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Tribological Characteristics Evaluation of Mustard Oil Blends

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ABSTRACT

A progressive increase in the desire for environmentally friendly lubricants by users and strict government regulations for the use of these lubricants has provided an opportunity to use plant oils as biodegradable lubricants, therefore vegetable oils have been investigated to replace oil lubricants because of their maintaining the conditions of nature (environment) properties. In this paper, the influences of the blending ratio of mustard seeds oil with commercial mineral oil (SAE40) on the tribological characteristics were investigated and compared with mineral oil using the four-ball tribotester. Mustard seeds oil was blended with mineral oil at a volumetric ratio ranging from 22.5 to 90%. All experimental works were confirmed to ASTM D4172-B standard. The results exhibit that some blends of mustard seeds oil with mineral oil have lower wear scar diameter, friction torque, Friction coefficient and a higher parameter of flash temperature value compared to mineral oil and neat mustard seed oil. In conclusion, the mustard seed oil blend (MU22.5) shows a better anti-wear and anti-friction performance compared to oil samples. Therefore, mustard seeds oil has the potential to be used as a lubricant of mating surfaces.

Keywords: Mustard oil; bio-lubricant, four-ball tribotester; wear scar diameter; parameter of flash or glow temperature.

تقييم خصائص المداهنة لخلائط زيت الخردل

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الخلاصة

ان الزيادة في الطلب على مواد التزييت الصديقة للبيئة من قبل المستهلكين نتيجة للوائح الحكومية الصارمة بضرورة أستخدام زيوت ومواد تشحيم صديقة للبيئة وقابلة للتحلل قد فتحت الأفاق في محاولات استخدام الزيوت النباتية كبدائل عن الزيوت والشحوم البترولية كونها قابلة للتحلل وبالتالي هي صديقة للبيئة, في هذه الدراسة، تم التحقيق في تأثير نسبة المزج لزيت بذور الخردل مع زيت معدني تجاري(SAE40) في خصائص المداهنة ومقارنتها بخصائص المداهنة للزيت المعدني وذلك بأستخدام جهاز الاربع كرات. وكانت نسب الخلط الحجمية المعتمدة لزيت بذور الخردل مع الزيت المعدني تتراوح (22.5-90%). كما تم اعتماد المواصفة الامريكية (ASTM D4172-B) في اجراء جميع الاختبارات. واظهرت النتائج اداءاً متفوقا لبعض نسب

المزج لزيت بذور الخردل مع الزيت المعدني من خلال اعطاء اصغر قطر ندبة، عزم دوران احتكاك ومعامل احتكاك كما اعطت هذه النسب اعلى قيمة لمعامل درجة الحرارة الوميض بالمقارنة مع الزيت المعدني والزيت النقي لبذور الخردل.كما اظهرت النتائج ان مزيج زيت بذور الخردل (MU22.5) حقق أفضل أداء في مكافحة التآكل ومقاومة الاحتكاك بالمقارنة مع نماذج خلائط الزيوت الاخرى. بذلك يكون لزيت بذور الخردل القدرة على استخدامة كزيت تشحيم في السطوح المتلاصقة.

1. INTRODUCTION

The environmental pollution and toxicity issues attributed to the use of mineral oils mainly as lubricants including their various additives and the rising costs linked to a global shortage have resulted in fresh interests in the utilization of the following vegetable oils **Lathi** and **Mattiasson, 2007** such as canola, soybean, coconut, sunflower, castor, and sesame as lubricants that are eco-friendly **Rudnick, 2009.**

Normally, vegetable oils have efficient lubrication properties, for instance, they have low volatility, they have a natural lubricity quality, they are highly viscosity index, non-toxic and they can easily mix with other fluids **Wilson, 1998.** The increased demand for materials that are biodegradable in nature has led to fresh avenues for using vegetable oils as a substitute to mineral oil lubricants **Li, et al., 2001,** mainly in running machines. The public awareness regarding issues related to environmental destruction has been constantly growing, **Eichenberger, 1991.**

Better intrinsic lubrication features are observed in the long chain fatty acids and the large amount of unsaturated and polar ester groups present in vegetable oils, **Petlyuk and Adams, 2004.** These lubricants can work to provide great lubrication as they help in minimizing friction coefficients. However, many researchers have also reported that most agricultural oils have little friction coefficient and higher non-chemical corrosion rate **Golshokouh, et al., 2014a.**

