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TRIBOLOGICAL PERFORMANCE OF MUSTARD SEEDS OIL UNDER DIFFERENT LOADS USING PIN-ON-DISK TRIBOTESTER

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ABSTRACT

Vegetable oil has been investigated to displace products which are derived from petroleum because of its environmentally-safe properties and has become a vital source for bio-lubricants. Vegetable oil availability as one of the renewable sources is one of the usefulness of it. Additionally, the vegetable oils based lubricant has indicated the potentials for reducing carbon dioxide and hydrocarbon emission while operating in internal combustion engines and in industrial processes. In this study, the mustard seeds oil was investigated to study its lubricant characteristics under different loads while comparing it with commercial lubricant using a pin-on-disk tribometer. The whole experiential works were corresponding to American Society for Testing and Materials (ASTM G99).Under low load, the results exhibit that the mustard seeds oil shows adequate tribological characteristics compared to other petroleum oil samples. In conclusion, the mustard seeds oil has a better wear and friction resistance. Therefore, mustard seeds oil can be used for lubrication of mating components.

KEYWORDS: Mustard seeds oil; Commercial lubricant; Wear scar diameter; friction Coefficient.

الأداء التربولوجي لزيت بذور الخردل تحت الاحمال مختلفة باستخدام PIN-ON-DISK TRIBOTTESTER

محمد حسان جبل مهند زيدان خليفة عبدالمنعم رعد عبدالمنعم

الخلاصة

تم دراسةامكانية استخدام الزيوت النباتية لتحل محل المنتجات المشتقة من البترول بسبب خواصها الآمنة بيئياً ، والتي أصبحت مصدراً حيوياً لمواد التزييت الحيوية. يعتبر توافر الزيت النباتي كواحد من المصادر المتجددة هو أحد فوائده ، تشير زيوت التزييت القائمه على زيوت النباتية إلى إمكانيات خفض انبعاثات ثاني أكسيد الكربون والهيدروكربون أثناء التشغيل في محركات الاحتراق الداخلي وفي العمليات الصناعية. في هذه الدراسة تم فحص زيت بذور الخردل لدراسة خصائص التزييت تحت ألاحمال مختلفة أثناء مقارنتها مع زيوت التزييت التجارية باستخدام مقياس قبضة الدبوس على القرص (pin-on-disk) كانت جميع الأعمال التجريبية متوافقة مع الجمعية الأمريكية للاختبارات والمواد .(ASTM G99) تحت الحمل المنخفض ، أظهرت النتائج أن زيت بذور الخردل يظهر خصائص تريبولوجية كافية بالمقارنة مع عينات زيوت بترولية اخرى .نستنتج أن زيت بذور الخردل لدية خصائص افضل في البليان ومقاومة الاحتكاك لذلك فان زيت بذور الخردل ، يمكن استخدام زيت بذور الخردل لتزييت الاسطح المحتكة فيما بينها.

الكلمات المرشدة: زيت بذور الخردل، زيوت التزييت التجارية، قطر بليان الخدش، معامل الاحتكاك.

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INTRODUCTION

Bio-lubricants, which are also called bio-based lubricants are made from a set of edible oils like canola, palm ,coconut oils, soybean, sunflower and rapeseed and the non-edible oils from jatropha, mustard and jojoba oils. Food vs. Fuel problems, lubricants problems and environmental and economic issues related to edible vegetable all can be overcome by using of bio-lubricants from non-eatable. Non-eatable oils are inappropriate to be used inhuman being food because of some toxic components are found to be present in the oils. The using of non-eatable oils as lubricants requires extensive characterization studies **Abdullah et al.[2014].**

The benefits of picking vegetable oils instead of mineral oils sources are the way that they are biodegradable and are less lethal when contrasted with petroleum-based oil. They are not difficult to create from a sustainable source. Moreover, during an investigation on the tribological behaviour of two contact sliding metals between one another using biodegradable oil as lubricant, they demonstrated that the vegetable oils have even a superior greasing up capacity contrasted with mineral or manufactured oils since they contain a lot of unsaturated and polar ester bunches segments that positively influenced the conditions during the reciprocating sliding motion **Mohammed Hassan[2016]** and **Golshokouh et al. [2014]**. Additionally, the long chain unsaturated fats in vegetable oils have better characteristic lubricants properties.Vegetable oils uncover great lubricating capacities since they produce low coefficients of frictions.

