Study of Friction And Wear Characteristic of Jatropha Oil Blended Lube Oil

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Abstract
The revolution in industrialization throughout the world has boosted the utilization of machinery and shifted the muscle power to machines. The use of machines in various sectors has increased the demand of petroleum based lubricants. Lubricants act as an antifriction media, facilitating smoother working, reducing the risks of undesirable frequent failures and maintaining reliable machine operations among different rotating parts of machines. Due to the depleting of petroleum resources and environment concern, the demand of non-edible vegetable oil based lubricants has increased as well. In this regard, the effect of the Jatropha oil blended with lube oil on the friction and wear characteristics has been investigated in this paper. Experiment has been carried out by using Cygnus Wear Testing Machine under the load of 30N, a high rotating speed of 2000 rpm and one hour of running. Lubricant SAE 40 has been used as a base lubricant in this study. The experiment has been conducted on aluminium pins and cast iron disc which lubricated with Jatropha oil blended bio-lubricant (JBL). To prepare the bio-lubricant, 0%, 20%, 30%, 40% and 50% by volume of Jatropha oil were blended with lubricant SAE 40. In order to understand the characteristics of lubricant, viscometer and multi oil analyser tests have been conducted. It has been found that 10% of Jatropha oil bio-lubricant gives lowest wear and creates less amounts of heat than others samples, and with above 10% contamination, the wear and lubricating temperature increases significantly.

1. Introduction
Lubricating oil is used in all most all mechanical instrument and rotary machines. Various type of lubricating oils are being used nowadays in this purpose including mineral oil, synthetic oil, refined oil and vegetable oil. Most of lubricants are based on mineral oil, extracted from petroleum oil which is not apt to maintain the safety of environment due to their toxicity and non-biodegradability [1]. Nowadays, due to the detrimental characteristics of fossil fuel, the usage of petroleum oil based lubricants are creating concern regarding environmental issues [2]. At

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this circumstance, an alternative lubricating oil source based on vegetable oil can be played a vital role to reduce the usage of petroleum oil based lubricating oil as well as the renewable source of lubricant [3]. Vegetable oils based lubricants have numerous advantages over mineral lubricant since they are renewable, environmentally friendly, less toxic, more biodegradable and contain higher stearic acid [4]. Therefore, vegetable oils based have the potential to substitute petroleum based lubricating oil as well as the interest in the use of animal fats and vegetable oils derived lubricant is increasing precipitously. The rapid depletion of the crude oil and higher price has drawn the attention to use bio-lubricants instead of petroleum based lubricant.

Vegetable oils are mainly triglycerides which contain three hydroxyl groups and long chain unsaturated free fatty acids attached at the hydroxyl group by ester linkages [5]. Despite of having lots of advantages of bio-lubricant over petroleum based lubricant, the attempt to formulate the bio-lubricant and its applications are very few. Hsu et al. [6] stated that hydrodynamic effect of the lubricating oil does not affect surface wear significantly while, the interaction between the contact surfaces and the lubricating oil with or without additive influences the tribological properties. Different feedstock is used, to formulate the vegetable oil in the different part of the world. In Europe mostly rape seed oil is used as the source of lubricating oil which showed excellent tribological properties and compatibility with the equipment seal and the elastomers as well as environment adaptability.

Thus, in this article, we experimentally analysed the tribological characteristics and compatibility of non-edible Jatropha oil based bio-lubricant for the automotive application. The reason for selecting Jatropha oil as a feedstock is that it is non-edible food and can be grown on marginal land as well.

2. Experimental setup

2.1 The Cygnus friction and wear test machine configuration

The Cygnus friction and wear test machine is used to evaluate the friction and wear characteristics of lubrication in this experiment. The Cygnus friction and wear test machine is designed to study friction and wear in dry or lubricated sliding over a wide range of speed, load and temperature. It is a tri-pin-on-disc machine which is conducted by using three pins on a disc as testing specimens. Specifications of the Cygnus friction and test machine is mentioned in table 1.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test disc diameter</td>
<td>110.0 mm</td>
</tr>
<tr>
<td>Test pin diameter</td>
<td>6.0 mm</td>
</tr>
<tr>
<td>Test disc speed range</td>
<td>25 to 3000 rpm</td>
</tr>
<tr>
<td>Motor</td>
<td>Tuscan; (2000rpm, 1.5 kW)</td>
</tr>
<tr>
<td>Load range</td>
<td>0 KG to 30 KG</td>
</tr>
<tr>
<td>Electrical input</td>
<td>220 Volt AC 50 Hz</td>
</tr>
</tbody>
</table>

