

## **PHYSICOCHEMICAL CHARACTERISTICS OF THE RAPESEED OIL AS A RENEWABLE -BIO FLUID**

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### **Abstract**

Plant fluid has been investigated to replace petroleum-based products due to its environment-friendly characteristics and has become a vital source of bio-fluids. The usefulness of vegetable fluid is its availability as one of the renewable sources. Additionally, the vegetable fluids 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 fluids as bio-fluids, either by directly using the neat vegetable fluids without blending or using certain blending ratio of the vegetable fluids along with the commercial fluids. In this experimental work, the influences of the blending ratio of commercial mineral fluid with one type of vegetable fluid was investigated on the performance characteristics and compared with commercial fluid using the vertical universal friction and wear testing machine. Renewable rapeseed fluid was blended under mixing ratio ranging from 5% to 20% with commercial mineral fluid. All experimental works were conforming to "American Society for Testing and Materials". The results exhibit that 0.05 blends of rapeseed fluid with commercial mineral fluid have lowest wear scar diameter compared to mineral fluid. Most blends exhibit lower friction coefficient compared to value of commercial mineral fluid. As conclusion, the blends of rapeseed fluid with commercial mineral fluid have better tribological performance compared to commercial mineral fluid or neat rapeseed fluid.

Keywords: Coefficient of friction, Flash parameter, Mineral fluid, Rapeseed fluid, Universal machine.

## 1. Introduction

Energy is an essential factor of every community because it helps maintaining and improving comfort. This is found in several forms, from a variety of sources. In the last century, with the rapid development in economic, energy needs have grown, using natural resources such as wood, water and fossil energy Fuel, and nuclear energy. Industrial fluids and oils play a major role in all areas of production and industry, therefore since from beginning of the last century, academics, researchers and engineers found effective solutions to raise the crude petroleum production. This has caused the production and development of many types of liquids with low prices, producing low fluids from crude oil derivatives, which have caused many problems, including greenhouse effects and global warming issues.

The growing global concerns about human and animal health and the environment in addition to the reduced the crude oil resources have increased importance of using eco-friendly resources. Also, great interest in keeping the climate and atmosphere of the human, animal, and plants from bad effects which caused by mineral oil-based fluids has been paid. It has been found that lubricant wastes in the amount of almost 12.5 million tons were dumped into the environment annually [1]. 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 or fluids. Animal fats and plant oils are considered as good substitutes for the mineral-based fluids as lubricants. One of the studies discovers that the plant fluids were utilized in the constructing of monuments in primitive Egypt [2].

According to this report, the employment of the plants fluids as work fluids in the engineering and applications industrial sector is not new matter. Since plant fluids are biodegradable and less toxic than petroleum-based fluid, they have more advantages than mineral fluids sources. Also, it is easy to produce them from renewable sources. Furthermore, during an investigation on the tribological behaviour of two contact sliding metals between one another using biodegradable fluid as lubricant, it was found that because vegetable oils have a big quantity of unsaturated and polar ester groups components which positively enhance the conditions during the reciprocating sliding motion, they have better lubricating ability in compared to mineral or synthetic oils [3]. Moreover, vegetable oils not only have long chain fatty acids which possess superior essential boundary lubricant properties but also worthy lubricating capabilities due to their ability to produce low coefficients of frictions. On the other hand, other scholars have reported that most vegetable oils have lower coefficient of the frictions, but with 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 thin metallic soap films were moved away through rotating sliding and produce the non-reactive detergent which raises the friction [4].