On the other hand, other scholars have reported that most vegetable oils having lower coefficient of the frictions, but has higher wears rate. In another study on the chemical reaction on the surfaces of metal where the unsaturated fats were available in the vegetable oils, they discovered that the metallic soap films are washed away while sliding, then produces unreactive detergent which expandthe wear **Golshokouh et al.[2014].**

There is a rapid increase in the research, development, and use of vegetable oil for lubrication purposes in industries and automobile engines , which includes crude palm oil as a potential fuel in dieselmotors **Bari et al.[2002]** and **Abdullah et al.[2014]**, the potential ofvegetable oil as hydraulic fluid **Wan Nik et al.[2005]** and **Wan Nik et al.[2007]** and the attributesof vegetable oil as a metal shaping lubricant **Syahrullail et al.[2005]** and **Syahrullail et al.[2011].**

Studies of vegetable oils as a potential substitute for mineral base oils can be categorized into four major groups, where studies that was focused on the tribological attributes of neat vegetable oils **Abdul Fattah et al.[2017]** and **Ing et al.[2012];** vegetable oil emulsion (Nor Hayati et al.2009), vegetable oil with additives **Jabal et al.[2014]** and studies that was focused on the tribological characteristics ofvegetable oil as an additive **Maleque et al.[2000].** Every one of them discovered that vegetable oil indicated acceptable outcomes and can possibly be utilized broadly in engineering applications.

In the previous studies, researchers used various vegetable oil-based lubricants and additives, but there are very limited references that use mustard seeds oil as a base lubricant. This study investigates the anti-frictions and anti-wear performance of mustard seeds oil under different loads using a pin-on-disk tribometer.

EXPERIMENTAL WORK

Tribotester Apparatus

The pin-on-disk tribometerusedfor examination friction and wear processes under sliding situations as shown in Fig 1,and personal computer (PC) is connected to it with data acquisition system. It can be operated for boundary lubrication with liquid lubricants and for solid friction (dry friction) without lubrication. Hence both lubricant and material tests can be executed.

Two specimens are needed for the pin-on-disk wear test. One, a pin with a spherical tip, is setperpendicular to the other, commonly a flat circular disk. A ball, rigidly held, is frequently utilizedas the pin specimen. The test machine leads to either the the pin specimen or disk specimen to spin about the disk center. In both of cases, the sliding path is a circle on the disk surface.

The pin specimen is pressed against the disk at a predefined load usually by means of attached weight sand lever or arm. Further loading methods have been utilized for example, hydraulic or pneumatic.

Wear results are reported as a dimension in micrometer for the pin and the disk separately. When testing two different materials, it is suggested that each material be tested in both the disk and pin positions.The estimation of wear is carried out by measuring appropriate linear dimensions of both specimens before and after the test by usinga linear voltage differential transformer (LVDT) sensor .

The friction coefficient (μ) is identified during the test by measuring the force of friction by means of the deflection of the elastic arm (strain gages bonded on the elastic body of the arm convert it in a force sensor and permit the direct measurement of the frictional force).

Specimen Material

Wear and coefficient of friction behavior were performed with a stainless steel spherical tip pin was chosen for the experiment. Pin samples were prepared as 6 mm in diameter and 20 mm in length. The density of stainless steel is 7.48 g/cm^3. A stainless steel flat disk (Ø165*8mm EN-31,hardened to 62 Hrc,ground to 1.6Ra) had been selected as shown in Fig. 2.

Lubricants

The lubricants used for this experimental study was the vegtable oil (mustard seed oil) and mineral oil (SAE 40 mineral engine oil and commercial hydraulic oil). The results obtained from experiments using mustard seed oil under different loads were compared with the results from commercial mineral oil. Each trial test used 5 ml of the lubricant.

Test Procedure

Based on the standard test (ASTM G99) principle , a stationary test specimen (pin) with a determined normal force is compressed against the rotary disk surface ,wear and coefficient of friction had been studied under different loads (2 kg=9.62N ,3 kg=29.43N and 5 kg=49.05 N) during 3600 sec.1200 rpm was set as rotational speed of the rotary disk and wear track diameter of 40mm.

In this study , the lubricant was let to flow through the disk without pumping it , a 5ml of the lubricant was dropped on the disk.After the fulfillment of both test, abrasive paper with the grain size of the abrasive material of 1000μm was utilized to grindthe surface so that the surface finished was between specifications. Before conducting the test it was guaranteed that the surface of the specimens are cleaned completely i. e, dirt or debris free. Alcohol was used for the purposeof cleaning.The block diagram of friction and wear testing are shown in Fig. 3

Kinematic Viscosity

Kinematic viscosity is a measure of the resistances of a fluid that deformed by either the shear stresses or the tensile stresses of the fluid. It is also defined as internal frictions of the fluid. A rotary viscometer (shown in Fig. 4) was utilized for measuring the viscosity for lubricants under different temperatures. The viscometer has a spindle that rotates with a certain speed. After inserting the spindle into the lubricant, the speed of the spindle resisted the fluidity or viscosity of the lubricant and the viscosity could be measured.