The Cygnus friction and wear test machine is connected with a computer having embedded a block diagram-based application construction program Visual Designer. Visual Designer allows developing custom data acquisition, analysis, display in the form of graphical chart or numerical meter. The programs can be controlled simply by drawing a program’s data structure in the form of a block diagram. The block diagram can also contain textual comments, allowing the process being monitored or controlled to be documented. The block diagram can also contain textual comments, allowing the process being monitored or controlled to be documented. The block diagram of this experiment is shown in Fig. 1. During this test, the load of disc is 30 N and velocity of disc is 2000 rpm which are fixed for each pin.
2.2 Preparation of the Specimen

The specimens were made of aluminium and cast iron material. Aluminium is used to build three pin and cast iron is used for disc. The pins are made in workshop by using lathe and cutting machine. The dimensions and geometry of pins and disc are shown on Fig. 2. Prior to conduct the test, the surface of specimens was cleaned properly from dirt and debris. Alcohol was used to clean the surface of specimens.

Fig. 1 Block Diagrams of Friction and Wear Testing

Fig. 2. The dimensions and geometry of pins and disc specimens
2.3 Lubricant analyser

Multi element analyser (MOA) was used to analyse metallic wear particles in lubricant atomic emission spectroscopy (AES). AES provides quantitative and qualitative analysis of wear debris in lubricating oil. In the AES technique a rotating disc electrode brings a continuous sample into a gap between the disc and stationary rod electrode causing the individual atoms in the sample to give off light or radiant energy. Whereas, for viscosity measurement the automatic Anton Paar viscosity meter was used with standard ASTM D 445. The viscosity was measured for both 40°C and 100°C controlled bath temperatures.

2.4 Preparation of lubricant sample

In this experiment, to prepare lubricating oil, Jatropha oil was mixed with ordinary mineral oil (lubricant SAE 40) at various percentages from 10% to 50% of Jatropha oil instep of 10%. Mineral oil (lubricant SAE 40) was used as base line lubricant. The samples were mixed with mineral oil (lubricant SAE 40) by a homogenous mixture machine.

2.5 Friction and wear evaluation

2.5.1 Coefficient of friction measurement

The coefficient of friction was calculated from following equation which is the multiplication of the mean friction torque and spring constant (IP-239 Standard, 1986).

\[ T = \frac{\mu \times 3W \times r}{\sqrt{6}} \quad \text{or} \quad \mu = \frac{T \sqrt{6}}{3W \times r} \]  \( (1) \)

Where \( \mu = \) coefficient of friction; \( r = \) distance from the centre of the contact surfaces on the low balls to the axis of rotation, which is 3.67 mm. \( T = \) frictional torque in kg-mm; \( w = \) applied load in kg.

3. Results and discussion

3.1. Cygnus friction and wear testing machine result analysis

3.1.1. Friction and wear characterization

Fig. 3. show the curves of pins wear as a function of sliding time for various Jatropha oil blended with lubricant SAE 40. The values of linear pin wear under 2000 rpm and 30 N loads for each pin vary from 0.02 to 0.05 mm. It was observed that the higher or maximum wear occurred in the beginning of the experiment for some of the test specimens. It is clear from graph that maximum wear occurred for JBL40 and for JBL10 wear is minimum. We also can observe from the graphs that except JBL40, for each JBL, pin wear decreases gradually and constantly. In the beginning of the test, we can see the wear rate was fast in the period of time that is called the running-in period. During this section, the asperities of the sliding surface are cut off and the contact area of the sliding surface grows to an equilibrium size. We can see from our daily life, that is why we need to service new cars after short period of time running. For the certain time, equilibrium wear conditions between pins and disc surface established, the wear rate will become steady. During this steady state, there is a direct linear relation between the wear volume and the...
sliding time. The graphs of different JBL curve are difference and decrease almost steady throughout this state. It means that different JBL give difference rate of wear to the specimens. Generally, the graphs may be divided into two groups which is the first group is higher value of pin wear and the second group is lower value of pins wear. It can be seen that JBL30, JBL 40 and JBL50 have high value of wear while pure lubricant SAE 40, JBL10 and JBL20 have low value of pin wear and their value are nearly with each other.