Many investigators and interested people have examined the palm oil in industrial also engineering implementations, which includes crude palm oil as a possibility fuel in the machines and engines [5], the possibility of palm fluid (bio) as a energy transmission fluid [6, 7] and the potential use as a lubricant during metal forming [8, 9]. The studies on the fluids of palm as a bio fluid can be classified into four main groups, where uses (first) the pure fluid of palm as a test fluid [10, 11], (second ) fluid of palm as emulsion [12], (third ) use the palm fluid with additives

[13] and (fourth) fluid of palm as an additive [14]. Most of the researchers discovered that the fluid of palm displays satisfying outcomes and can be widely put in use in engineering applications. Yet, the plant fluid oxidation factor among others must not be neglected. Not too long ago in the 1990s, crude palm oils have successfully been converted into palm oils methyl ester by the Palm Oil Research Institute of Malaysia-PORIM also known as Malaysian Palm Oil Board-MPOB. Using trans-esterification method, PORIM was able to reduce the palm oil molecular chain from nearly 57 to 20 molecules which led to decreasing the viscosity of the palm oil viscosity and making it more environmentally friendly.

As reported by Maleque and Masjuki [15], the up mentioned method enhanced the palm oil thermal stability as well. Although several studies have been done in the past on using different types of plant-fluid-based lubricants and additives, very limited papers are available on using rapeseed oil as the base lubricant. This paper investigates the frictions coefficient as well as wears performance of rapeseed oil blends with mineral fluid in different mixing ratio using the wear testing machine and vertical universal friction.

## 2. Experimental Procedure

This study uses the wear testing machine and vertical universal friction Fig. 1 for investigate the fluids characteristics. The instrument used specimens as a ball, one ball at the top and three at the bottom. The three balls were held tight in a ball pot having the tested lubricants and pushed against the top ball which is allowed to spin at the wanted speed. Before executing each test, acetone was used to clean the components surfaces. In order to measure the temperature ( $^{\circ}\text{C}$ ) of the fluid, a thermocouple was implanted at the ball pot bottom.

A heating block was located at the bottom of the ball pot which controls the temperature of the experiments. In this study, wear test was conducted at 50 kg loads and at 1000rpm for 60 mints at fluid temperatures of  $65^{\circ}\text{C}$ . The four balls utilized in this experimental study were made from AISI (E-52100) chrome alloy steel and have the following specifications: extra polish (EP) grade 25; diameters 12.7 mm; hardness 64–66 HRC (Rockwell C Hardness).



Fig. 1. Photograph of the wear testing machine.

### Fluids

Pure plant oil which is the first-generation bio-fluids is conventionally produced from vegetable oil, a refined oil that has not been used for preparing food. Because

refining and cleaning are eliminated, this reduces the time needed to produce the bio-fluid. Another advantage of using pure base vegetable oil is its lower acidic level which to achieve a successful chemical reaction needs less methanol and catalyst. The second generation of bio-fluid is produced from waste fluids which in turn demand more cleaning and refining to turn into a bio-fluid. Fluids play a major role in energy transfer as well as the cooling process and reducing friction.

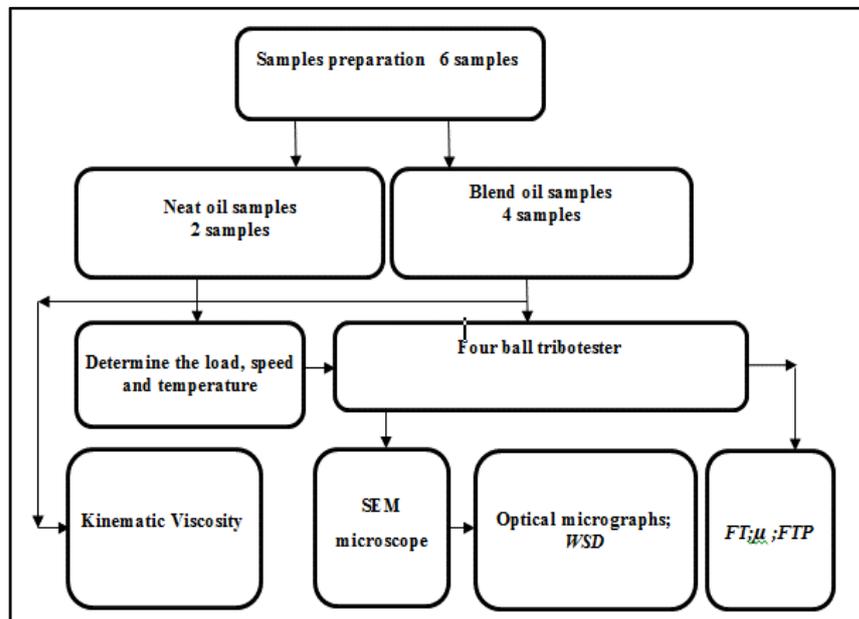
The fluids used for this experimental study was rapeseed fluid, this fluid was blended separately 0.05-0.20 volume with mineral fluid. The outcomes obtained from experiments work using rapeseed fluid in various mixing ratios were compared with the outcomes of the sample of the commercial mineral fluid (SAM6). Each trial test used 10 ml of the fluid. Table 1 shows the specifications of the samples.