Wear Scar Diameter

The wear scar diameter of each of the pins after 1 hour of runing was measured to determine the lubricity performance of the test lubricant. The wear scar was assessed by computer optical and scanning electronic microscope (high resolution) software and from the captured micrographs.

Frictional Force and Coefficient of Friction

From the pin-on-disk tribometer machine, the frictions force was recorded during 1 hour utilizing particular data acquisition system. The frictions force for the wholetest lubricants has increased quickly at the beginning of the test to 300sec. The friction force data became stable and insteady state condition after 300sec.The average of friction force at the steady-state condition was recorded and the friction coefficient, as calculated according to IP-239, is shown in Equation (1):

$$\mu = \frac{F}{N} \quad (1)$$

Where: μ is the frictions coefficients, F is the frictional force in Newton, N is the apply loads in Newton. The same calculation method was used by,[11].

Flash Temperature Parameter

The flash temperature parameter (*FTP*) is a single number which is utilized for expressing the critical flash temperatures, when the lubricants fail under certain given condition. The *FTP* shows fewer possibilities of lubricant films for breaking down,[12]. High value of *FTP* shows high performances of the lubricants.
The *FTP* can be measured by using the Equation (2):

$$FTP = \frac{L}{(WSD)^{1.4}} \quad (2)$$

Where: L is the applied load in kg and WSD is the wear scar diameter in mm.

RESULTS AND DISCUSSIONS

The tribological performance of vegtabail and mineral lubricants were investigated and characterized. The results give an insight to better understanding the behaviour of spherical tip pins with mustard seeds oil using oil analysis like flash temperature parameter, coefficient of friction , wear scar diameter and Kinematic viscosity. The results were compared with commercial mineral and hydraulic lubricant.

Kinematic Viscosity

A comparison this parameter quantities for neat mustard oil, mineral and hydraulic oil under two different temperatures of (40 and 100^{o}C) with free load, were illustrated in Fig.5. 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[3] and [13].

At high temperature 100°C, Viscosity of all oils performed was comparable to each other. Depending on the results of the kinematic viscosity in Fig.5, it can be concluded that the mineral oil shown higher kinematic viscosity value (54.16 and 12.13 mm^2/sec at 40 and 100^{o}C respectively), then hydraulic oil (46.18 and 10.80 mm^2/sec at 40 and 100^{o}C respectively) and the lower value for the mustared oil (25.86 and 10.10 mm^2/sec).On the other hand, it was noticed that, the neat mustard oil has a higher value of viscosity index compared to the value mineral and hydraulic.

Wear Scars Diameters

After the experiment being starts, a particular data acquisition system was used to record the wear sacar diameter of the pin-on-disk tribometer machine during 1 houre as a time test and by using a sem scanning electron microscope the wear scar diameter of each of the pins after 1 hour of runing were measured . Fig.6 a,b,c ,d and Fig.7 shows the comparison of *WSD* between the neat mustard seeds oil,mineral oil and commercial hydraulic oil. For figures, it could be concluded that the increment of the wear scar diameter relative to the time for the 2,3 and 5kg respectively. Under low loads (2 and 3kg respectively) the values of wear sacar diameter for the neat mustard seeds oil (24.79and 287.96 µm) was lower than the values of another oil samples (345.94 and 390.27µm for mineral and 442.68 and 463.80µm hydraulic oil).under high load (5kg) the mineral oil samples shown lower value of wear scar diameter compared with hydraulic oil and mustard seeds oil because the metallic soap film is rubbed away during sliding.Therefore, under (2 and 3 kg) the mustard seeds oil shown better anti-wear performance compared with another oil samples.

Coefficients of Frictions

The results of the coefficients of friction for the mustard seeds oil,mineral oil and commercial hydraulic oil were calculatedby using equation (1) and offered graphically as indicated in Fig.8a,b,c and d. The figure compares the coefficients of friction quantities of the oil samples. Based on the figure and under diffrent loads (2,3 and 5 kg), it was found that the all test lubricants showed decrement of coefficient of friction during the test time.
From Fig.8 could be observing, the values of friction coefficients for mustard seeds oil were still lower than that for mineral andhydraulic oil under diffrent load [13]. The lowest coefficient of friction value of0.0263 was identified in mustard seeds oil in respect to 0.0392 for mineraloil and 0.0508 for hydraulic oil under 2kg.

The results from the Fig.8 can be attributed to the fact that the bio-lubricants especially, mustard oil has strong affinity to act as a friction reducing additives and in addition portability to retain its property.