Many studies have been performed on engineering applications of vegetable oils under headings like the potential of vegetable oils as lubricants, hydraulic fluid, biodiesel and used as an additive **Golshokouh, et al., 2014b, Jabal, et al.,2014** and **Golshokouh, et al., 2013a,** most of these studies indicate low non-chemical resistance to corrosion and thermal stability. **Anbumani** and **Singh, 2006,** conducted experiments with different ratios of mixing mustard and neat bio-neutral in C.I. Engine found mustard oil in a mixture of 20% better leads among them. Mainly has been used mustard oil in butyl esters extract, and blend of 20% diesel satisfies the ASTM standard biodiesel properties. Down your fuel consumption slightly (0.135 kJ/kW-h to 0.045 kJ/kW-h) due to better fuel combustion. **Zannatul, et al., 2011** experimented with 20%, 30% and 50% mustard oil blended with diesel and found BSFC is inversely proportional to load. **Bannikov, 2011** investigated the direct injection diesel engine using mustard oil methyl ester as fuel and found a 15% increase of BSFC and 3% decrease the efficiency of fuel conversion performance brake compared to diesel fuel while the performance of mechanical efficiency was not changed.

By using the four-ball tribo-tester compliance with the ASTM D4172-B standard, this paper presents the tribological behaviour characteristics for the mustard oil with mineral oil blends as a bio-lubricant.

2. EXPERIMENTAL WORK

2.1 Experimental apparatus

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 shown in **Fig.1(a,b)**. The tribotester had total 4 balls; three balls in the bottom part, while placing the remaining ball on the upper part. The balls were held firmly down inside the ball container containing the lubricants to be confirmed, and the pressure was placed on the overall system against the ball in the upper. The upper ball is rotated as quickly as possible and three of the balls were placed in the bottom part are pressed. Some measures must precede the adoption of the tests, use acetone for cleaning the surfaces of all components. The thermal inside the ball base was embedded to know the temperature property of oil, also a block to heat down the ball bowl that helps control the temperature adjustment experiment. A study of wear was performed at 1200 rpm for one hour, with 40 kg of pregnancy at 75 ° C.

2.2 Balls

The balls were standardized in this paper, they have been developed from chrome-alloy steel EIS-52100. Characteristics of balls 12.7 $X10^{-3}$ m in diameter, 25 grade Eb and 64-66 Hardness (R.WC hardness test). Includes all tests, four new balls were used with all the above characteristics.

2.3 Lubricants

This study adopted lubricants neat mustard oil (MU) and SAE40 mineral engine oil (MO). Moreover, four blend lubricant samples of mustard oil with mineral engine oil under several percentages (i.e., 22.5-90% v/v of vegetable oil as shows **Table 1** were prepared by using the measuring tube and electric mixer under rotation speed 500 rpm and for 30 min.

2.4 Kinematic viscosity

Fluids used have a very important property in determining resistance to the internal impulse provided by the fluid against spills. It affects the high fluid surface directly along with wear the surface rate at which the fluid slips.

To find the viscosity value limits for lubricants, a rotary viscosity device was used. There is a spindle within the viscosity meter that rotates at a certain velocity. The spindle was introduced inside emollients, thus providing resistant to the impulse resistance oils.

2.5 Wear surface characteristics

Optically add high-resolution electron detection microscope was used to study the properties of non-chemical corrosion from the worn surface and to wear scars on the three balls for bearings after complete experiments. Micrograph pictures captured through microscopes were used to find radius scars wear, the median value was determined.

2.6 Torque and coefficient for the friction

To determinate the resistance of contact between the surfaces, torque must be calculated. There is also a need to calculate the value of the friction coefficient and this data can be fed directly into the Windocom program of a four-balls tribe machine. The proportion of force that maintains contact with the body and strength of friction coefficient that resists the velocity of a body it shows through friction coefficient. Using this equation to determine the value***:***

$$\mu = \frac{F}{N}$$

$$F = \frac{T}{r}$$

$$N = \frac{3.W.r}{\sqrt{6}}$$

$$\mu = \frac{T\sqrt{6}}{3.W.r} \qquad (1)$$

2.7 Flash temperature parameter

Flash temperature parameter(FTP), it is a non-dimensional value, stating the critical this parameter when emollients will fail to operating conditions. The expected of degeneration of the lubricant films can be observed for this parameter, **Masjuki,** and **Maleque, 1997.** Increase the value of FTP demonstrates good performance.
FTP value is found from the following equation:

