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Friction and wear performance of Jatropha oil added with molybdenum disulphide nanoparticles

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Abstract. Nano-materials offer potential scope for an increasing numerous novel applications when engineered to deliver availably functional properties. The nano sized additives when added to biodegradable oils improve their tribological performance and contribute to energy saving and sustainability. In the present study, the MoS_2 nanoparticles with different mass ratios were employed as lubricant additives in the base jatropha oil, and their tribological properties were evaluated using a reciprocating ball-on-disc tribometer for steel-steel contacts. The results demonstrate that the MoS_2 nanoparticles exhibit superior lubrication performance. The optimal concentration of MoS_2 nanoparticles in the base oil was found to be 0.5% for minimum friction and wear rate. Addition of load decreased friction and increased wear rate. The coefficient of friction and wear rate was reduced by 63% and 35% respectively. The excellent lubrication properties of the MoS_2 nanoparticles are attributed to the physical synergistic lubricating actions of nano-MoS_2 during the rubbing process.

Keywords: Jatropha oil, Nanoparticles, Molybdenum disulphide, friction, wear

1 Introduction

The demand for energy is increasing with time which is leading to the swift depletion of fossils [1]. The researchers are extensively in search of renewable sources in order to reduce environmental pollution and mitigate the dependence on fossils [2]. Tribology and sustainability are very closely related to each other and when used together can be helpful in increasing the sustainability of the environment. Sustainable tribology can save energy by reducing the losses due to friction and wear by introducing the lubricants [3]. The demand for ecofriendly lubricants is going to see a considerable spike in the next few years [4]. Biolubricants are the ones to

replace petroleum based lubricants due to their highly favorable lubricating properties. These properties can further be improved by mixing of desirable additives [5]. The lubricating properties of vegetable oils can be vehemently improved by the addition of nanoparticles [6]. Using nanolubricants can reduce consumption of energy and maintenance costs, thereby increasing the life span of the machines and tools [7]. Jatropha oil has excellent lubricating properties as compared to mineral oils [8]. Biolubricant can be prepared by adding some proper additives to the jatropha oil which can be a good substitute to use in place of mineral oils [9]. MoS_2 nanoparticles are very effective in enhancing the tribological properties of vegetable oil [10] and Polyalphaolefin (PAO4) [11].
This research analyzes the friction and wear characteristics of jatropha oil with and without MoS_2 nanoparticles. The nanoparticles were added with three different mass ratios and tribological testing was undertaken for steel-steel tribo-pair. The variation of friction and wear with load was also figured out.

2 Materials and Experimental Procedure

2.1 Lubricant and Sample Preparation

The jatropha oil was used as base oil whose properties are presented in Table 1. The nanoparticles of MoS_2 were acquired from a reliable supplier and its properties are given in Table 2. They were added to the base Jatropha oil in mass ratios of 0.25%, 0.5%, and 0.75%. The mixtures were stirred in a test tube and ultrasonicated for 4 to 6 hours to allow uniform dispersion of particles. EN-8 steel disc and 52100 steel balls (12.7 mm diameter) were used as a friction-pair. The surface of the disc was made fairly smooth by the rubbing action of abrasive particles on the sand papers. Sand papers of size ranging from 280 to 2000 were used in sequence to give proper finish to the surface. The average roughness of the surface was 0.3231μm which was calculated using surface profilometer by taking multiple readings at different points.

Table 1. Properties of Jatropha oil.

S. No.	Property	Jatropha oil
1.	Kinematic Viscosity @ 40°C	48 – 52 Cst.
	Kinematic Viscosity @ 100°C	10 cSt.
2.	Viscosity Index	182.
3.	Density	0.92×10^3 kg/m^3
4.	Pour Point	6°C.
5.	Flash Point	180°C.

Table 2. Properties of MoS_2 nanoparticles.

S. No.	Property	MoS_2
1.	Appearance	Black powder.
2.	Purity	99.9%.
3.	Size	80 – 100 nm.
4.	Density	5.05 g/cm^3.
5.	Melting point	1182^{o}C.
6.	Molecular weight	160 g/mole.