Flash Temperature Parameter

The amount offlash temperature parameter was estimated under the influence of loadsby using equation (2) for the vegetable and mineral test samples,the results for 1 hour test time and under (2,3 and 5 kg) are shown in Fig.9 a,b,c and d. From Fig.9 a and b could be observing the highest values of FTP were occurred for the mustard seeds oil compared with the values for the mineral and hydraulic oil under low load values (2 and 3 kg) during 3600 sec, that mean, when the neat mustard seeds oil was used as lubricant, it will minimize the probabilityof lubricants film breaking down and increasing the lubricity performance in comparison to other oil samples.Under high value of load 5kg (see Fig 9c) the mineral oil shown the highest values of FTP compared to the mustard and hydraulic oil samples.

The results of this investigation showed that the decrement of the flash temperature parameter to the time for the 2,3 and 5kg .For the 5kg, mineral test sample shown highest amount of FTP (18.81) compared to the 15.76 for the mustard seeds oil and10.41 for hydraulic oil.In case of 2 and 3kg respectively, the amount of flash temperature parameter for the neat mustard seeds oil (16.53 and 18.65) was higher than the values (6.79 and 9.40) of hydraulic oil samples and10.11 and 12.30 for mineral oil samples.That refers to, under low load the mustard seeds oil shown better lubricity performance compared to another oil samples.

CONCLUSIONS

The conclusions that are extracted from the present paper are as following:

i. Under low load,The lowest WSD and highest FTP amount for the mustard seeds oil indicate to better anti-wear performance compared to the commercial mineraland hydraulic oil samples.
ii. Under diffrent loads,the mustard seeds oil showed a lower value of friction coefficient (good anti-friction performance) compared to the commercial hydraulic and mineral oil.
iii. The overall analysis suggests that, the mustard seeds oil has the potential to be used as alternative bio-lubricant according to bio-degradability and a well wear phenomena and lubricating performance.