![Graph of Linear pin wear as a function of sliding time for various bio-lubricants.](image)

**Fig. 3. Linear pin wear as a function of sliding time for various bio-lubricants.**

### 3.1.2. Coefficient of friction

Fig. 4. shows the curves of friction coefficient plotted against the sliding time for various Jatropha oil based bio-lubricants. The results in fig. 4 depict that the lubricant regimes that occurred during the experiment were the boundary lubrication where the value of friction coefficient ($\mu$) for boundary lubricant is in the range of 0.001 to 0.2 except for JBL50. For 0% of Jatropha oil based bio-lubricants, it can be seen that the coefficient of friction is highest at the beginning and then it falls down rapidly up to minimum value compared to all samples. This phenomenon can be explained by attributing oxide layer on the aluminium surface. Lubricant additives reacts with oxide layer which causes to form a thick tribo-film on aluminium surface. At the initial stage, the shear stress of the tribo-film is high, thus, coefficient of friction is high at early time. With continuing the sliding, the aluminium pin is eroded and fresh metal surface is exposed. Since fresh metal surface has lower tendency to react with lubricant additives, the formation rate of tribo-film decreases than beginning. Therefore, shear stress becomes lower than beginning and lower friction force is experienced. As a result C.O.F decreases with increasing the sliding time. The difference between the values of coefficient of friction is of Jatropha oil based bio-lubricants and pure lubricant (except for JBL50) is very small which ensures the apt of Jatropha oil based bio-lubricants as lubricant. The JBL10 and JBL30 shows the same C.O.F which is almost 0.15 and JBL50 shows almost same C.O.F throughout the whole operation time which is 0.235.
3.1.3. Lubricants temperature

Fig. 5. shows the relation of the averages oil temperature of varies percentage of Jatropha oil based bio-lubricants with the sliding time respectively. The range of temperature is about 20°C to 100°C. From the graphs, we can see that lubricant temperature increases with increasing sliding time for each percentage of Jatropha oil based bio-lubricants. The maximum temperature rise occurred for JBL40 and minimum temperature rise occurred for JBL10. The progressive increasing in temperature period is known as the running-in period during the asperities of the sliding surface are progressively cut off. From the graphs, it can be noticed that the 30% and 40% of Jatropha oil based bio-lubricant are produce more heat than other while the 10% of Jatropha oil based bio-lubricant is generated lower heat.
3.1.4. Viscosity

Figure 6 show that the viscosity of Jatropha oil based bio-lubricants decreases exponentially for both 40°C and 100°C operation temperatures. Table 2 shows the viscosity grade requirement for the lubricants set by the International standard organization (ISO) while figure 6 shows the behaviour of the viscosity of Jatropha oil based bio-lubricants at 40°C and 100°C operation temperatures. Comparing the table 2 and figure 6, it can be stated that at 40°C operation temperature 10%, 20% and 30% of Jatropha oil based bio-lubricants meet ISO VG100 requirement but 40% and 50% of Jatropha oil based bio-lubricants do not meet the requirements. However, it can also be noted that all bio-lubricants have higher viscosity than standard value.

Table 2 ISO viscosity grade requirement [7]

<table>
<thead>
<tr>
<th>Kinematic viscosity</th>
<th>ISO VG32</th>
<th>ISO VG46</th>
<th>ISO VG68</th>
<th>ISO VG100</th>
</tr>
</thead>
<tbody>
<tr>
<td>@ 40°C</td>
<td>&gt;28.8</td>
<td>&gt;41.4</td>
<td>&gt;61.4</td>
<td>&gt;90</td>
</tr>
<tr>
<td>@ 100°C</td>
<td>&gt;4.1</td>
<td>&gt;4.1</td>
<td>&gt;4.1</td>
<td>&gt;4.1</td>
</tr>
</tbody>
</table>

Fig. 6. The viscosity of various percentages of Mineral Oil for temperature 40°C and 100°C operation.

4. Conclusion

Based on the above experiment, the following conclusions can be summarized:
1. The rate of wear for various percentage of Jatropha oil based bio-lubricant was different. However, the rate of wear for 10% and 20% of Jatropha oil based bio-lubricant are near to the pure lubricant SAE 40.
2. In this experiment, temperature of lubricating oil increases with sliding increasing time for each percentage of
Jatropha oil based bio-lubricant. However, JBL10 showed significant performance as it generates less amount of heat compared to the other samples.

3. In this experiment, it has been found that having lower wear resistance bio-lubricant contains higher coefficient of friction.

4. Since jatropha oil based bio-lubricants have higher coefficient of friction compared to pure lubricant SAE 40; it can be assumed that the fatty acid molecules available in Jatropha oil do not build a soap film on a surface test.

5. For each experiment, Iron, Aluminium and Chromium content increase because of wear occur in pin and disc.

6. In term of viscosity, except JBL40 and JBL50, all bio-lubricants meet the ISO VG100 requirements.

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References


