribological behaviour of two contact sliding metals between one another using biodegradable oil as lubricant, they showed that the vegetable oils possess even a better lubricating ability compared to mineral or synthetic oils because they contain a large amount of unsaturated and polar ester groups components that favourably affected the conditions during the reciprocating sliding motion [3]. Moreover, the long chain fatty acids in vegetable oils have better intrinsic boundary lubricant properties. Vegetable oils reveal good lubricating abilities because they produce low coefficients of frictions. On the other hand, other scholars have reported that most vegetable oils having lower coefficient of the frictions, but has higher wears rate. In another study on the chemical reaction on the surfaces of metal where the fatty acids were present in the vegetable oils, they discovered that the metallic soap films are washed away during sliding, and produces the non-reactive detergent which increases the wear [4].

Several researchers have tested palm oil for engineering applications, which includes crude palm oil as a potential fuel in diesel engines [5], the potential of palm oil as hydraulic fluid [6, 7] and the characteristics of palm oil as a metal forming lubricant [8, 9]. The research on palm oil as lubricant can be categorized into four major groups, where (1) uses 100% palm oil as a test lubricant [10, 11], (2) uses palm oil emulsion [12], (3) uses palm oil with additives [13] and (4) uses palm oil as an additive [14]. All of them found out that palm oil showed satisfactory results and has a potential to be used widely in engineering applications. However, some factors such as the oxidation of vegetable oil must be taken into consideration. In the early 1990s, the Palm Oil Research Institute of Malaysia – PORIM (presently known as Malaysian Palm Oil Board – MPOB) has successfully converted crude palm oils into palm oils methyl ester. PORIM used the trans-esterification method, which shortens the molecular chain in the palm oil to twenty molecules from about fifty seven, reducing the palm oil viscosity and making it less polluting. According to Maleque and Masjuki [11], the transesterification also improved the thermal stability of palm oil. In the previous studies, researchers used various vegetable-oil-based lubricants and additives, but there are very limited references that use refined, bleached and deodorized (RBD) palm olein as the base lubricant. This study investigates the coefficient of frictions and wears performance of RBD palm olein blends with mineral oil in different blending volume ratio using a four ball tribotester.

2.0 EXPERIMENTAL METHOD

This study uses a four-ball wears tester machine as described by Boerlage [15] in the investigations of the characteristics of the lubricant. The instrument used four balls, three balls at the bottom and one ball on the top. The three-bottom ball is held strongly in a ball pot having lubricants that being tested and pressed against the top ball. The top ball is made to rotate at the desired speed while the bottom three balls are pressed against the top ball. The surfaces of the components were cleaned with acetone before conducting each test. A thermocouple was embedded at the bottom of the ball pot to measure the oil temperature. A heating block is located at the bottom of the ball pot which controls the temperature of the experiments. In this study, wear test was conducted at 40 kg loads and at 1200 rpm for 1 hour at lubricant temperatures of 75°C.

2.1 Materials

The standard balls used in this experimental study are made from AISI E-52100 chrome alloy steel, with the following specifications: diameters 12.7 mm; extra polish (EP) grade 25; hardness 64–66 HRC (Rockwell C Hardness). Four new balls were used for each test.

2.2 Lubricants

The lubricants used for this experimental study were RBD palm olein. This oil was blended separately with 20-80% by volume of mineral engine oil. The results obtained from experiments using RBD palm olein oil in different volumetric blending ratios were compared with the results of the commercial mineral oil (SAE 10W-30) (ENG100). Each trial test uses 10 ml of the lubricant.

3.0 TEST PROCEDURES

Before setting up the tribotester, the ball pot and the steel balls were thoroughly cleansed using acetone and wiped dry using fresh lint free industrial wipe. No trace of solvent should have been left when the lubricants were introduced and the parts were placed together. The steel balls were placed into the ball pot assembly and the assembly was tightened using a torque wrench in order to prevent the bottom steel ball from moving during the experiments. The top, spinning ball was locked inside the collet and tightened onto the spindles, then the test lubricants were introduced into the ball pot assembly. The assembled ball pot components were installed onto the non-frictions disc in the four-ball machine and the test load was applied slowly to avoid the shock loadings. Thereafter, the lubricant was heated to 75°C by the tribotester built-in heater. When the set temperature was reached, the motor was switch on to drive the top balls at a desirable speed. After one hour, the heater was turned off and the oil cups assembly was removed from the machine. The test oil was drained off from the oil cup and the ball bearings were wiped using fresh lint free industrial wipe.