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

3. RESULTS AND DISCUSSION

3.1 Kinematic viscosity

A comparison of this parameter quantities for neat mustard oil, mineral oil and blends of mustard with mineral oil under different temperatures of (25-100^{o}C) and freeload, were illustrated in **Fig. 2**. Adoption of this figure previously mentioned kinematic viscosity of all tested samples was reduced when temperatures increased. Consequential results on reducing the viscosity value were obtained through high temperatures by **Golshokouh, et al., 2013b** and **Haseeb** and **Masjuki, 2010.** The viscosity of all oils was similar to each other.
At a high temperature of 75°C, the viscosity of all oils performed was comparable to each other. The blending process resulted in increasing the values of kinematic viscosity compared to the neat mustard oil. Also, this type of viscosity values was obtained for the oil samples ISO VG32 requested level. Depending on the results of the kinematic viscosity in **Fig.2**, it can be concluded that the blend MU22.5 had shown higher kinematic viscosity, then the blend MU45 compared to other oil samples. The neat mustard oil MU100 and blend MU90 were comparable to each other in the terms of the kinematic viscosity.

3.2 Wear surface characteristics

Fig.3 representing blends of mustard and mineral oil ball specimens shows variable abrasive wear values forms with parallel grooves on the worn surface. The grooves in the dark region are deep, whereas those in light-colored areas are shallow with different scars; these have been the surfaces of the ball identified as shown in **Fig.3 (d and f).**
Wear scars for all blending ratios of mustard and mineral oil had the circular view is evident in **Fig.3**. As clear in **Fig.3** and **Fig.4**, the blending process of mustard and mineral oil blends reduce

the value of WSD compared to neat mustard oil and mineral oil, such as in the cases of MU22.2 and MU45, **Shahabuddin, et al., 2013,** and **Liaquat, et al., 2012.** The lowest value of diameter wear scar value was 420.56 µm for the MU22.5 blend, compared with neat mustard oil 647.73µm as well as for mineral oil 578.8µm.

3.3 Friction torque

The data for friction torque were tabulated from four-ball tribo-tester with the help of a computer and presented statistically as clear by **Fig.5**, It compares the moment torque friction value for blends of mustard and mineral oils. The final figure illustrates friction torque values were reduced compared to clean mustard and mineral oils during the blending procedure **Masjuki, et al., 2011.** The lowest FT are calculated 0.09715 Nm for MU90 blend, for comparison pure mustard oil at 0.13182 Nm and that of mineral oil at 0.14424 Nm.

Fig.6 shows the friction torque plotted against the sliding time for various mustard oil based bio-lubricants. The results of **Fig.6** show that the friction torque is highest at the beginning and then it came down rapidly. Throughout the operation time, the bio-lubricant percentage 90% (MU90) showed the lowest values of friction torque compared to another oil samples. The fatty acid components of the bio-lubricants formed a multi and monolayer on the surface of the rubbing zone and made a stable film to prevent the contact between the surfaces.

3.4 Coefficient of friction

Fig.7 shows the comparison of this coefficient values for mustard and mineral oil mixtures. From the figure, this coefficient values will decrease by comparison with pure mustard and mineral oils due to mixing procedure **Shahabuddin, et al., 2013, Liaquat, et al., 2012** and **Masjuki, et al., 2011.** The value was the smallest value of the friction coefficient 0.05508, which was identified in the sample of the MU90 blend, compared to that of neat mustard oil at 0.07474 and that of mineral oil at 0.08179.

Relationship of this coefficient value of various blending ratio percentages of bio-lubricants with the sliding time given in the **Fig.8**, show the results that the MU90 has the highest potential to reduce the friction coefficient compared with another oil samples and show that this coefficient is highest at the beginning and then it came down rapidly.

3.5 Flash temperature parameter (FTP)

Fig.9 shows the outcomes of this parameter *FTP* for mix mustard and mineral oil, pure mustard oil, and mineral oil. Based on this figure, blending process escalated the *FTP* values as shown in the case of MU22.5 and MU45, compared to neat mustard and mineral oils **Shahabuddin, et al., 2013**, and **Liaquat, et al., 2012.**

The highest value for the flash temperature was 134.49 for the MU22.5 blend, compared to that of neat mustard oil at 73.47 and that of mineral oil at 86.01.

4. CONCLUSIONS

The conclusions drawn from this paper will be presented.

i. The mixing process leads to reduce the value of the wear scar diameter compared to the value of the neat mustard oil and mineral oil.

ii. The blending process results in an improvement in the tribological characteristics, which led to reduce the friction coefficient. In addition, the blending process led to the value goes up *FTP*.

iii. From the study, it can be recommended that the blends of mustard oil with mineral engine oil (MU22.5 and MU45) could be an effective alternative bio-lubricant, as it shows better impact on wear and offered a good lubricant characteristic.

