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RESEARCH

Investigation of Lubrication Characteristics of Virgin and Additive Blended Jatropha Based Grease

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A B S T R A C T

Increasing interest in utilizing bio-lubricants has been sparked by pollution caused by the mineral oil-based lubricants and their depletion. This study aimed to assess the effectiveness of Jatropha oil based grease as a basis and sodium thickener as an additive. The grease's lubricating abilities were tested using the ASTM 2266 four ball test and molybdenum disulphide as an additive. According to the findings, adding molybdenum disulphide particles decreased wear and the coefficient of friction, with the latter falling by 69% when compared to virgin Jatropha grease. Given that Jatropha grease passed the four ball test, a simulation of real-world conditions, this indicates that it is a reliable lubricant. Wear examinations were performed on steel balls using an optical microscope and scanning electron microscopy, and the results were consistent. It was found that addition of 0.25% MoS_2 to virgin Jatropha grease reduced coefficient of friction to 0.12 (69%) from 0.39. Similarly wear scar diameter reduced from 800.583 μ to 788.44 μ in presence of 0.25% MoS_2 blended grease. The study concludes that the grease prepared could an alternative to grease made from mineral oils. The focus on adopting Jatropha grease as a more sustainable and bio-degradable option can preserve the environment.

1. INTRODUCTION

Jatropha oil and its uses as a lubricant and fuel have been the subject of extensive research. Golshokouh, et al. [1] investigated the characteristics of Jatropha oil to determine its potential as a renewable and environmentally viable lubricant. A series of tests were performed on a four-ball tribo-tester to conduct the analysis. Different loads (200, 400, and 600 N) and temperatures (55, 95, and 125°C) were used in the experiments. The experiments were carried out in accordance with ASTM D 4172. The experiments examined the viscosity, coefficient of friction, wear scar diameter, anti-friction, and anti-wear properties of Jatropha oil. To evaluate the Jatropha oil's lubricating properties, the research findings were compared with those of a commercial mineral oil-based lubricant, specifically hydraulic oil. The results showed that, at different temperatures and loads, Jatropha oil has a higher lubrication capability compared to hydraulic mineral oil. Syaima, et al. [2], studied the utilization of bio-lubricant as substitute to fossil-based lubricants as an alternative to address the crude oil depletion. The study discovered that the properties of both unmodified and modified Jatropha curcas oils did not meet the characteristics of commercial lubricants. This indicates that there is a scope for further research to improve Jatropha curcas-based bio-lubricants by incorporating other additives to achieve the desired lubricant properties that align with commercial SAE standards. Imran, et al. [3] investigated the characteristics of Jatropha oil blended with lube oil on the friction and wear. It was found that 10% of Jatropha oil gives lowest wear and generates less amounts of heat. However, more than 10% of lube oil blend, the wear and lubricating temperature increases significantly. Bilal, et al. [4], analyzed the Jatropha oil for its chemical and physical properties such as density, acid value, % FFA (free fatty acids), saponification value as well as viscosities at 40 and 100^{o}C and viscosity index. The result of this analysis revealed that it has a very high % FFA (free fatty acids) (14.6%). Syahrullail, et al. [5], tested the performance of vegetable oils as a lubricant using a four ball tribotester under extreme pressure conditions, which conforms to ASTM D2783. The results showed that vegetable oils have a high friction coefficient compared to mineral oil. Also, the wear scars produced by vegetable oil were slightly higher than those produced by mineral oil. The conclusion was that vegetable oils have a good potential as lubricants and can be improved by adding proper additives. Faiz et al. [6], discusses the potential of Jatropha oil as a renewable energy source as well as lubricant feedstock. It was concluded that the viscosities and pour point of Jatropha bio-lubricant are comparable to other plant-based bio-lubricants. Shahabud din, et al. [7], investigated the friction and wear characteristics of Jatropha oil-based lubricant using Cygnus Wear Testing Machine. Finally, it was found that addition of 10% Jatropha oil in the base lubricant is the optimum for the automotive application as it showed best overall performance in terms of coefficient of friction, wear, viscosity, temperature etc. Different nano particles have been used for different application such as Tio2 for fire proofing, Mos2 for tribological applications, cBN for wear resistance, grapheme for antifriction applications, enhanced heat transfer applications, for enhancing the performance of diesel oil-based lubricants, carbon nano particles for heat transfer enhancement etc [8-11].