3.1 Wear Scar Diameter

The wear scar diameter of each of the three bottom test balls was measured to determine the lubricity performance of the test lubricant. In general, the larger the wear scar diameter, the more severe the wear. The wear scar was evaluated by computer optical and scanning electronic microscope (high resolution) software and from the captured photomicrograph. Using this process, the wear scar diameter was determined for each of the three fixed balls.

3.2 Friction Torque and Coefficient of Friction

From the four-ball tribotester machine, the friction torque was recorded using specific data acquisition system. The frictions torque for all test lubricants has increased rapidly at the beginning of the test from 5 to 10 min. The friction torque data became stable and steady-state condition after 10 min.

The average of friction torque at the steady state condition was recorded and the friction coefficient, as calculated according to IP-239, is shown in Equation (1):

$$\mu = \frac{T\sqrt{6}}{3Wr} \tag{1}$$

where μ is the frictions coefficients, T is the frictional torque in kg mm, W is the apply loads in kg and r is the distance from the center of the contact surfaces on the lower balls to the axis of rotation, which was set as standard 3.67 mm for the specific ball diameter. The same calculation method was used by [16]. The frictional torque data was recorded by the computer, which calculated the friction coefficient automatically.

3.3 Flash Temperature Parameter

The flash temperature parameter (FTP) is a single number which is utilized for expressing the critical flash temperatures at when the lubricants will fail under certain given condition. The FTP shows fewer possibilities of lubricant films for breaking down [17]. High value of FTP shows high performances of the lubricants.

The FTP can be measured by using the Equation (2):

$$FTP = \frac{W}{(WSD)^{1.4}} \tag{2}$$

where W is the applied load in kg and WSD is the wear scar diameter in mm.

4.0 RESULT AND DISCUSSIONS

The effects of RBD palm olein and blends lubricant were investigated and characterized. The results provide an insight to better understanding of the worn surface of ball bearings with RBD palm olein and blends using oil analysis like the kinematic viscosity analysis, WSD, COF and FTP. The results were compared with 100% commercial mineral lubricant.

4.1 Kinematic Viscosity and Viscosity Index

Kinematic viscosity is a measure of the resistances of a fluid which is deformed by either the shear stresses or the tensile stresses of the fluid. It is also defined as internal frictions of the fluid. A viscometer was utilized for measuring the viscosity for both lubricants and for evaluating the fluidity. The viscometer has a spindle that rotates with a certain speed. After inserting the spindle into the lubricant, the speed of the spindle resisted the fluidity or viscosity of the lubricant and the viscosity could be measured. *Fig. 1a* shows the comparison in amount of kinematic viscosity of the RBD palm olein with mineral oil blends in different temperatures, i.e. 40, 75, 100 and 125 °C. This figure clearly shows that the kinematic viscosity for all blends of RBD palm olein with mineral oil decreased with the increases of the temperatures. This figure shows also, at higher temperatures the amounts of viscosity for all oils were comparable to each other. The highest amount of kinematic viscosity obtained at 40°C is 79.01 mm^2/s for blend RBD palm olein (E80/RB20), as compared with 33.86 mm^2/s for the neat RBD palm olein (E0/RB100) and 42.85 mm^2/s for the mineral engine oil (E100). However, the lowest amount of viscosity obtained at 125°C of the (E80/RB20) blend is 7.289 mm^2/s compared with the 9.16 mm^2/s for the mineral engine oil.

Fig. 1b shows the viscosity index of the RBD palm olein, mineral oil and its blends. From the figure, it is observed that the neat RBD palm olein still has a higher value with 296.97 compare with the 267.69 for the mineral engine oil. The lowest amount of viscosity index obtained for (E80/CC20) blend is 113.50. The figure also shows that the blending process cause the reduction in the amount of viscosity index but all this values are still high than required for the viscosity index (VI > 90, ISO VG32).