**Table 1. The specifications of the fluid samples.**

Sample	SAM1	SAM2	SAM3	SAM4	SAM5	SAM6
Rapeseed fluid mixing ratio	0.05	0.10	0.15	0.20	100	0.0

### 3. Test Procedures

In the investigation of the characteristics of lubrication, friction and wear (non-chemical corrosion) of the lubricant samples, a four-ball wears tester machine was used which was in compliant with the ASTM D4172-B standards, Diagram for experimental setup shown in Fig 2. In this part, the machine details which used to evaluate the performance of environmentally friendly and mineral fluids are explained. Before setting up the vertical universal friction and wear testing machine, acetone and fresh lint free industrial wipe are used to comprehensively clean and dry the steel balls and the ball pot.



**Fig. 2. Block diagrams for experimental setup.**

Great attention had been paid to get rid of any solvent residuals before introducing the lubricant and assembling the components together. A torque wrench was used to constrict the assembly that contains the steel ball inside the ball pot to avoid any movement in the bottom balls throughout the experiment. The top ball was placed in place over the bottom balls and then fastened onto the spindles. After that, the ball bot and its inside components were lubricated. The frictionless disc in the vertical universal wear testing machine was used to place. To reduce the shock loadings, the test load was gently added. Then, the tribotester which is placed inside the heater was used to heat up the lubricant to 65°C.

The motor was turned on to spin the top ball at a wanted speed after the desired temperature was achieved. 60 minutes later, the heater was switched off and then the fluid cups were detached from the machine. A withdrawal step was initiated to remove the test fluid from the fluid cup and fresh lint free industrial wipe was used to dry clean the ball bearings.

### 3.1. Wear area

The wear area dimensions were determined and measured for each of the three lower exam balls to test the lubricating features for the fluids. In general, large value of the wear area mean more severe the wear. Dimensions of wear and tear are determined by optical computer program and scanning electron microscopy (high resolution) and from a microscopic image that is taken. Using this method, the diameter of the wear scar is determined for each of the three bottom balls.

### 3.2. Frictional moment and coefficient of friction

A specific information acquisition system was used to register the friction moment from the vertical universal friction and wear testing machine. It was noticed that the frictions moment has gradually increased during the second 5 minutes from the beginning of the test. The friction moment outcome turned stable and steady-state condition after 10 min.

At the stable case, the mean value of friction moment was listed, then as calculated depending on IP - 239 , the friction coefficient is shown in Eq. (1) [15, 16]:

$$\text{Coefficient of friction} = \frac{\text{Friction Torque (kg-mm)} \times \sqrt{6}}{3 \times \text{Applied load (kg)} \times \text{Distance (mm)}} \quad (1)$$

where the distance between the axis of rotation and the center of the interaction surfaces on the bottom balls, which was set as standard 3.67 mm for the specific ball diameter. Identical process of calculation for coefficient of friction was processed by [17, 18]. The frictional moment outcomes were listed using the lab computer, which was determined all values of the coefficient of friction automatically.

### 3.3. Parameter of the flash temperature

The flash temperature parameter (FTP) is a single number which is utilized for expressing the critical flash temperatures at which the lubricants will evaporated ignite under certain given condition. The FTP shows fewer possibilities of lubricant films for breaking down [11, 19]. High rate of the parameter of flash temperature (FTP) shows high performances of the lubricants.

