Wear Resistance Characteristic of Vegetable Oil

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Abstract. The main source for lubricant oils is mineral oils, but the source of mineral oils are depleting from day to day and it is also a major cause for environmental pollution in the world. This aim of research is to introduce vegetable oil as an alternative source of lubricant oil in industrial applications. In this study, we measured the physical properties of Jatropha, palm fatty acid distillate (PFAD) and empty fruit bunches. All experiment were done according to the American Society for Testing and Materials (ASTM) condition, method B and with the use of four-ball tribotester, CCD camera, microscope and viscometer to obtain results. The test oils were measured of their coefficient of friction, wear, viscosity and flash temperature parameter. To evaluate the results, the same conditions were applied for all experiments with the use of engine and hydraulic mineral oil. The results showed that the anti-friction ability of Jatropha oil and PFAD was higher than the engine and hydraulic mineral oils.

Introduction

Mineral oils with base lubricant have been used in all kinds of applications many years ago. Nowadays scientists are trying to find a new alternative renewable source of lubricant oils instead of continuing to use mineral oils. This is because mineral oils are the main causes of pollution to the environment, which are harmful to human, animals and plants. Besides that, mineral oils can pollute nature through burning or entering into the air, inland water resources and seas. Previous researches showed that petroleum and mineral oil have harmful influences towards the fish life and other aquatics [1].

Vegetable oils are promising alternative oils because they have several advantages such as being environmental-friendly, renewable, cheap and easily manageable with simple manufactory process, where there is an acute need for modern forms of energy. Therefore, in recent years, several researches have been done on how to manipulate vegetable oils to create all kinds of synthetic mineral oils, for example lubricant oils, diesel oils and biofuel oils. In addition, researchers have come with novel methods to extract oil from biomass such as pyrolysis, fast pyrolysis, thermo chemical process, flash pyrolysis and vacuum pyrolysis [2, 3].

The investigation of the effects of wear and friction of blended palm oil methyl ester lubricant and showed that at lower load and temperature, the wear rate with the use of palm oil methyl ester lubricant was low, under 5%, whereas at higher loads, the wear rates were higher. Also, the viscosity decreased with an increase in temperature but increased with increasing load [4]. Moreover, several biodegradable oils, in particular vegetable base oils, possess a good lubricating ability that is often much better than mineral or conventional synthetic oils. Furthermore, vegetable oil-based products hold a great potential for stimulating the rural economic development because farmers would benefit from the increasing demand for vegetable oils. Various vegetable oils, including palm oil, soybean oil, sunflower oil, rapeseed oil and canola oil have been used to produce lubricants.

In this experimental works, the researchers calculated the amount of friction and wear according to the American society for testing and materials (ASTM) using four-ball tribotester. Jatropha oil (JO), palm fatty acid distillate (PFAD), empty fruit bunch oil (EFBO) as vegetable oil and engine
(EO) and hydraulic oil (HO) as representative of mineral oil were used as test lubricants. Results were focused on the coefficient of friction (COF), wear scar diameter (WSD) and worn surface observation.

**Method and Material**

**Experimental Procedure.** These tests were carried according to the American Society for Testing and Materials (ASTM) condition and usage from ASTM D4172 method test B. Conditions for experiment: Temperature: (75 ± 2)°C, Speed: (1200 ± 60)rpm, Time:(60 ± 1)minutes and Load: (392 ± 2)N. The details of the experimental procedure could be found in previous publications [5, 6].

**Test Lubricants.** Jatropha oil (JO), palm fatty acid distillate (PFAD) and empty fruit bunch oil (EFBO) were used as test lubricants. They are the representative of vegetable oils. The results were compare with commercial engine oil (EO) and hydraulic oil (HO). Tests were conducted at 75°C. The viscosity of test lubricants at 75°C was shown in Table 1.