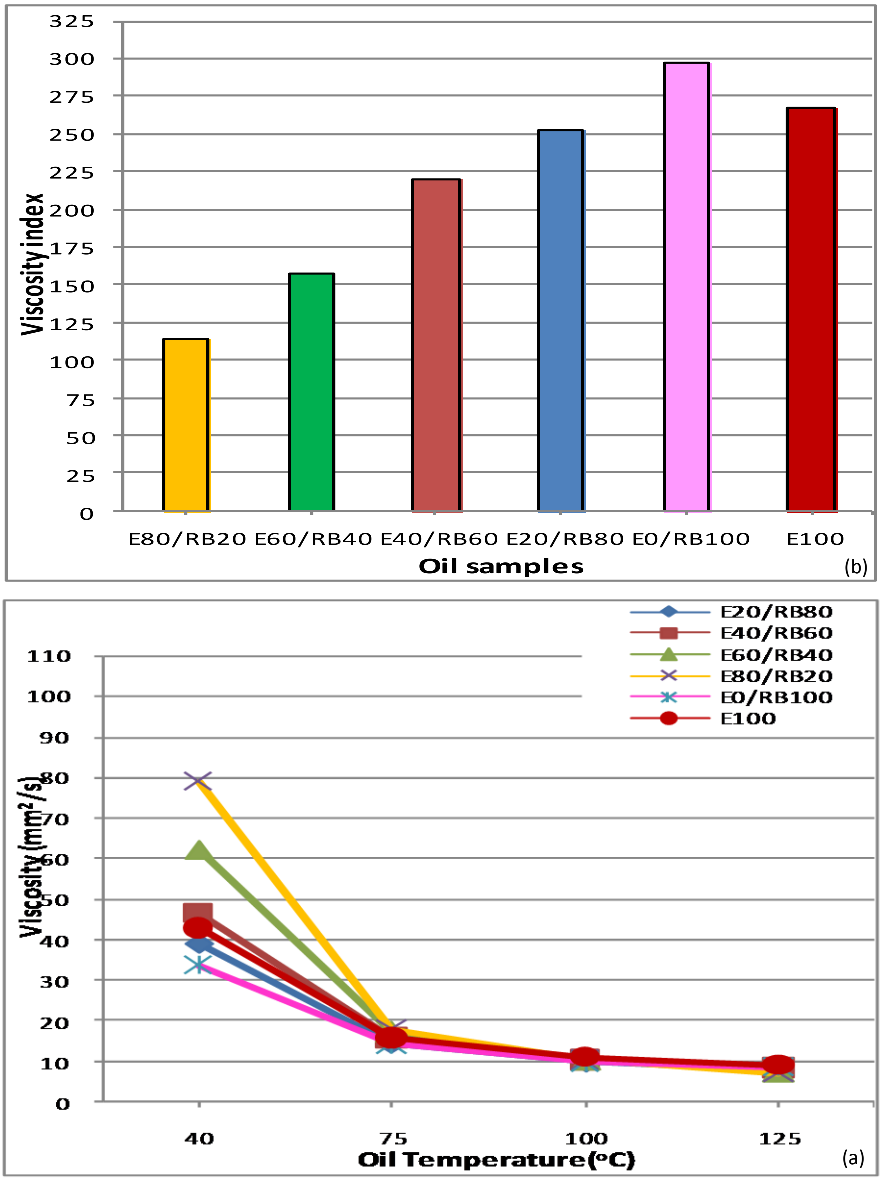

Figure 1 : RBD palm olein with mineral engine oil blends viscosity test result: (a) kinematic viscosity of the oil samples and (b) viscosity index of the oil samples

4.2 Wear Scars Diameters

The result for wears scars diameters of the three bottoms steel balls were measured using a special microscope and the mean values of three were calculated. *Fig. 2* shows the comparison of WSD between the neat RBD palm olein, blends of the RBD palm olein with mineral oil and the mineral engine oil. From the figure, could observe that the lower wear occurred at volumetric blending ratio 40% (E60/RB40), For RBD palm olein blends, the higher WSD occurred at the volumetric blending ratio 80% (E20/RB80), on the other hand, the higher wear scar diameter value occurred for the neat RBD palm olein compared to other percentages of blends and comparing with the 100% commercial lubricant. The lower value of the wear scar diameter is 408.46 μm observed for the E60/RB40 compared with the 660.8 μm for the neat RBD palm olein(E0/RB100) and

546.46 µm for the mineral oil(E100). Therefore, RBD palm olein blends works as one of the anti-wear additives and reduces the wear scar diameter.

