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Effect of bio-lubricant on tribological characteristics of steel

M. Habibullah[a,*], H. H. Masjuki[a], M. A. Kalam[a], A. M. Ashraful[a], M. A. Habib[b], H. M. Mobarak[a]

[a]Centre for Energy Sciences, Faculty of Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia
[b]Instructor, Power, Bogra Polytechnic Institute, Bogra, Bangladesh

Abstract

The purpose of this study is to investigate the effect of jatropha oil doped with lube oil on tribological characteristics of IP 239 standard using four ball tribotester. The ball test material was EN31 steel, 12.7mm in diameter with a surface finish of 0.1 micrometer center lime average (CLA). The test was performed at temperature of 75^{0}c with different loads (15 kg and 40 kg) where rotating speed was 1500 rpm and test duration of 3600s. The lube oil used for this experiment was SAE 40 and contaminated with a various blends like 1%, 2%, 3%, 4%, 5%, of jatropha oil. The lubricants were characterized by viscosity using viscometer. From the experimental result, it is found that wear scar diameter is increased with the increase of load for lube oil and reduced by addition of percentage of jatropha oil. Friction torque analyzed in this experiment and J5 shows dominant performance at 40 kg load. Flash temperature parameter also studied in this experiment and results shown that 5% adding jatropha oil has the less possibility to film breakdown. The overall results of this experiment reveal that the addition of 5% jatropha oil with base lubricant shows better performance and anti-wear characteristics. This blend can be used as lubricant oil which is environment friendly in nature and would help to reduce petroleum based lubricant substantially.

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Kewords: Renewable energy; Biolubricant; Fourball tribotester; Wear and friction characteristics; Friction torque;

1. Introduction

The depletion of world's fossil fuel reserve, increasing fossil fuel price and other issues related to environmental

* Corresponding author. Tel.: +60162007837; fax: +603 79675317
E-mail: habib63119@yahoo.com

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consideration have brought about renewed interest in the use of bio-based materials. Furthermore, petroleum based lubricant is not renewable and has a limited source for fuels. Lubricants are used in automotive, industrial, marine applications to decrease the possible power loss and friction. The disposal of crude oil leads to the pollution and has been proven that its combustion is responsible for emission of traces of metals such as calcium, phosphorus, zinc, iron, nanoparticles and magnesium [1]. To solve these problems, lubricants should be produced from vegetable oil derivatives which are renewable, biodegradable and environmentally friendly in nature [2]. In this experiment, jatropha oil contaminated with lube oil will be used as lubricant.

Jatropha, commonly known as physic nut or purging nut, is a non-edible oil-yielding perennial shrub [3]. Jatropha grows well in tropical and subtropical climates. Jatropha is chosen because of its characteristics of the cheapest feedstock and it possesses the amicable fuel properties with higher oil contents compared to others [4]. Being non edible oil seed feedstock it will not affect food price and spur the food versus fuel dispute.

Shahabuddin et al. [5] studied the comparative tribological investigation of bio-lubricant formulated from a non-edible oil source (Jatropha oil) and recommended that the addition of 10% jatropha oil in the base lubricant is the optimum for the automotive application which showed best overall performance in terms of wear and friction characteristics. Noor Hafizah et al. [6] studied the synthesis of Jatropha curcas fatty acid based trimethylolpropane ester temperature effect on wear and friction characteristics. Zulkifli et al. [7] studied the wear prevention characteristics of a palm oil-based TMP (trimethylolpropane) ester as an engine lubricant and show that 3 % palm oil had the lowest WSD and COF with compared to other lubricants. Resul et al. [8] studied the temperature dependence on the synthesis of jatropha biolubricant and recommended that jatropha curcas has great potential as feedstock for producing biodegradable lubricants. This paper investigates the effect of jatropha oil doped with lube oil on tribological characteristics of IP 239 standard using four ball tribotester.

Nomenclature

COF coefficient of friction
FT friction torque
FTP flash temperature parameter
WSDwear scar diameter
TMP trymethylolpropane

2. Materials and Methodology

2.1. Lubricant sample preparation

The lubricant SAE 40 was used as base lubricant and comparison purpose. This lubricant was then contaminated with 1%, 2%, 3%, 4%, and 5% by volume of jatropha oil to produce others sample as shown in Table 1. A magnetic stirrer was used to blend the compositions of base lubricant and jatropha oil homogeneously. The physical and chemical properties of jatropha oil have been given in Table 2.

Table 1. Different lubricant sample preparation.