The parameter of the flash temperature calculated using the Eq. (2) [20].

$$\text{Flash friction} = \frac{\text{Applied load (kg)}}{\text{Wear scar diameter}^{1.4}(\text{mm})} \quad (2)$$

#### 4. Result and Discussions

The results and discussion for the experimentally obtained data (fluids performance features), included measured the wear scar area, torque and flash parameter. Investigation and characterization were done to the effects of the rapeseed fluid and blends fluid. A better grasp is offered by the obtained results on the ball bearings worn surface with rapeseed fluid and blends utilizing fluid analysis like the kinematic viscosity analysis, wear scars diameter, coefficients of frictions, and the (FTP) flash temperature parameter. The outcomes were compared with pure commercial mineral fluid.

##### 4.1. Kinematic viscosity

Kinematic viscosity is a standard of the resistances of a fluid which distorted by its shear stresses or the tensile stresses and can also be explained by the fluid's interior frictions. To measure the viscosity for samples of fluid, a viscometer was utilized which has a spindle that spins at specific speeds. The viscosity could be determined once the spindle is placed inside the lubricant by measuring the spindle's speed resisting the fluidity. Figure 3 shows the comparison in amount of kinematic viscosity of the rapeseed fluid with mineral fluid blends in different temperatures, i.e. 40, 75, 100 and 125 °C. This figure clearly displays that the kinematic viscosity for all blends of rapeseed fluid with mineral fluid decreased with the increases of the temperatures. This figure also shows, at greater temperatures the amounts of thickness for all fluids compared to each other. The highest amount of kinematic viscosity obtained at 40°C is 73.72 mm<sup>2</sup>/s for rapeseed fluid (SAM4) blend, compare with a 39.06 mm<sup>2</sup>/s for the neat rapeseed fluid (SAM5) and a (42.84 mm<sup>2</sup>/s) for the sample of mineral engine fluid (SAM6). However, the least quantity of viscosity attained at (125°C) of the (SAM1) blend is (4.92 mm<sup>2</sup>/s) compare with the 9.157 mm<sup>2</sup>/s for the sample of the mineral fluid (SAM6).

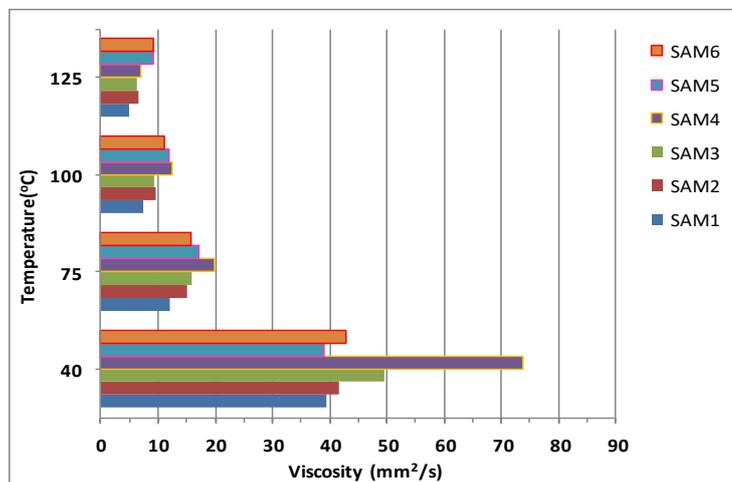


Fig. 3. Viscosity for the fluid samples under different temperature.

## 4.2. Wear area

The wear area gives an accurate and clear picture of the fluid performance, especially in the field of friction reduction. A particular microscope was utilized to examine the outcome for wear scar diameters (WSD) of the bottom steel balls and the mean values were determined.

Figure 4 displays the comparison of WSD between the neat rapeseed fluid, blends of the rapeseed fluid with mineral fluid and the mineral engine fluid. From the figure, lowest the wear ( $375.8\mu\text{m}$ ) occurred at mixing ratio 0.20 (SAM4). For rapeseed fluid blends, the highest WSD ( $807.933\mu\text{m}$ ) occurred at the mixing ratio 0.10 (SAM2), compared to other percentages of blends and comparing with the 100% commercial fluid ( $469.133\mu\text{m}$ ). Therefore, rapeseed fluid blends work as one of the anti-wear additives and reduces the wear scar diameter; this property is due to the long fatty acid chain of rapeseed.