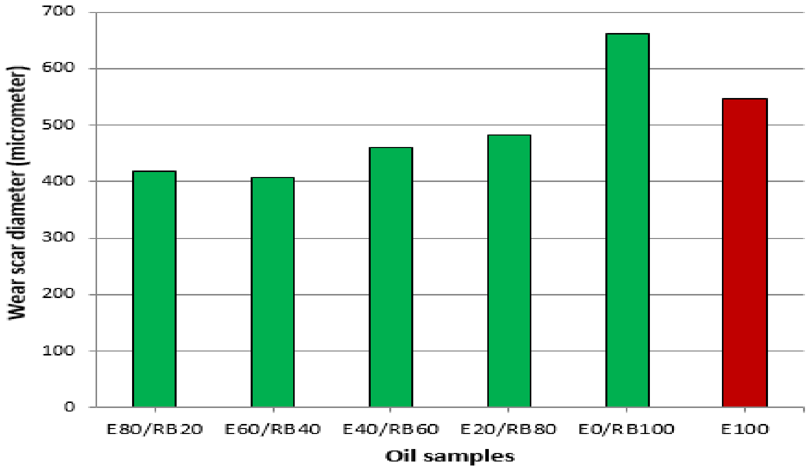

Figure 2 : Wear Scar Diameter values for oil samples.

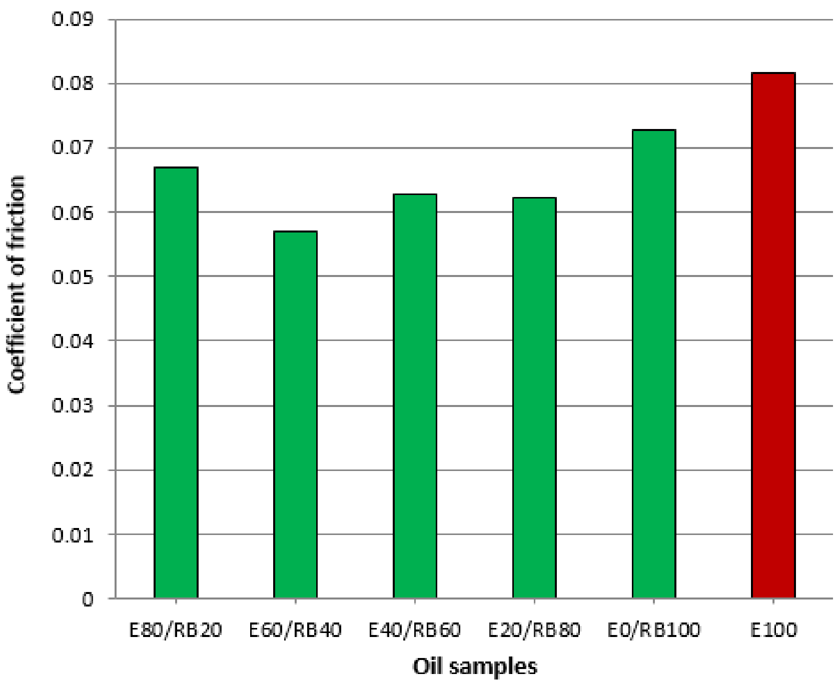

Figure 3: Coefficient of frictions values for oil samples.

4.3 Coefficients of Frictions

The coefficients of friction (COF) for RBD palm olein blends and the 100% commercial lubricant were investigated. Under each experimental condition, the COF were calculated, tabulated and the results were analyzed from *Fig. 3*. For the blends of RBD palm olein, the lowest COF occurred at volumetric blending ratio 40% (E60/RB40) it was 0.056848.