Lubricant sample	J0	J1	J2	J3	J4	J5
Jatropha oil (%)	0	1	2	3	4	5
Fresh lube oil (%)	100	99	98	97	96	95

Table 2. Different lubricant sample preparation.

Properties	Specific Gravity	Flash Point (°C)	Calorific Value (KcaL/Kg)	Carbon Residue	Cetane Value	Kinematics Viscosity (cSt)	Sulphur content
Value	0.9186	240/110	9470	0.64	51.0	50.73	0.13%

2.2. Four ball configuration

The Four-ball machine was used as required by standard IP239 in these investigations. This machine consists of the device on which a ball bearing can be rotated in contact with three fixed ball bearing which are immersed in the sample. Different loads are applied to the ball by weight on the load lever. The upper rotating ball is held in a special chuck at the lower end of the vertical spindle of a constant speed electric motor. The lower fixed balls are held in position against each other in a still cup by a clamping ring and locking nut. The arrangement is illustrated in fig. 1.

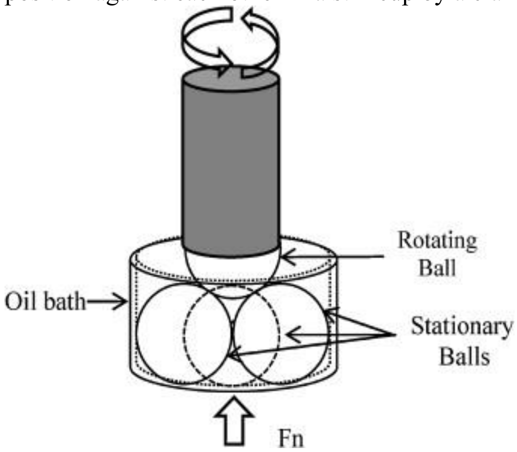

Fig. 1. Schematic diagram of the four ball tribotester.

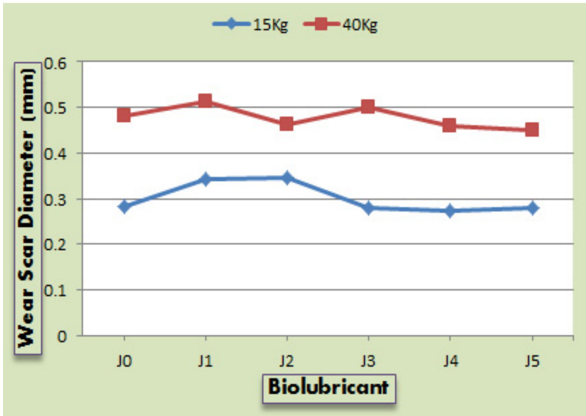

Fig. 2. The effect of Jatropha oil on the wear scar diameter.

2.3. Ball materials

The standard balls test material was EN31 steel, 12.7mm in diameter with a surface finish of 0.1μm CLA. Four new balls were used in each test. Before starting a new test in each time, the balls were cleaned with toluene and wiped dry using tissues. The chemical composition and hardness of this material are listed in Table 3.

Table 3: Chemical composition (wt. %) and hardness of EN31 steel ball material.

Material	C	Si	Mn	S	P	Cr	Fe	BHN
EN31	1.0	0.35	0.5	0.05	0.05	1.3	Balance	805

2.4. Test procedures

The balls and the oil cup was cleaned thoroughly first using toluene and then wiped using tissue until they are completely dry. The ball-cup was placed on the erecting plate and three clean balls were put into the cup, than both of them were hold in position with the clamping ring. Sufficient sample was poured in (approx. 10ml) to cover the balls to depth of at least 3mm. The mounting disk was placed between the thrust bearing and the cup. The test run was carried out at load 15kg and 40kg at 1500rpm with test duration of 3600 sec at 75°C which shown in Table 4.

Table 4: Summary of test conditions using a Four-ball machine.

Test Parameter	Load (kg)	Temperature (°C)	Speed (rpm)	Test Duration (sec)
Condition	15, 40	75	1500	3600

2.5. Wear scar diameter

In the Four-ball machine test, under conditions of low load and low friction the wear causes only small smooth circular scars on the three stationary balls and a ring on the rotating ball. The diameters of these scars are slightly larger than the diameter of indentation due to the static load. The wear is increasing when load and friction increased. The optical microscope was used to calculate the wear scar diameter of the ball. Suitable magnification lens was chosen and the focus was adjusted until clear image is shown on the computer screen. After that, using software available in the computer, the wear scar diameter from the image was measured.