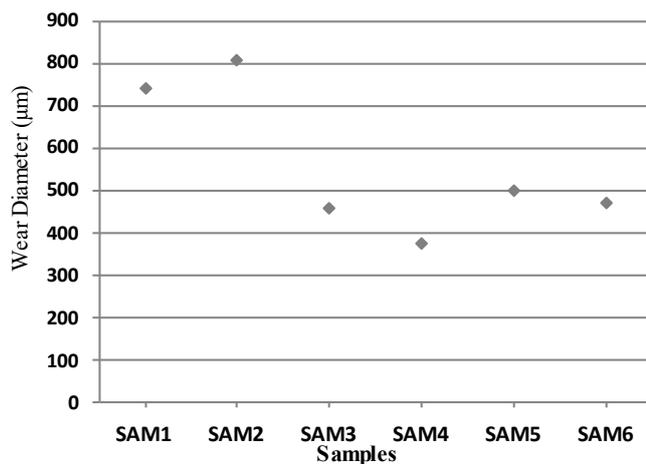


Fig. 4. Wear scar diameter values for fluid samples.

## 4.3. Coefficients of frictions

The coefficients of friction (COF) for rapeseed fluid blends and the neat commercial lubricant were investigated. Depending on the status of each experimental test, the COF values were calculated, listed and the outcomes were analysed depending on Fig. 5. For the blends of rapeseed fluid, the lower value of the (COF) happened at mixing ratio 0.05 (SAM1) was 0.048089 compared with 0.084589 for the mineral fluid (SAM6). Therefore, when 0.05 of rapeseed fluid

blend with 0.95 of mineral fluid is used as a fluid, it would produce enhanced lubricity capability in the matter of rotational friction compared to the pure rapeseed fluid and the neat mineral fluid.

## 4.4. Frictional moment

The friction performance of rapeseed fluid blends under normal load of 491 N (50 kg) was studied; Experiments were done at 1000 rpm rotational speed and 65 °C bulk fluid temperature for 60 minutes. The outcomes of the frictional moment tests were schemed and demonstrated in Fig. 5. The friction moment outcomes of

rapeseed fluid blends were compared with the neat commercial fluid and the neat rapeseed fluid. The lowest value of the friction moment was 0.085063 Nm occurred at mixing ratio 0.5 (SAM1). From Fig. 6, all the blends and neat of the rapeseed fluid have the low value of friction moment compared with the mineral fluid. Therefore, the rapeseed fluid blended lubricants has better lubricity abilities in terms of the frictions, because the rapeseed fluid has fatty acids which increase the ability of the lubricant molecules to contains fatty acids that help the lubricant molecules to cling to the surface of steel ball surface better and preserve the lubricant film. The attendance of the slim lubricant layers between the steel ball exteriors lessened the substantial transfer and adherence of the two faces.

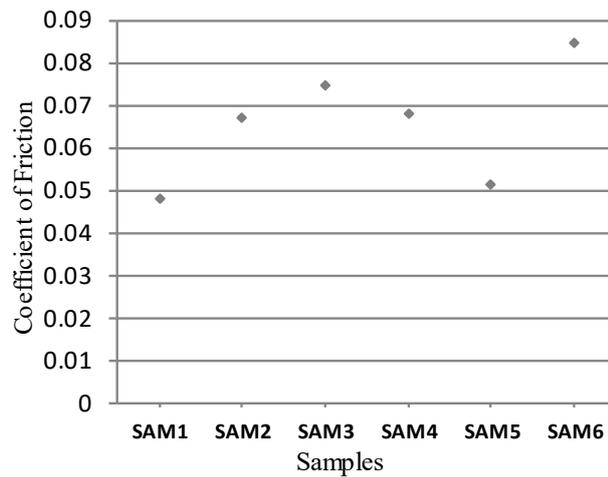


Fig. 5. Coefficient of frictions values for fluid samples.