Demas, et al. [12], studied the friction and wear occurring in presence of poly-alpha-olefin (PAO10) base oil with 3 wt % boron nitride (BN), and molybdenum disulfide (MoS2) nano-particles. The results showed that MoS2 nano-particles were very successful in reducing both friction and wear, compared to the base oil. Vadiraj, et al. [13], tested the friction and wears behavior of boric acid, MoS_2, TiO_2 and graphite. MoS2 and graphite showed 30 to 50% reduction in mass reduction compared to other lubricants at different sliding speeds. Coefficient of friction of dry as well as lubricated samples varied from 0.2 to 0.55 with MoS2 additive and lowest value existed at 0.2. Shabbir et al [14] investigated the tribological properties of date seed oil and castor oil added with halloysite nanotubes. The lubricant so developed reduced friction and wear substantially**.** Rawat et. al and Erhan et. al. [15,16] studied the lubrication effect of greases based on vegetable oil on steel-steel configuration. Souza et. al. [17] examined the tribological properties of Jatropha and Tung-based oils as bio-lubricants on Al-7050-T7451 alloy. The research works have reported that the COF and wear diminishes with the additives. The recent works in this field are summarized briefly in Table 1. It has been noticed from the literature review that Jatropha oil has a good anti-friction and anti-wear properties; however, no study has been carried out to evaluate the characteristics of grease produced from Jatropha oil. This investigation aims to study the lubrication characteristics of Jatropha grease. Moreover, in order to improve the lubrication characteristics of Jatropha grease, additives have been used.

Table 1. Recent research work in the field of Bio-oils as lubricant.

1	Zaid, M., et. al. [19]	Studied the improvement in lubricity of the raw jojoba oil with TiO_2 nanoparticles as an additives at different loads
2	Shafi, et. al. [20]	Studied the rheological properties of hazelnut oil mixed with zirconium-dioxide nanoparticles
3	Sadriwala et al. [21]	Analysed jojoba oil and its combinations with mineral oil to determine it's tribological properties. A blend of 10% jojoba oil made a substantial decrease in COF and wear.
4	Asnida, et al. [22]	Studied influence of copper oxide nanoparticles as additive in engine oil with respect to friction and wear.
5	Raina, et. al. [23]	Investigated the lubrication performance of synthetic oil mixed with diamond nanoparticles.
6	Camila et al. [24]	Explored the use of Tilapia oil as primary feedstock for lubricant . The synthetic route was carried outthrough transesterification,, epoxidation and ring-opening reaction with different long chain alcohols,

2. EXPERIMENTAL METHODOLOGIES

2.1 Preparation of grease

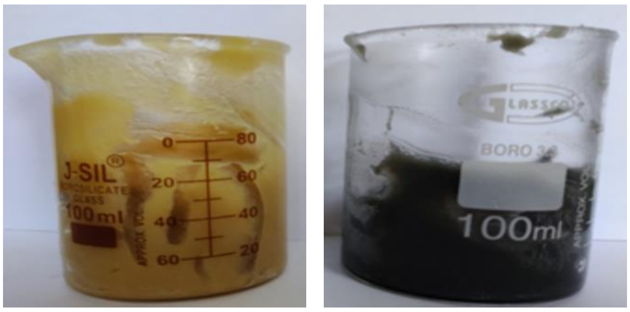
Grease is made up of three main components, which are base oil, thickener, and additives. The base oil accounts for the largest portion of grease, usually around 70 to 80 percent. This study uses Jatropha oil as the base oil for producing grease. To thicken the grease, soap is used as a thickening agent. The most commonly used soap thickeners are calcium soap, sodium soap, and aluminum soap thickeners. The physiochemical properties of Jatropha oil are presented in Table 2.

Table 2. Properties of Jatropha oil.