2.6. Flash Temperature Parameter

Flash Temperature Parameter is a single number used to express the critical flash temperature above which given lubricant will fail under given conditions [5]. For conditions existing in the four-ball machine test the following formula has been derived:

Flash Temperature Parameter, $\mathrm{FTP} = \frac{W}{d^{1.4}}$

Where;

W = load in kg, d = mean wear scar diameter (WSD) in mm at this load

3. Result and Discussion

3.1. Wear Scar Diameter Analysis

Fig. 2 shows the effect of different percentage of Jatropha oil on the wear scar diameter (WSD) for two types of load (15kg and 40kg). From the figure, it is clearly can be observed that the WSD increases gradually with an increase in wear load. From the facts, well known that when the normal load is increase, the pressure on the surface will be higher, thus the two surfaces move closer together. This will lead in increasing of the WSD.

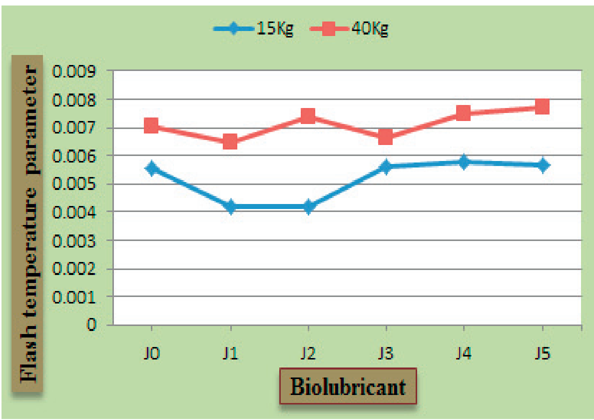

Fig. 3: The effect of Jatropha oil on the FTP for different load.

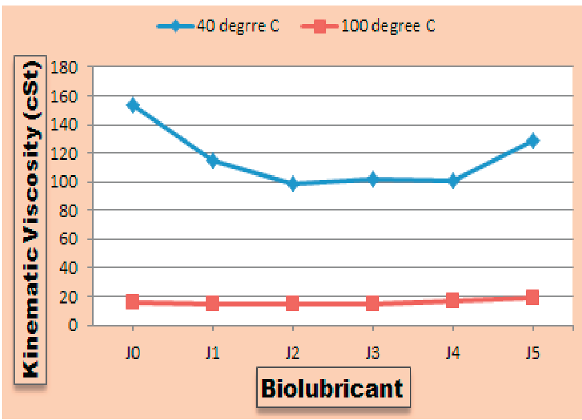

Fig. 4: The effect of temperature on kinematic viscosity.

For 15kg load, it shows that the contamination of lube oil at 1% - 2% of Jatropha oil, the WSD is considered higher. For other percentages of contamination, the WSD was founded to be lower compared to contaminations in between 1% - 2%. While for 40kg load tested, there have two peak or maximum value of WS D at 1% and 3% contamination of Jatropha oil with lube oil. For other percentage of Jatropha oil contaminated lube oil, their WSD are slightly decreased slowly. For both load condition, 5% of Jatropha oil shows lowest wear scar diameter.

3.2. Flash Temperature Parameter (FTP)

Fig. 3 shows the plot of different percentages of Jatropha oil versus flash temperature parameter (FTP) for two kinds of load (15kg and 40kg). Generally by observation, the trend of FTP is increased when the load is increased. For a 15kg load, the lubricant performance was improved by 4% and 5% contaminated of Jatropha oil with lube oil. It is based on the higher value of FTP compared to other percentage of contamination. It proves that 4% and 5% of Jatropha oil is potential anti-wear additive for lube oil. The lowest value of FTP is found to be at 1% and 2% of Jatropha oil.

While for 40kg load test, figure shows 5% of Jatropha oil is the highest value of FTP. Means, 5% of Jatropha oil is the best additive for fresh lube oil at the temperature of 40^{o}c, in order to reduce wear phenomena. The lowest value is occurred at 1% and 3% of Jatropha oil. That means, both 1% and 3% contamination of Jatropha with lube oil was making much wear on steel bearing surface at 40^{o}c.

3.3. Kinematic Viscosity

The most important property of oil for lubricating purposes is viscosity. It affects the film thickness and the wear rate of sliding surfaces.