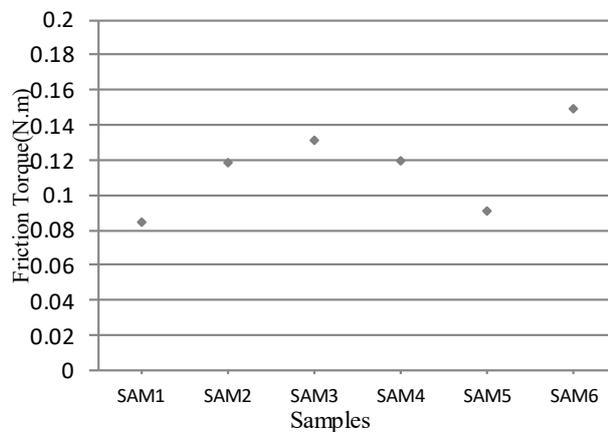
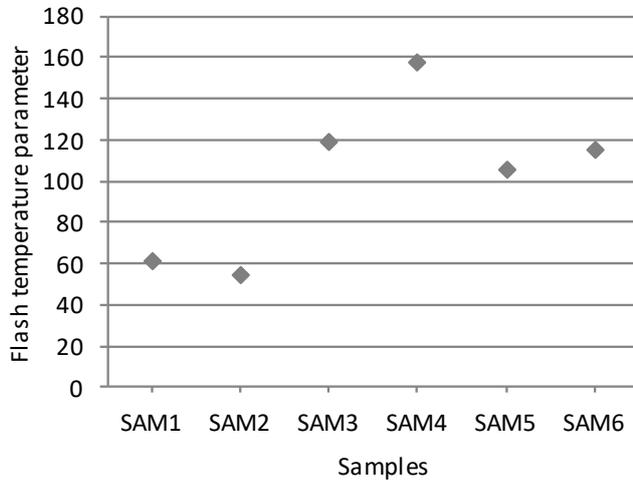


Fig. 6. Frictional moment values of the fluid samples.

#### 4.5. Flash parameter

This parameter is very important in determining the fluid performance, because it gives an accurate form of the fluid's possibility to working in the specific conditions before the breakdown. Parameter of the flash temperature values were determined

and listed for rapeseed fluid blends. The results are shown in Fig. 7. For the blends of rapeseed fluid, the highest FTP occurred at SAM4 with value 157.441 compared with 115.41 for the mineral fluid (SAM6) and 105.109 for the neat rapeseed fluid (SAM5). Therefore, when 15% of the rapeseed fluid was blended with the mineral fluid, it will reduce the possibility of the fluids film to collapse and increase the performance of lubricity compared with the (SAM6) commercial fluid.



**Fig. 7. Flash temperature parameter values (FTP) for the fluid samples.**

## 5. Conclusions

From the experimental and theoretical work outcomes, can be conclude the following:

- Blends of rapeseed fluid showed great credibility with respect to requirements of the viscosity. Because the results of the all viscosity evaluating for the fluid samples were met with the viscosity grade requirement.
- The 20% of rapeseed fluid blend improves the performances based on the lower *COF* and lower value of frictional moment as comparing with the commercial fluid and neat rapeseed fluid.
- The wear scar diameter (*WSD*) results of the rapeseed fluid blends show the mixing process lead to reduction in the values of the wear scar diameter. This means that the blend of rapeseed fluid has the potential to act as anti-wear fluid.
- The overall analysis suggests that, the rapeseed fluid has the ability to grow into a partial substitute bio-fluid because the blends show no negative effect on the wear phenomena and performance.
- Working in this field requires more testing in the future

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**Nomenclatures**

<i>F</i>	Frictional force, N
<i>FT</i>	Frictional torque, N.mm.
<i>FTP</i>	Flash temperature parameter.
<i>N</i>	Applied loads, N
<i>W</i>	Applied loads, kg
<i>WSD</i>	Scar diameter of wear, mm

**Greek Symbols**

$\mu$	Coefficients of frictions
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