Density(kg/m3)	0.918
Kinematic viscosity at 40oC (cSt)	45-54
Flash point (°C)	186
Pour point(°C)	-6

To produce the thickener, hydroxides of metals such as sodium hydroxide (used in this work), lithium hydroxide, or calcium hydroxide are mixed with stearic acid or long chains of carboxylic acid in a proportion of about 3:17, respectively. This results in the formation of respective thickener. Stearic acid is found mostly in tallow or lamb lards. 20% by mass of sodium soap thickener is mixed with 80% by mass of base oil. Base oil which is Jatropha oil in this case and soap (thickener) which is sodium soap are heated to about 100°C using hot plate magnetic stirrer. The RPM of magnetic stirrer was set to 1600 RPM. The mixture of base oil and soap was heated continuously for 6 hours then cooled down to room temperature to get the product.

Two samples were prepared for the experiments. The first sample was made of virgin Jatropha grease without any additives and the second sample had a similar composition to the first sample but included an addition of approximately 0.25% molybdenum disulphide additive, by mass as shown in the Figure 1.



(a) (b)

Fig. 1. (a) virgin Jatropha grease (80% Jatropha oil, remaining thickener, (b) 80% jatropha oil, 0.25% MoS_2, remaining thickener.

2.2 Friction and wear test

In this study the coefficient of friction was measured with the help of four ball tester. In this experiment four steel balls of 12.7 mm in diameter were used. As per the ASTM D-2266 standard, specific load, speed, temperature, and time were set as shown in Table 3, while rotating a steel ball against three lubricated stationary steel balls.

Table 3. Operation parameters for 4-ball tester.

Load	400N
Temperature	75°C
Rpm	1200
Time	3600 sec

The ASTM D-2266 standard outlines a 4-Ball wear test method, which involves rotating a steel ball against three stationary steel balls that have been lubricated and subjected to a specific load, speed, temperature, and time. The quality of the lubricant's anti-wear characteristics can be determined by measuring the wear scar or scar diameter on the three stationary balls. If the lubricant has better anti-wear properties, the wear scar diameter on the balls will be smaller. To measure the wear scar diameter, an optical microscope was used, and the results were confirmed by a scanning electron microscope. A smaller wear scar diameter indicates that the lubricant is better at preventing wear. In the experiment, the wear scar diameter of the balls used in virgin Jatropha grease was compared to the wear scar diameter of the balls used in Jatropha with 0.25% MoS2 grease using an optical microscope. In order to ascertain the quality of nano MoS_2, XRD (Figure 2) was performed. It was concluded from the XRD that the MoS_2 was of desired quality.

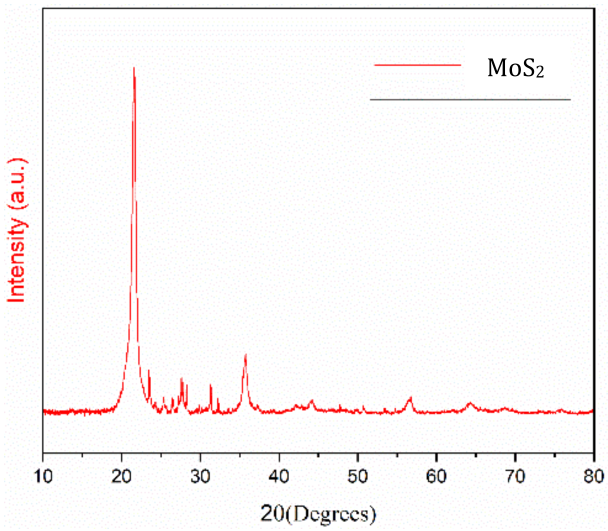


Fig. 2. XRD analysis of MoS_2.

3. EXPERIMENTAL EQUIPMENT

3.1 Four ball tester

Four ball tester is an equipment that is widely used to characterize or measure lubricant characteristics like wear prevention, extreme pressure, and frictional behavior. It is also known as shell four ball tester as shown in Figure 3.

Fig. 3. Orientation of chromium coated steel balls.