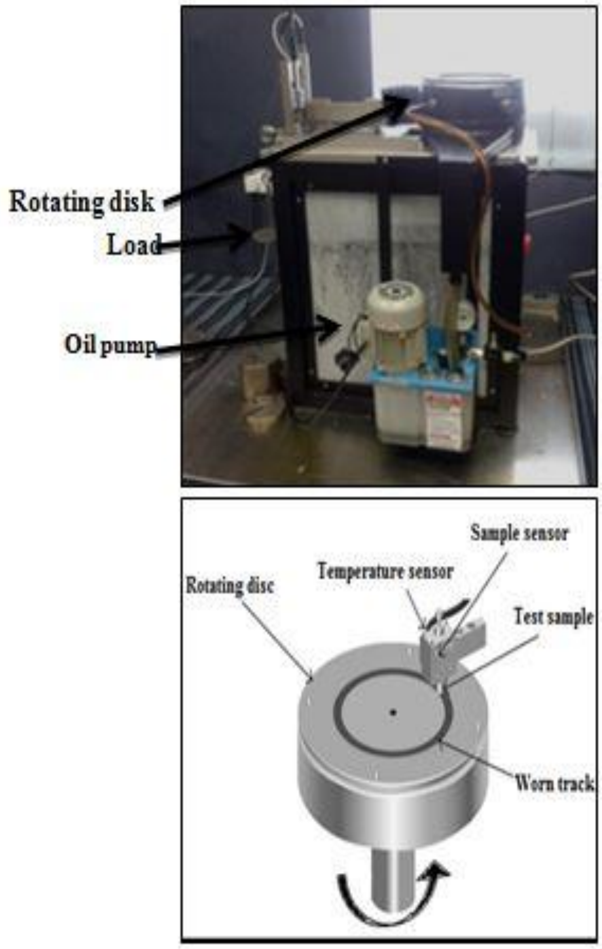

Fig.1.Pin-On-Disk Tribometer

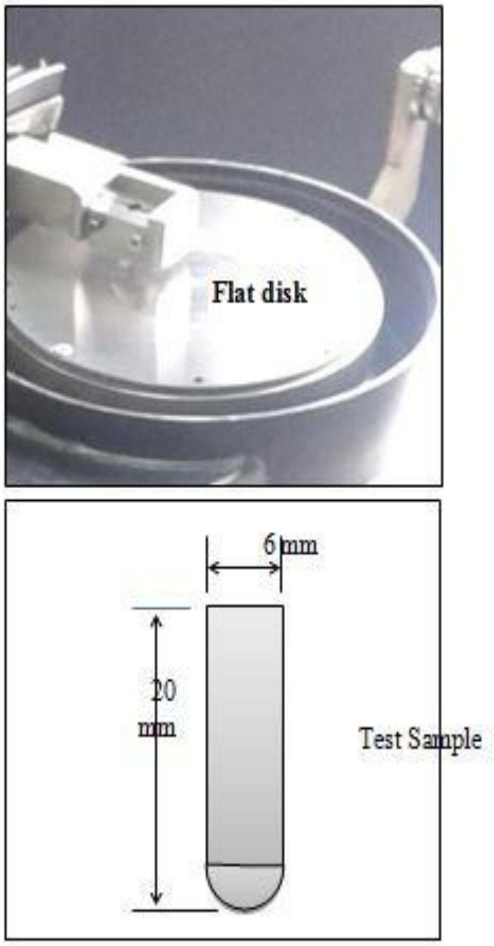

Fig.2.Flat Disk and Spherical Tip Pin Specimen

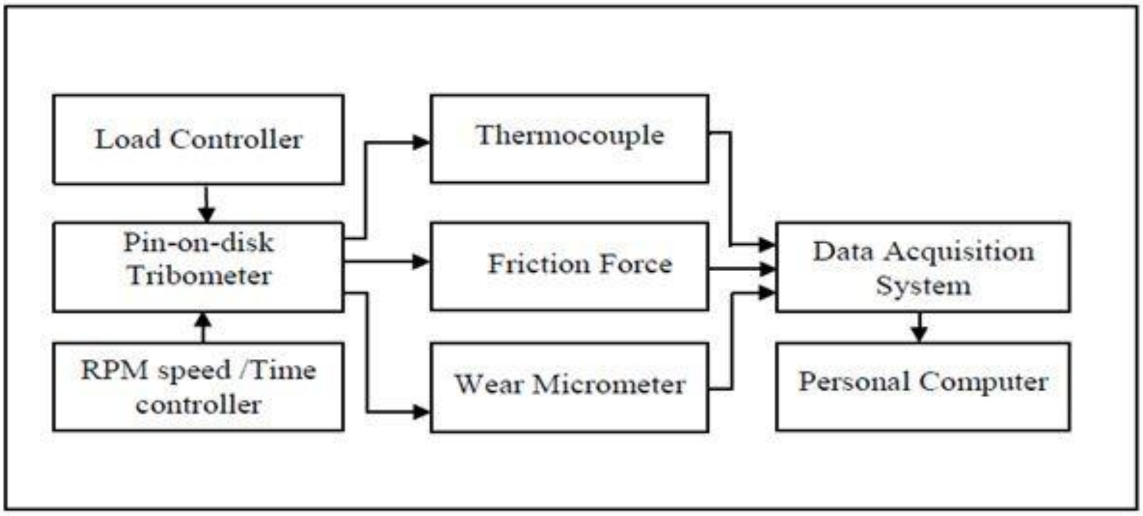

Fig. 3. Block Diagram of The Experimental Set-Up.