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NOMENCLATURE

F=frictional force ,N .
FT= friction torque,N.m
FTP=flash temperature parameter
MO =mineral engine oil
N=normal load ,N
r = the length between the hub and contact center on the balls is placed at lower surface, 3.67mm
W= application value of loads, kg.
WSD=wear scar diameter, μm
μ =friction coefficient.

Table 1. Percentages of the mustard oil and mineral oil in each sample**.**

Sample		Mustard oil (%)		Mineral oil(%)
MU22.5		22.5		77.5
MU45		45		55
MU67.5		67.5		32.5
MU90		90		10
MU100		100		0
MO100		0		100

Figure 1a. Photograph of the four-ball tester machine.

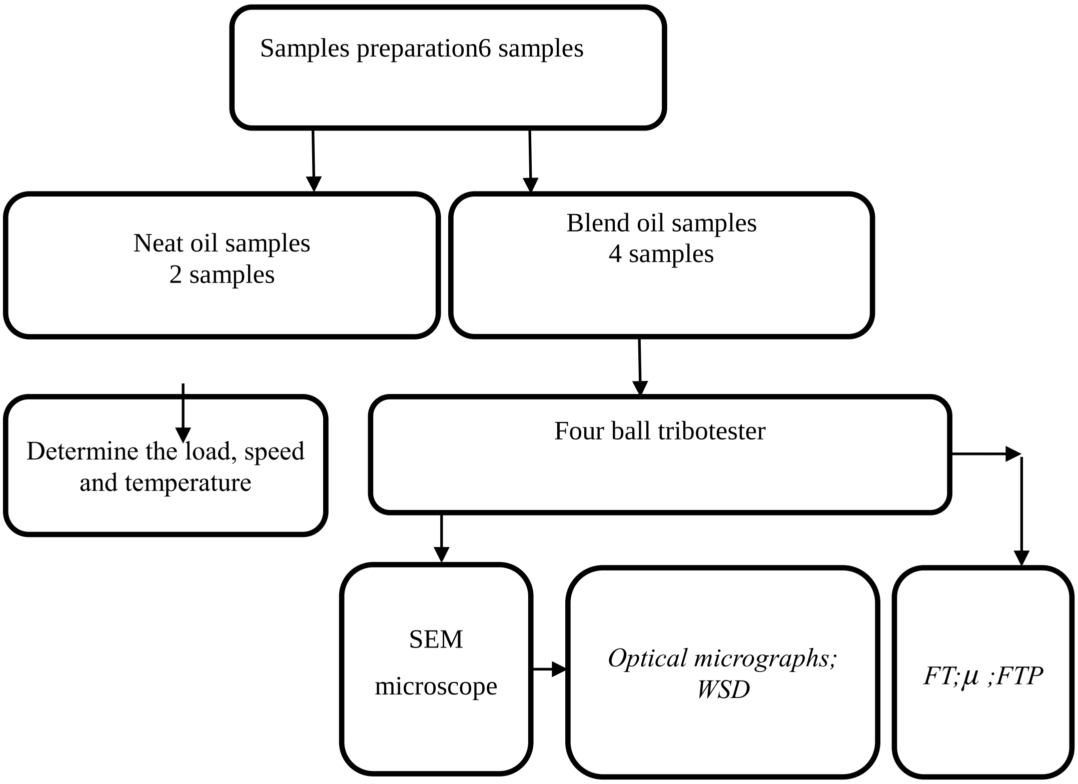

Figure 1b. Block diagrams of friction and wear testing of the four-ball tester machine.

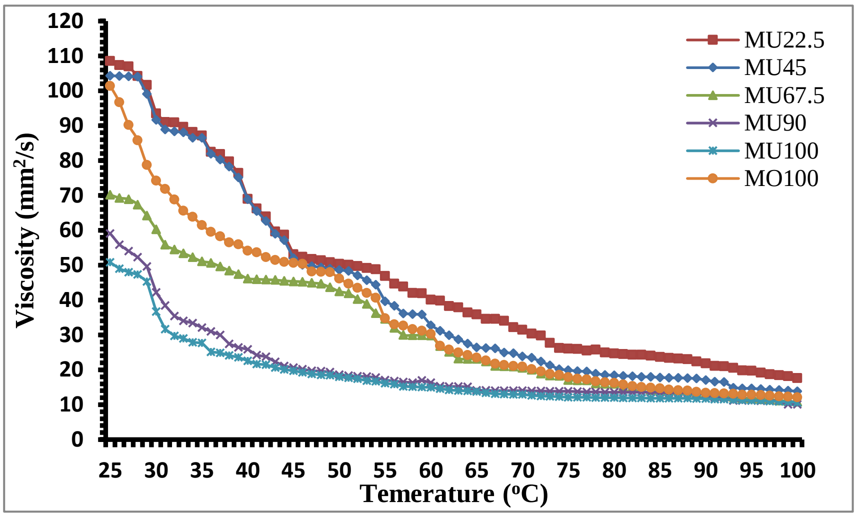

Figure 2. Kinematic viscosity values for the oil samples under different temperatures.