Therefore, when 40% of RBD palm olein blend with 60% of mineral oil and used as lubricants, it will give better lubricity ability in terms of friction compared to the neat RBD palm olein and the 100% commercial lubricant.

4.4 Friction Torque

To study the friction performance of RBD palm olein blends under normal load of 392.4 N (40 kg) , experiments were done at the rotational speed of 1200 rpm and the bulk oil temperature at 75 °C for one hour. The results of the friction torque tests were plotted and were illustrated in *Fig. 4*.

The friction torque results of RBD palm olein blends were compared with the 100% commercial lubricant oil and the neat RBD palm olein. The lowest value of the fiction torque compared with the all percentages of blends occurred at volumetric blending ratio 40% (E60/40RB), it was 0.10016 Nm. From the figure, all the blends and neat of the RBD palm olein have the low value of friction torque compared with the mineral oil. Therefore, the RBD palm olein blended lubricants has better lubricity abilities in terms of the frictions, because the RBD palm olein contains fatty acids that help the lubricant molecules to stick on the steel ball surface very well and maintain the lubricant layer. The presence of the thin lubricant films between the steel ball surfaces minimized the material transfer and adhesion of the two surfaces.

4.5 Flash Temperature Parameter

The flash temperature parameter is calculated and tabulated for RBD palm olein blends. The results are shown in *Fig. 5*. For the blends of RBD palm olein, the highest FTP occurred at E60/RB40 with value 140.1 compared with 93.21 for the mineral oil (E100) and 71.44 for the neat RBD palm olein(E0/RB100). Therefore, when 40% of the RBD palm olein was blended with the lubricant, it will reduction the possibility of the lubricants film to breaking down and increasing the lubricity performance compared with the 100% commercial lubricant.

4.6 Wear Worn Surface Characteristics

The optical photo micrographs in different volumetric blending ratio of the RBD palm olein with mineral oil blends shown in the *Fig. 6*. The figure shows several types of abrasive wear, such as uneven grooves and varying scar depths, were observed on the ball surfaces as shown in *Fig. 6(c and d)*. In *Fig. 6b*, parallel grooves can be seen with various depths on the worn surface.

Additionally, it could be seen the wear scar for all blending ratio of the RBD palm olein with mineral oil was found to be circular. *Fig. 6* indicates that the blend RBD palm olein with mineral oil cause a decrease in the value of the wear scar diameter compared with the neat RBD palm olein.