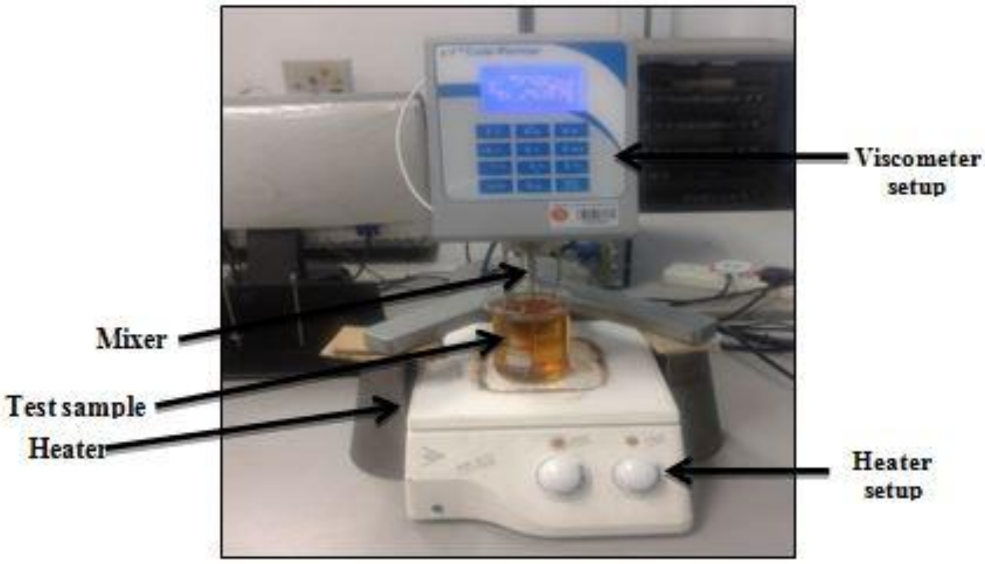

Fig.4.RotaryViscometer

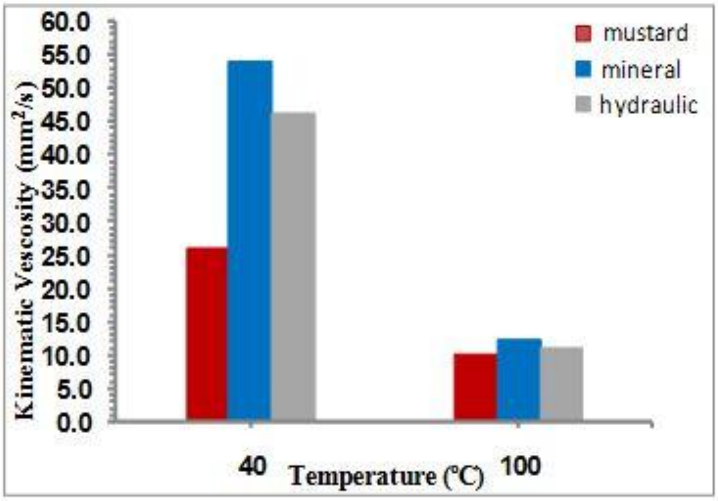

Fig.5. Kinematic Viscosity Values For The Oil Samples

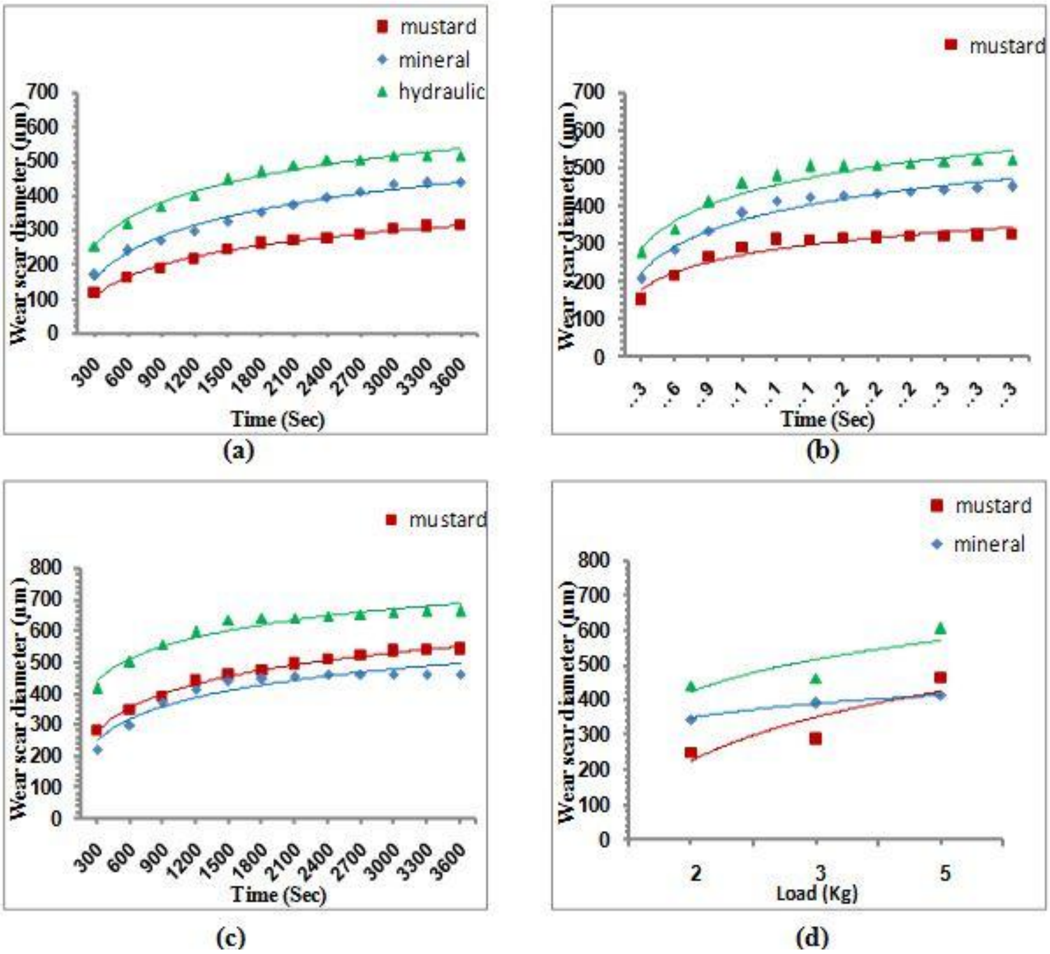

Fig.6.Wear Scar Diameter For The Oil Samples Under Diffrent Loads:
(a)2kg; (b)3kg; (c)5kg; (d)2,3 and 5kg