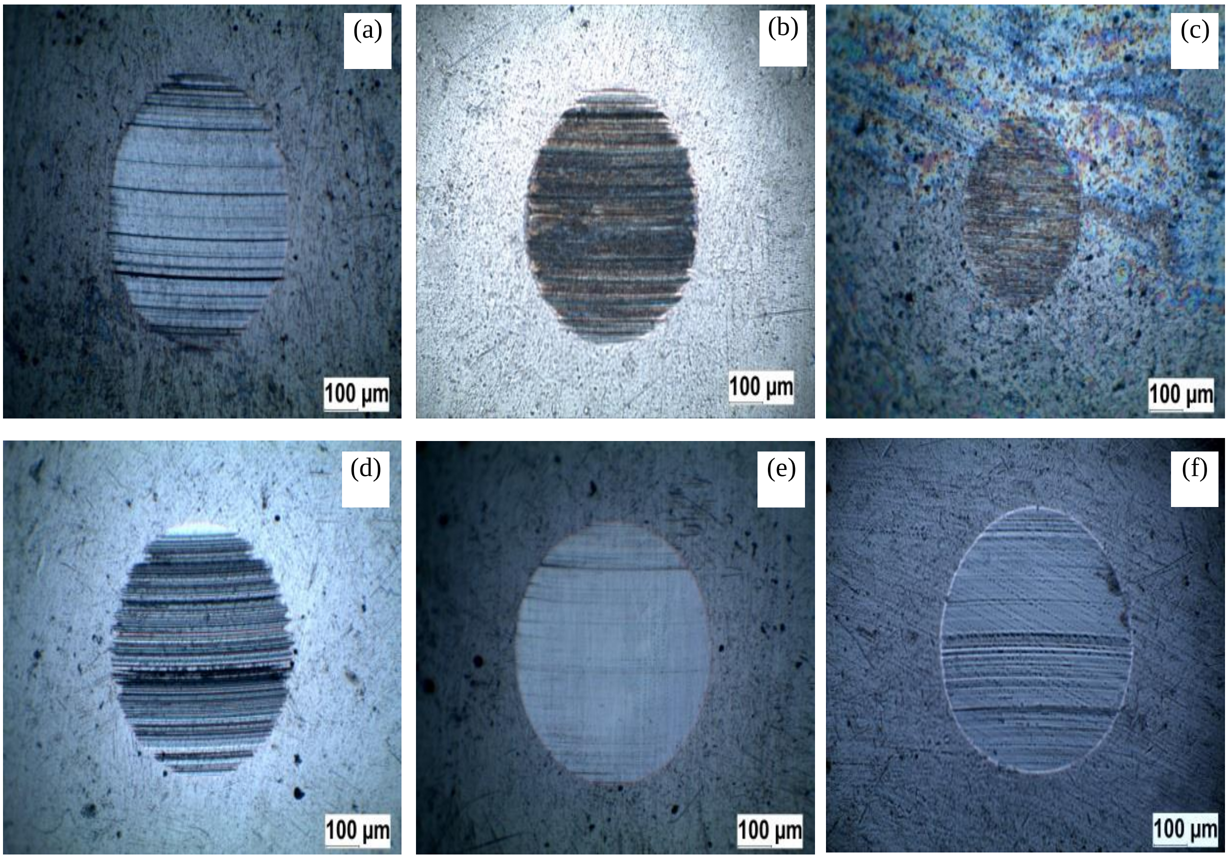

Figure 3. Optical micrographs of mustard oil samples in different volumetric blending ratio: (a) MU100; (b) MO100; (c) MU22.5 ; (d) MU45; (e) MU67.5 ;(f) MU90.