It is also used to evaluate the wear scar qualities in terms of diameter of scar using an image processing device. This test is to evaluate lubricant's anti-wear properties. Four steel balls are used per test. Three steel balls are placed close to each other and touching each other while the fourth steel ball is placed at the top of three steel balls and is rotated against three lubricated stationary steel balls which are kept below at a defined load, speed, temperature, and time in the 4-Ball wear test, as per ASTM D-2266 (grease). The smaller the wear scar, lesser the wear, which is measured by calculating the diameter of the scar on the three stationary balls, the better are the wear preventing or antiwear properties of lubricant. The three wear scars are measured at the end of the test, and the average value is taken. During the 60-minute test, the coefficient of friction is also measured, and the average is taken. The 4-ball data can be used to distinguish various lubricating greases with varying load capacity, wear protection, and friction reduction. The approach has established a standard in assessing extreme pressure, wear, and frictional functionality.

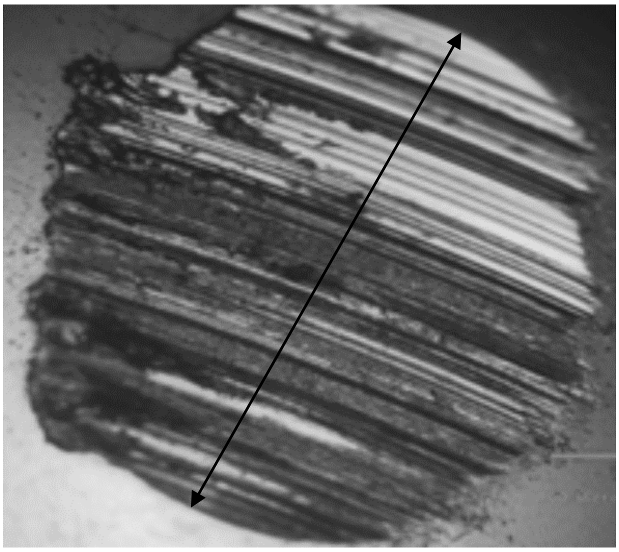
4. RESULTS AND DISCUSSIONS

4.1 Frictional torque variation

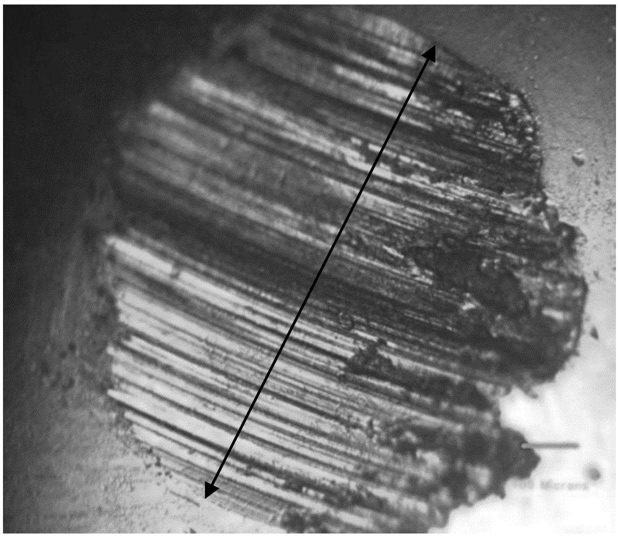
When the virgin Jatropha grease was subjected to four ball test the frictional torque showed considerable variations hence leading to instability and vibrations as shown in the Figure 6. The average coefficient of friction was 0.3907.

(a) (b)

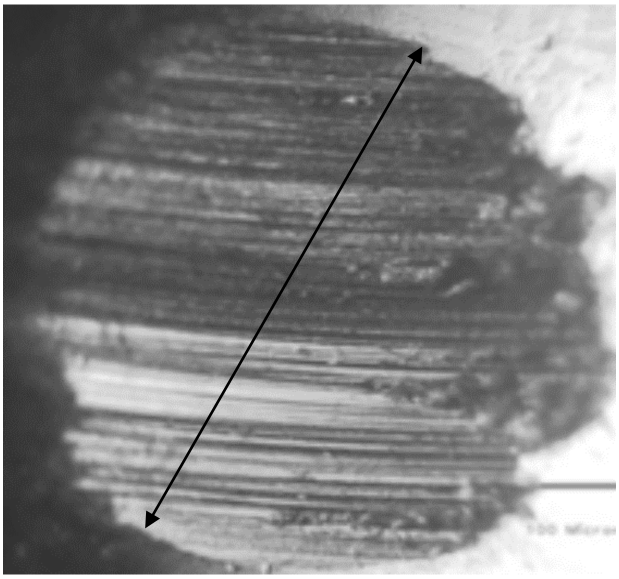
Fig. 4. (a) virgin jatropha grease, (b) oxidation after test.