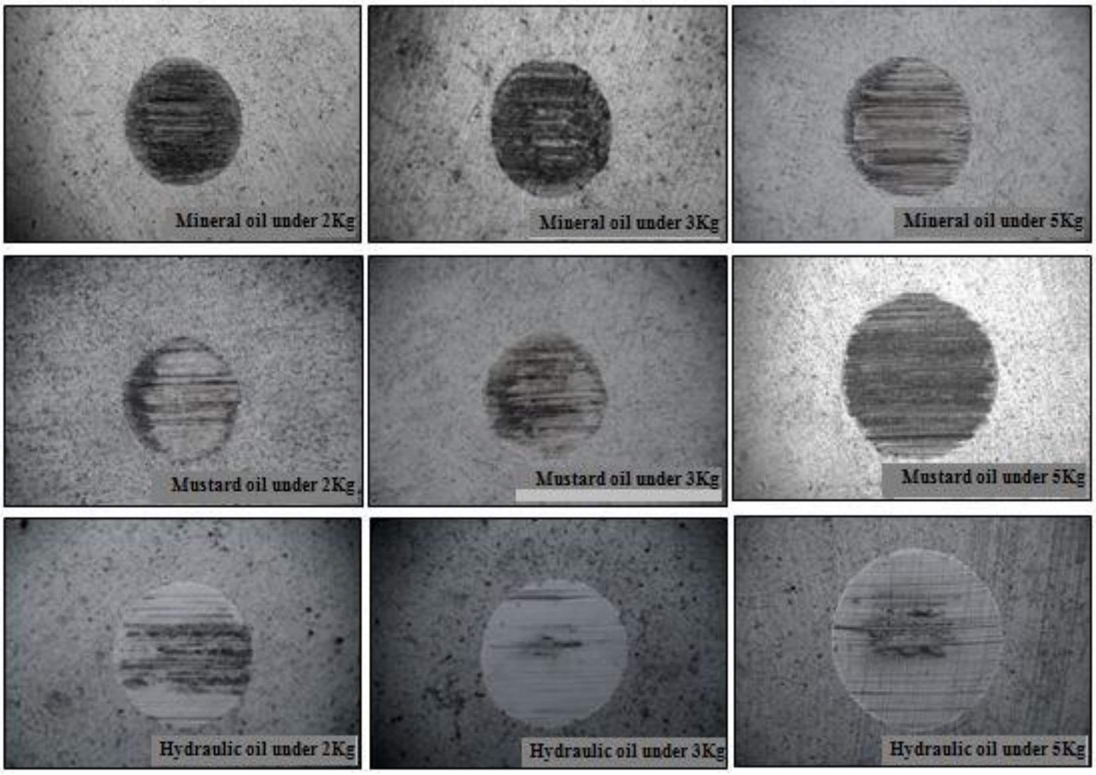

Fig.7.Optical Micrographs for the Oil Samples Under Different Loads

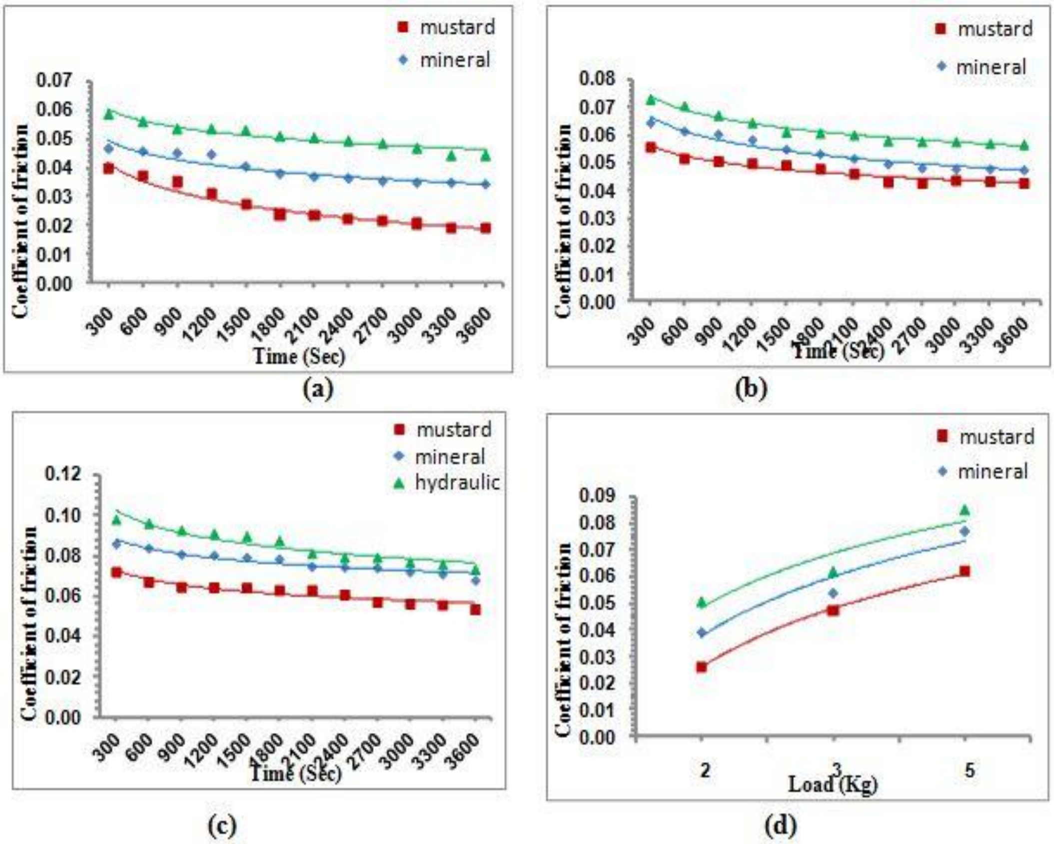

Fig.8.Coefficients of Frictions Values For The Oil Samples Under Diffrent Loads: (a) 2kg; (b) 3kg; (c) 5kg; (d) 2,3 and 5kg