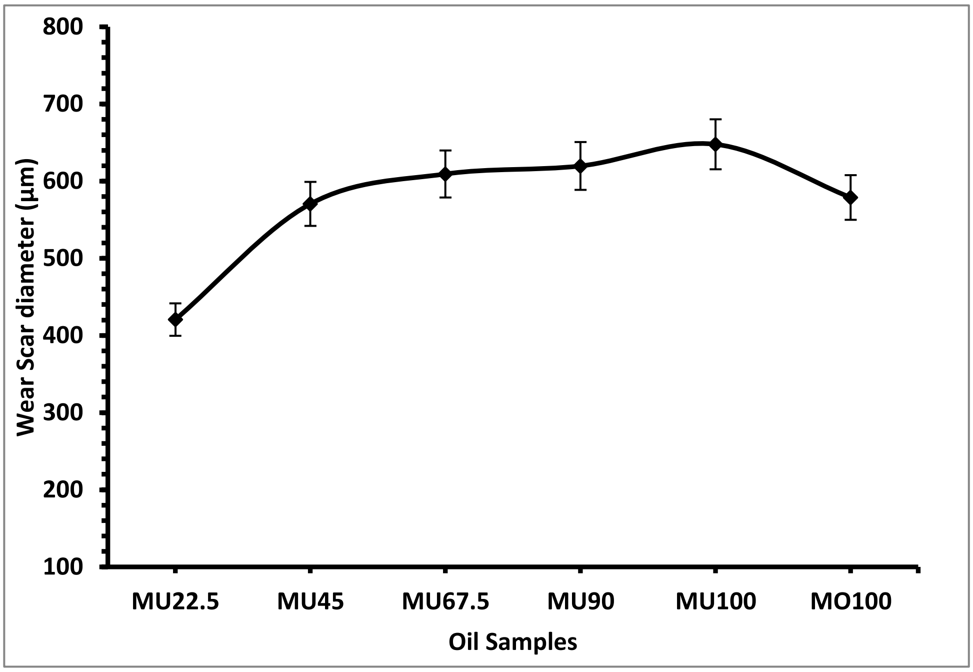

Figure 4. Wear scar diameter for the oil samples.

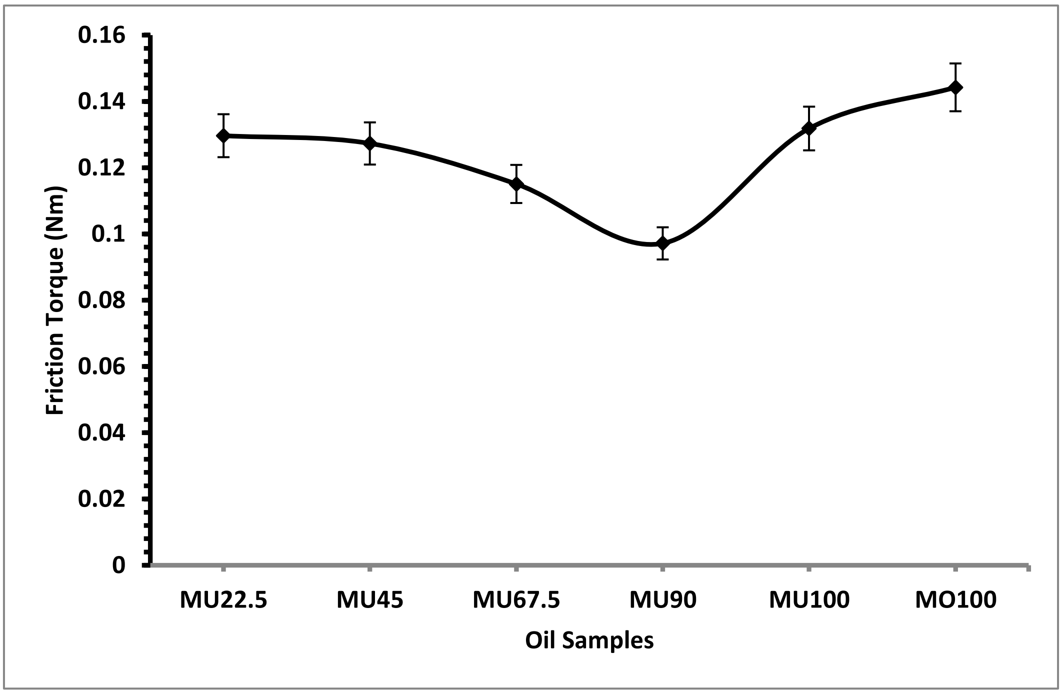

Figure 5. Friction torque values for oil samples.