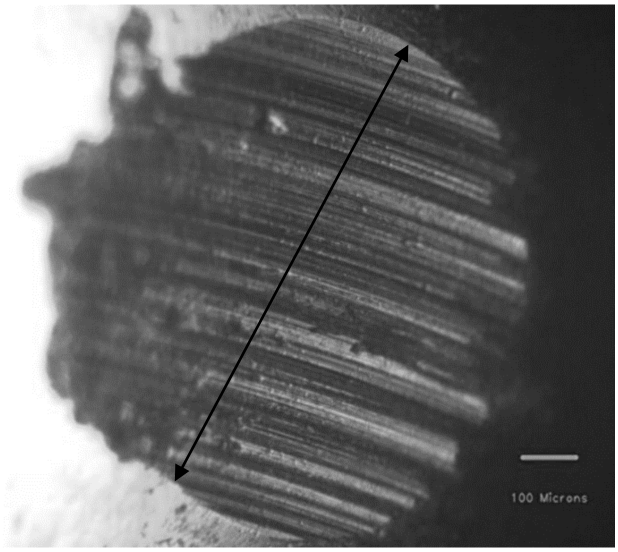
(a) Diameter = 805.58 microns



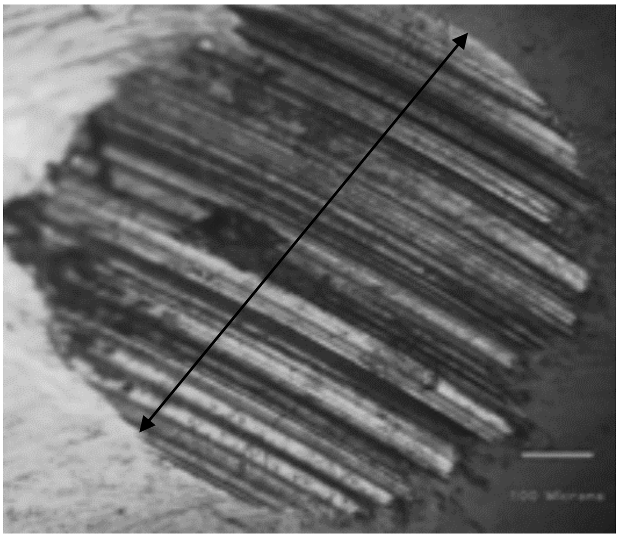
(b) Diameter = 804.84 microns



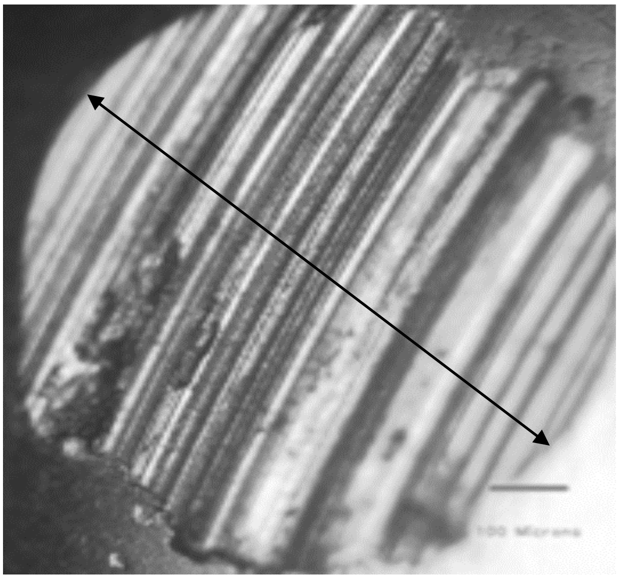
(c) Diameter = 791.33 microns



(d) Diameter = 793.6 microns



(e) Diameter = 781.24 microns



(f) Diameter = 790.48 microns

Fig. 5. (a–f) optical microscopy of the Cr-balls.