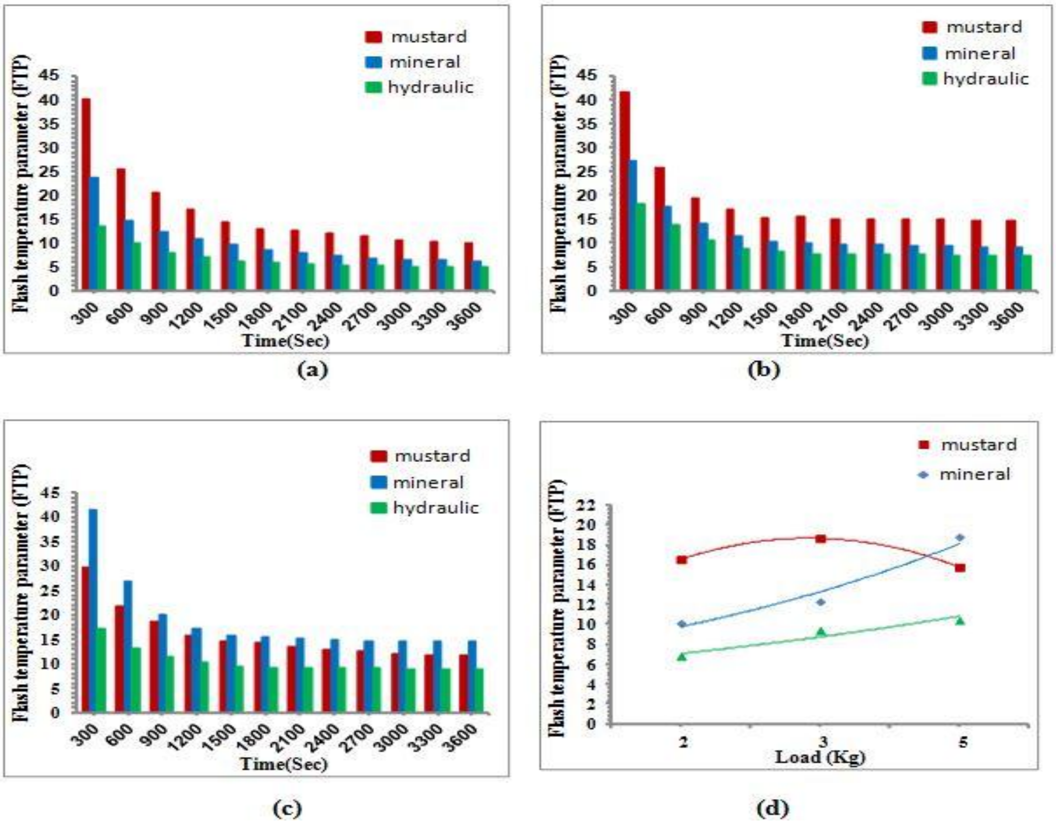

Fig.9.Flash Temperature Parameter Values For The Oil Samples Under Diffrent Loads: (a) 2kg; (b) 3kg; (c) 5kg; (d) 2,3 and 5kg

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