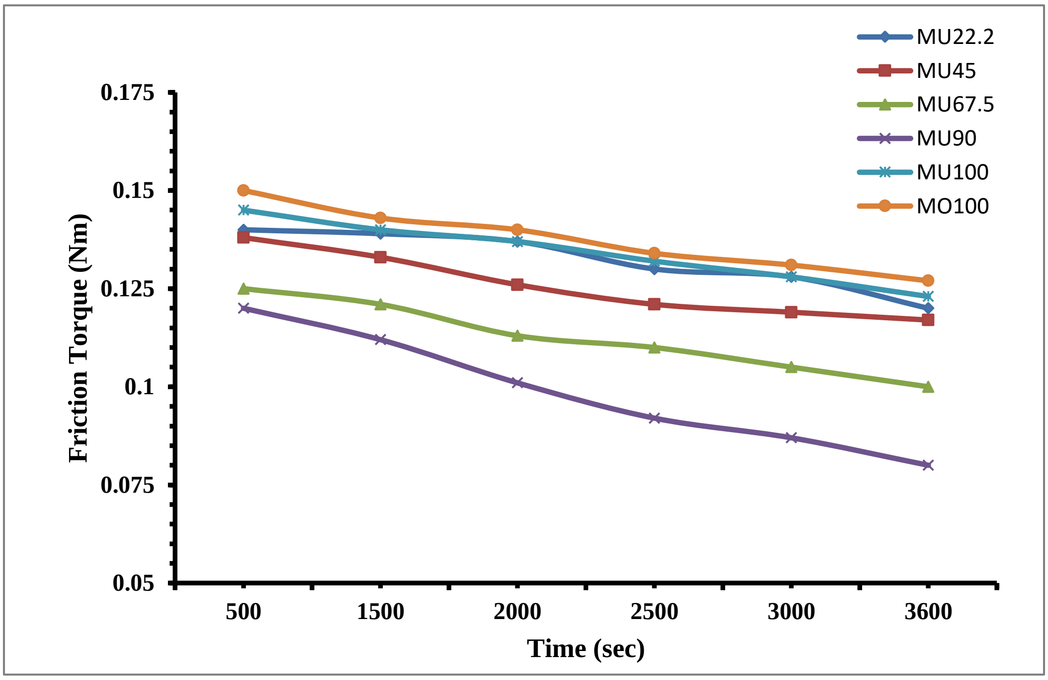

Figure 6. Friction torque as a function of sliding time for oil samples.

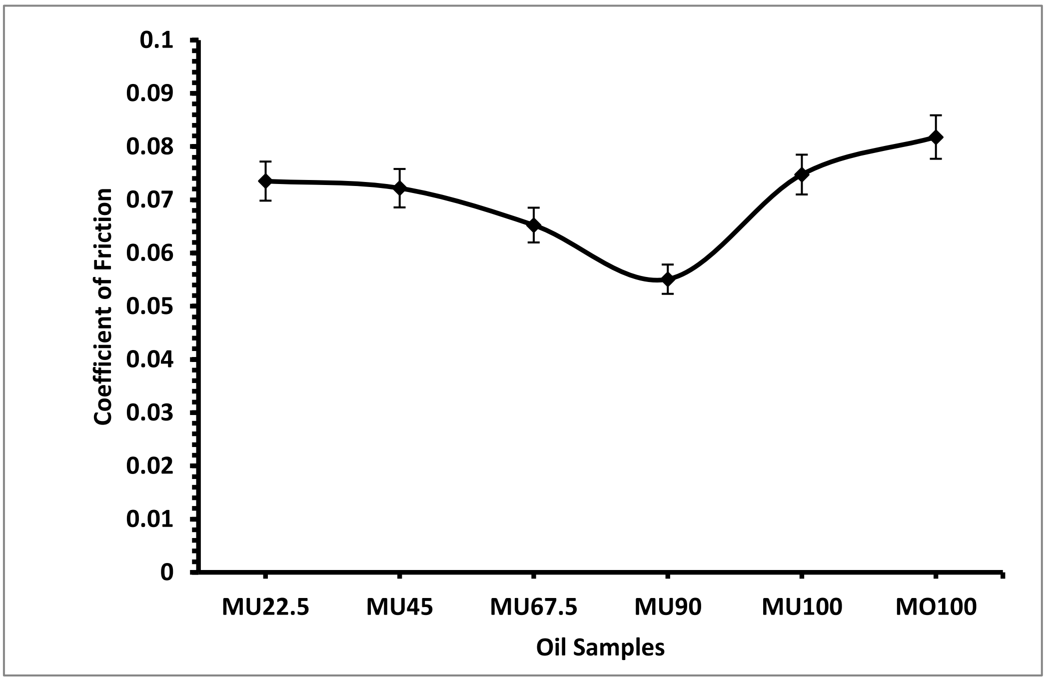

Figure 7. Coefficient of friction values for oil samples.