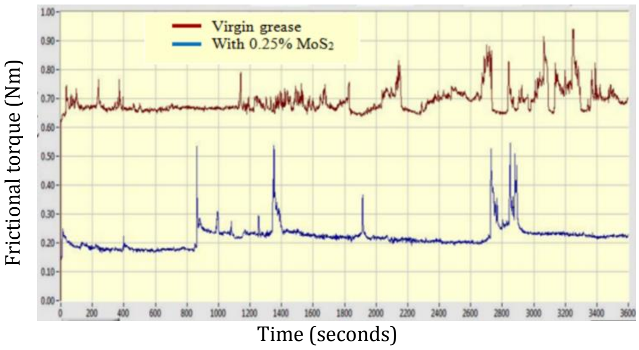


Fig. 6. Frictional torque comparison of virgin and additive blended Jatropha grease.

As can be seen clearly from Figure 6 that the frictional torque is approximately stable between 0 to 11×10^2 seconds. The instability increases after 11×10^2 seconds. After 2×10^3 seconds there are more fluctuations in frictional torque. This may be due to high coefficient of friction caused due to the virgin Jatropha grease. Due to high coefficient of friction, there is more heat generation, which leads to the oxidation of virgin Jatropha grease. Figure 4a and b shows the appearance of virgin Jatropha grease before and after performing tests on four ball tester respectively. As can been seen clearly from the Figure 4 (b) that the virgin Jatropha grease surrounding the contact points have been oxidized. This clearly proves the reason for fluctuations and instability in the frictional torque with respect to time. In order to prevent fluctuations of frictional torque and to increase the stability of grease 0.25% MoS2 was added and this reduced the coefficient of friction of grease and increased its stability as shown in the Figure 6. The average coefficient of friction after addition of 0.25% MoS_2 turned out to be 0.1252. The stability increased considerably particularly towards end. The sudden peaks in the Figure 6 are due to the worn-out debris which gets embedded between contacting surfaces of balls. A common plot is shown in Figure 6, where the variation of frictional torques with respect to time for both the greases are shown, for comparison. It is clear from Figure 6 that the performance of Jatropha grease has considerably improved with the addition of molybdenum disulphide.

4.2 Wear

The diameter of the scar on the balls shown in Figure 5 (a-f) was measured with the help of optical microscope as shown in Table 4.

Table 4. Sample scar diameter.

Grease sample	Average scar diameter
Virgin Jatropha grease	800.583 microns
Jatropha grease with 0.25% MoS_2	788.44 microns

Same procedure was followed for the balls (d, e, f) as shown in Figure 5, which were subjected to test using Jatropha grease with 0.25% MoS2. The average diameter of ball d, e and f came out to be = 788.44 microns. As per ASTM 2266 lesser the scar diameter less is the wear. Hence balls (d, e and f) encountered lesser wear as shown on Figure 5. The possible mechanism of the lubrication, which led to the reduction of wear scar, is thin film type lubrication. A thin film of grease (lubricant) separates the two surfaces which get adsorbed over the surface by weak Vanderwall forces of attraction. Thus, preventing the direct metal to metal contact and hence the friction and wear is reduced.

4.3 Wear scar analysis

Figure 7, shows the scanning electron microcopy images of balls which were subjected to wear test on four ball testers using virgin Jatropha grease. When the grease without MoS_2 is used the wear is combination of adhesion and abrasion. As is clearly evident from the images that deep abrasive and adhesive pits are formed and there are large number of furrows which are deep and wide. There is a heavy metal removal rate. The wear mechanism becomes relatively mild when 0.25% MoS_2 is added to the grease as shown in Figure 6. The pits are relatively smaller in width and depth indicating less material removal. The furrows are relative lesser in number, smaller in width and shallower.