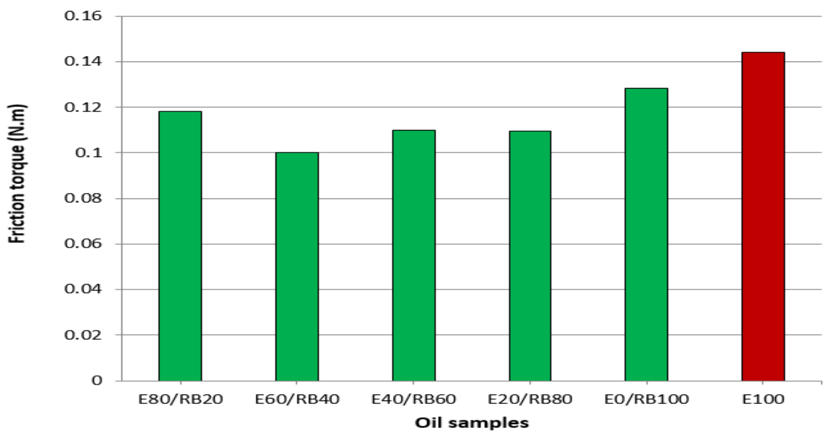

Figure 4: Frictional torque with various oil blends

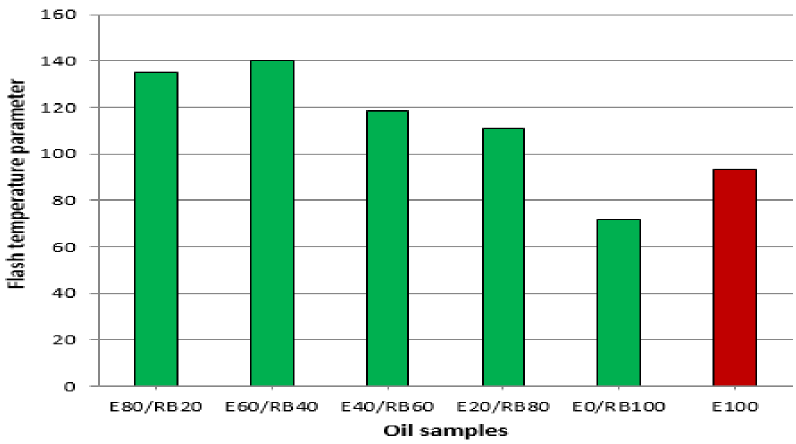

Figure 5: Flash temperature parameter values of the oil samples

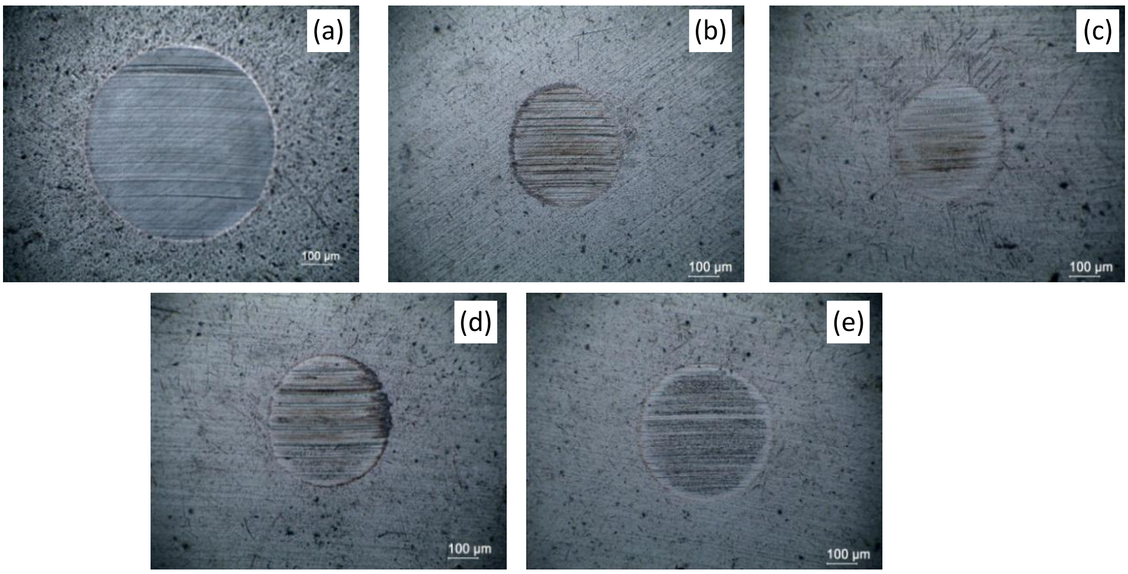

Figure 6: RBD palm olein samples Optical photo micrographs in different volumetric blending ratio : (a) 100% RBD oil ; (b) 20% RBD oil; (c) 40% RBD oil; (d) 60% RBD oil; (e) 80% RBD oil.

5.0 CONCLUSIONS

There are conclusions given below based on this study:

1. The blends of RBD palm olein showed great credibility with respect to requirements of the viscosity. The results of the all viscosity evaluating for the oil samples were met with the ISO viscosity grade requirement.

2. The 40% of RBD palm olein blend lubricant improves the lubricants performances based on the lower COF and lower value of friction torque as comparing with the 100% commercial lubricant and neat RBD palm olein.

3. The wear scar diameter results of the RBD palm olein blends lubricant shows the blending process lead to reduction in the values of the wear scar diameter. This means that the blend of palm oil in lubricant has the potentialities for acting as anti-wear lubricant.

4. The overall analysis suggests that, the RBD palm olein has the potential in becoming a partial alternative bio-lubricant because the blends did not give any negative effect on the wear phenomena and lubricating performance.

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