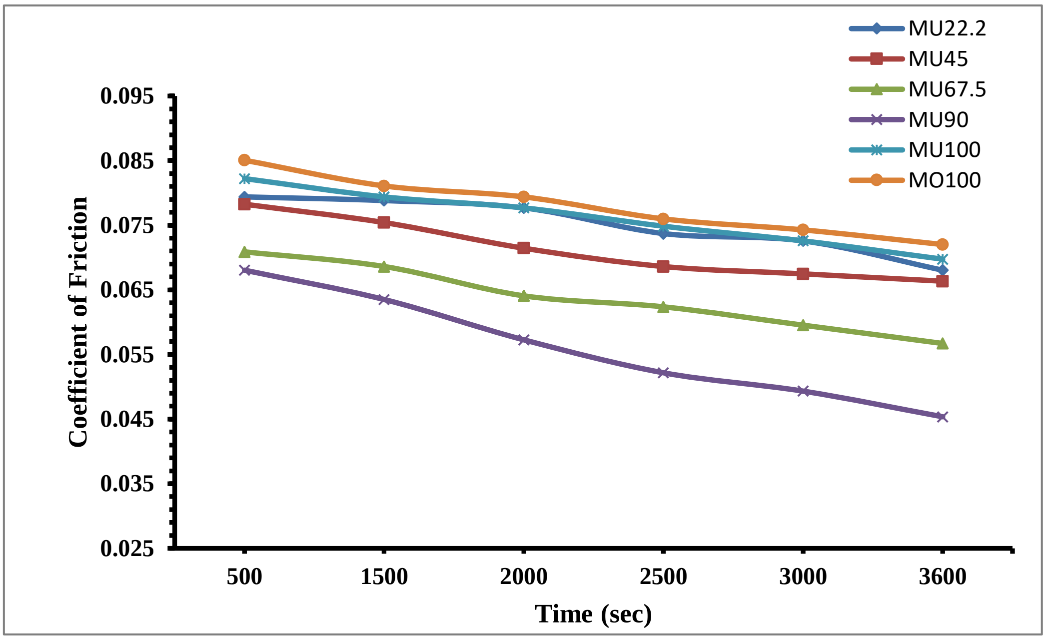

Figure 8. Coefficient of friction as a function of sliding time for oil samples**.**

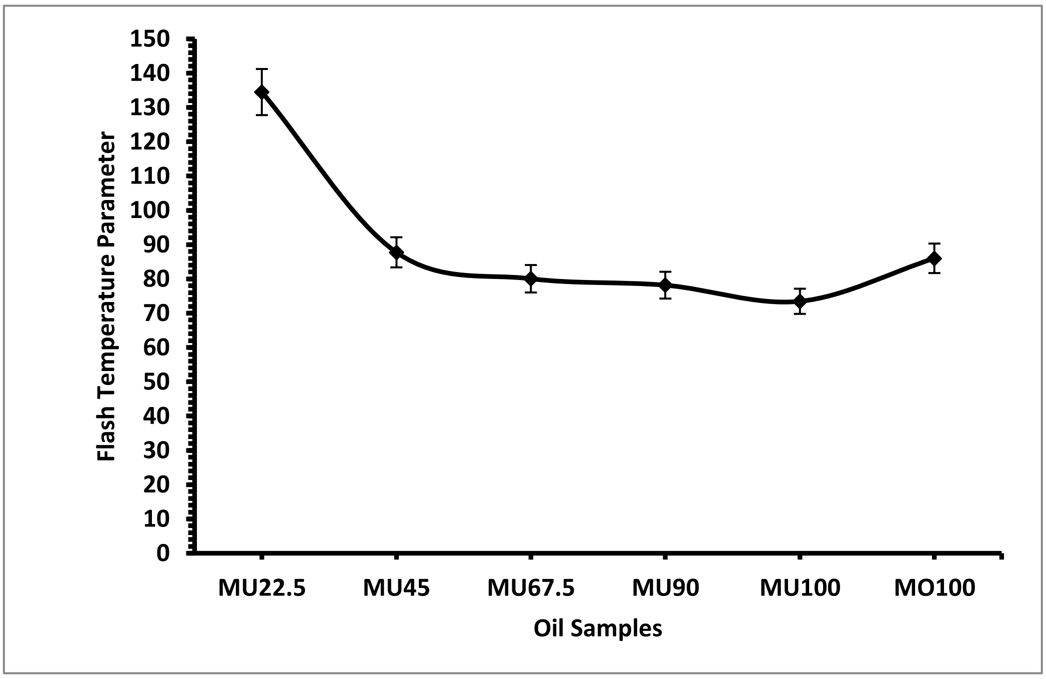

Figure 9. Flash temperature parameter values for oil samples.