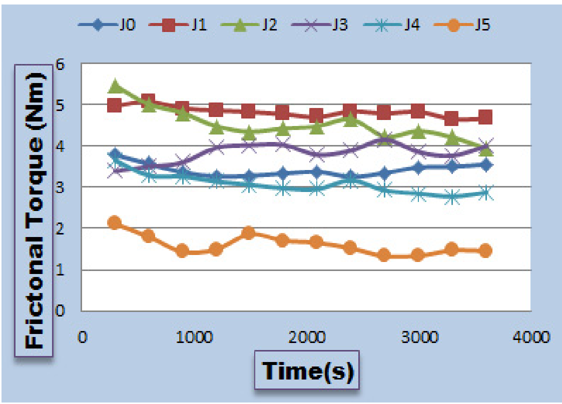

Fig. 5. The effect of 15kg load on frictional torque.

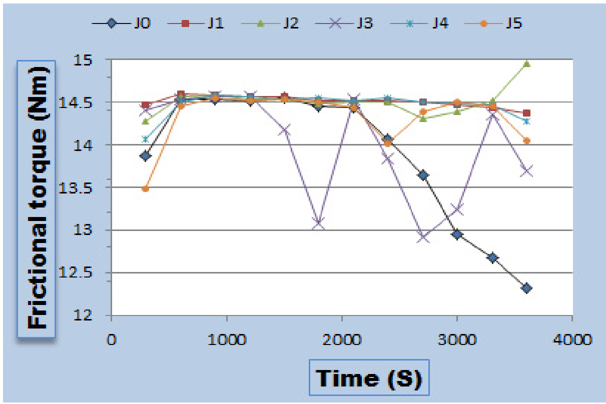

Fig. 6. The effect of 40kg load on frictional torque.

Fig. 4 shows the effect on kinematic viscosity for different percentage of Jatropha oil at the temperature of 40^{O}C and 100^{O}C. From the figure, it shows that for the contamination of Jatropha oil with lube oil, the highest value was stated for 5%. Means, 5% of Jatropha oil was the best contamination with lube oil in order to maintain the anti-wear characteristic such as kinematic viscosity. The figure also showed that normally the values of kinematic viscosity for all samples at 40^{o}c were higher than 100 centistokes (cSt.). It stated that basically the kinematic viscosity of these samples was lower than the samples at 40^{o}c which is about below 20 cSt. The lower value of kinematic viscosity was affected by the temperature. With higher the temperature, the kinematic viscosity will be lower due to the liquidity of the samples lubricant.

3.4. Frictional Torque

Friction torque is the torque caused by the frictional force that occurs when two objects in contact move. Fig. 5 and 6 shows the variation of friction torque for different percentages of Jatropha oil at various load (15kg and 40kg). Fig. 5 depicts that J1 exerts highest friction torque while the J5 is lowest at 15 kg load. It is also clear from Fig. 6 that the J1 bio-lubricant shows maximum friction torque with compared to other bio-lubricants at 40 kg load. The results from the graph can be attributed to the fact that the bio-lubricants especially, J0 and J1 has strong friction reducing additives as well as ability to retain its property. In addition, the results for J5 in Fig. 6 have the highest friction torque at 40 kg load and it reflects that above the 40 kg load, the friction torque tends to increase.

4. Conclusion

Based on the studies and results of the test, those conclusions can be drawn from this experimental study:

- The wear scar diameter (WSD) is more for 40 kg load compared to 15 kg load. That means, at lower loads the WSD under Jatropha contaminated lubricant (SAE 40) are lower, where at higher loads, the WSD are higher.
- The results shows that the contaminations of lube oil at 1% - 2% of Jatropha oil at l5kg load give higher WSD. While for 40kg load tested, maximum value of WSD stated at 1% and 3% of Jatropha oil. But then, at 5% of Jatropha oil, the value of WSD stated that it was the lowest. Which means 5% of Jatropha oil got the lesser scars and made it the best anti- wear.
- The higher value of flash temperature parameter (FTP) clearly observed when 5% of Jatropha oil was used. The 5% of Jatropha oil improves the lubricant (SAE 40) performance, indicating less possibility of lubricant film breakdown.
- From the observations on worn surfaces of these specimens, 5% of Jatropha oil contaminated lube oil shows better anti-wear lubricant properties than others.
- For the contamination of Jatropha oil with lube oil, the highest value of kinematic viscosity was stated for 5% at both two temperatures tested (40^{o}c and 100^{o}c).

According to the experimental result, 5% of jatropha oil contaminated with the base lubricant showed better performance in terms of wear and friction characteristics and can be the alternative lubricant for the automotive application especially for steel.

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