**Table 1 : Viscosity of test lubricants at 75°C.**

<table>
<thead>
<tr>
<th>Lubricant</th>
<th>Viscosity (mPa.s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>JO</td>
<td>18.75</td>
</tr>
<tr>
<td>PFAD</td>
<td>9.75</td>
</tr>
<tr>
<td>EFBO</td>
<td>19.93</td>
</tr>
<tr>
<td>EO</td>
<td></td>
</tr>
<tr>
<td>HO</td>
<td></td>
</tr>
</tbody>
</table>

**Results and Discussion**

**Coefficient of friction.** Coefficient of friction (COF) is a dimensionless scalar value to described ratio of friction force between two bodies and usually is the force pressing them together. From the four-ball tribotester, the friction torque was recorded and coefficient of friction was calculated using Eq.1 where \( \mu \) is the coefficient of friction, \( T \) is the frictional torque (kg.mm), \( W \) is the applied load (kg), and \( r \) is the distance from the center of the contact surface on the lower balls to the axis of rotation, which was determined to be 3.67 mm [5, 6]. The coefficient of friction was shown in Fig.1.

\[
\mu = \frac{T \sqrt{6}}{3Wr}
\]  

From figure, experimental works lubricated with palm fatty acid distillate (PFAD) shows the lowest coefficient of friction (0.015), followed by the jatropha oil (JO) and empty fruit bunch oil (EFBO),
which all of them was the representative for vegetable oils. The engine oil (EO) shows the highest value of the coefficient of friction which is 0.079. All the vegetable oils have fatty acid that could help the lubricant layer to maintain its thickness and stick well on the ball bearing surface to reduce metal-to-metal contact [7, 8].

**Wear scar diameter (WSD).** After the experimental works done at four-ball tribotester, the three ball bearings at the bottom were observed using a CCD camera. The picture of the wear scar was captured and the diameter of the wear scar was measured. The average value of WSD of the three bottom ball bearings were plotted as shown in Fig.2. The ball bearing lubricated with the hydraulic oil has the biggest wear scar diameter. This result was predicted because of the hydraulic oil was produced to transfer the energy but less efficient to reduce wear. The smallest WSD were those lubricated with PFAD (0.053) and EO (0.054). For PFAD, the fatty acid reduced the metal-to-metal contact; at the same time reduce the production of wear. For engine oil (EO), it was produce to reduce friction and wear for moving piston, so the anti-wear additive that was added into the engine oil act effectively reducing the wear.

![Fig.2: The average wear scar diameter for each test lubricant.](image)

**Flash temperature parameter (FTP).** The first point at which oil will start to evaporate is called as flash temperature parameter. At this point, the bonding between the lubricant molecules were broke and surface starts to have a starvation of lubricant. Then, the metal-to-metal contact would occur. The higher the value of FTP shows that the lubricant could maintain the lubricant layer for a longer period of time. The FTP value for each test lubricant was calculated using Eq.2, where $W$ is the load in kilograms, and $d$ is wear scar diameter (WSD) in millimeters [5, 6], as shown in Fig.3.

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

![Fig. 3 : Flash temperature parameter for each test lubricant.](image)
From figure, it is found that hydraulic oil (HO) and empty fruit bunch oil (EFBO) have the lowest value of FTP. The FTP value for Jatropha oil (JO) and palm fatty acid distillate (PFAD) were almost similar with engine oil (EO). It is showing that JO and PFAD have a possibility to be produce as lubricant.

Summary
This study compares the Jatropha oil (JO), palm fatty acid distillate (PFAD), empty fruit bunch oil (EFBO) as representative of vegetable oil with engine oil (EO) and hydraulic oil (HO) as representative of mineral oil. The tribological evaluation was conducted using a four-ball tribotester according to the ASTM condition. The results could be concluded that jatropha oil (JO) and palm fatty acid distillate (PFAD) have low coefficient of friction compared to mineral oil. The wear scar diameter for ball bearing lubricated with JO and PFAD also shows smaller wear scar value. The FTP value for JO and PFAD were almost similar with FTP value of engine oil, means that JO and PFAD could maintain the formation of the lubricant layer.

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