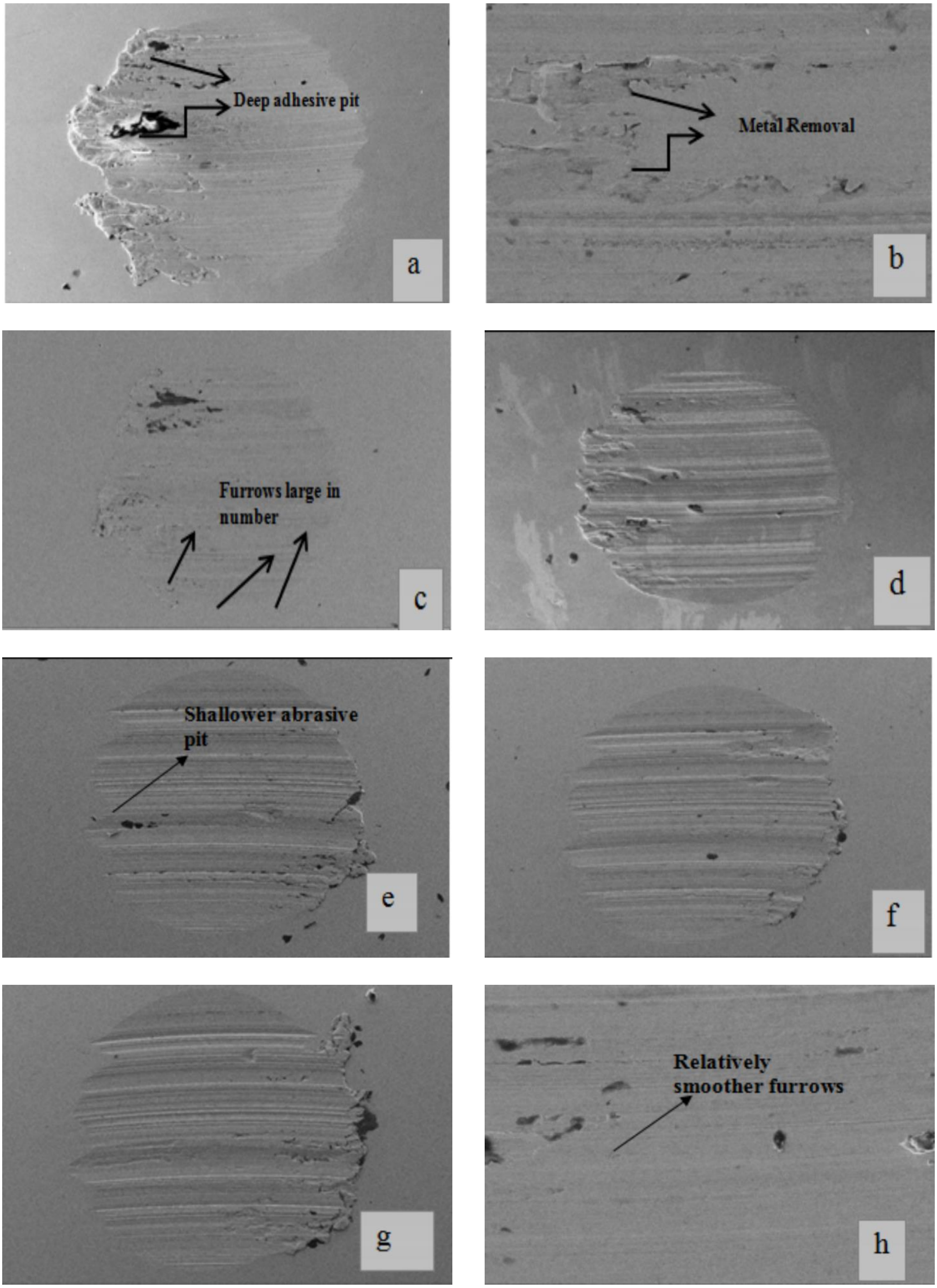


Fig. 7. SEM images of balls. (a), (b), (c) (d), (e), (f), (g) and (h) showing the furrows.

5. CONCLUSION

The coefficient of friction between the balls in presence of virgin Jatropha grease was very high of about 0.39 which led to the high heat production, due to which the grease got oxidized. Addition of 0.25% MoS_2 reduced coefficient of friction to 0.12 (69%) which led to lesser heat generation and prevented oxidation of Jatropha grease. Not only the reduction in coefficient of friction, but also there was a significant decrease in wear which can be verified from the wear scar diameter.

It can thus be concluded that the Jatropha grease has good lubricating properties which can be improved by additives. The Jatropha grease is a potential bio-degradable lubricant and thus can help in sustaining the clean environment and reducing the depletion of fossil fuels.

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