2.2 Friction and Wear tests

The tests were undertaken on a tribometer with reciprocating motion. EN-8 disc was held fixed in a clamp and the steel ball was slided against it. Different lubricant mixtures of base jatropha oil with and without additives were used to lubricate the friction-pair. The tests were conducted for 30 minute each, at ambient temperature and loads of 15N, 30N, 45N and 60N. The stroke and speed of each test were 2mm and 500Rpm respectively. The tribo-pair was washed by acetone before and after each test to remove the unwanted dirt and contaminants. The coefficient of friction was calculated with the help of a software system installed in computer attached to the tribometer. The wear volume (mm^3) of each scar was calculated with the help of 3D profilometer and equation (1) below was used to calculate the specific wear rate (mm^3/Nm).

$$Specific\,Wear\ Rate = \frac{Wear\ Volume}{Load \times Sliding\,distance}$$

(1)

3 Results and Discussions

3.1 Analysis of Friction

Fig 1 displays the variation of Average coefficient of friction (Cof) at different loads and MoS_2 mass ratios. The Cof between the friction-pair was on the higher when lubricated with base jatropha oil. As the addition of nanoparticles was started, the Cof values began to drop as shown in the Fig 1. The nanoparticles intrude between the surfaces of friction-pair, cover the asperities and limit their direct contact. The nanoparticles react with the base oil and the ambient atmosphere to form a protective layer on the surface. This layer acts as a shield and prevents the direct rubbing between the surfaces thereby decreasing Cof. [12,13].

As shown in Fig 1, the Cof between friction-pair increased with the increase in loads from 15N to 60N when it was lubricated with base oil without nanoparticles. This increment can be due to more rigid engagement between asperities at higher loads in absence of protective tribo-layer. But when base oil mixed with nanoparticles was used as lubricant, the Cof reduced with increase in load. However the decrement due to increasing load was marginal as compared to the decrement caused by addition of nanoparticles. The reason for this decrease in Cof with increasing load may be that the nanoparticles are better dispersed on the surface at higher loads. Also, there is more heat dissipation at higher loads which makes the reaction of nanoparticles with base oil and surroundings fast and expedites the development of the tribo-layer [14,15]. Generally the Cof was reduced by upto 63% as compared to base oil. The highest Cof (0.0956) was recorded for base oil as lubricant at 60N, while as the lowest Cof (0.0358) was recorded at 0.5% concentration of nanoparticles at 60N. As the weight ratio of nanoparticles was increased to 0.75%, the Cof began to rise marginally due to excessive concentration of nanoparticles. Hence 0.5% weight ratio was the optimum concentration of nanoparticles in the base jatropha oil for minimum Cof.

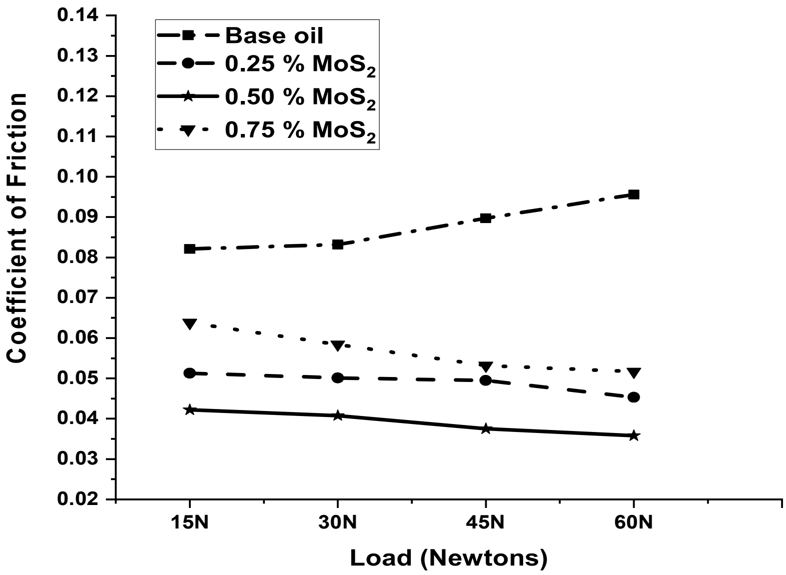

Fig. 1. Average Coefficient of friction values recorded at various testing conditions.

3.2 Analysis of Wear

The wear volume (mm^3) was calculated by using 3D profilometer by analyzing all the wear scars. The specific wear rates as calculated from the equation (1) are plotted in Fig 2. It was observed that the specific wear rates for scars lubricated with pure base oil were high, and started decreasing with the addition of nanoparticles. The specific wear rates at 0.5% nanoparticles addition were found to be the lowest, hence resembling the results of friction analysis. With increasing load, the specific wear rate exhibited a marginal increment as shown in the Fig 2. This can be attributed to the reduction in inter-molecular bonding between lubricant particles due to higher pressures [16]. The highest wear rate (15.566×10^{-6} mm^3/Nm) was recorded at 60N when the scar was lubricated with base oil without nanoparticles. While as the lowest wear rate (10.176×10^{-6} mm^3/Nm) was observed at 0.5% of nanoparticles concentration at 15N. The wear rate was reduced by upto 35% due to addition of nanoparticles as compared to base oil. The results received in the wear analysis were observed to be in agreement with the results from frictional analysis.

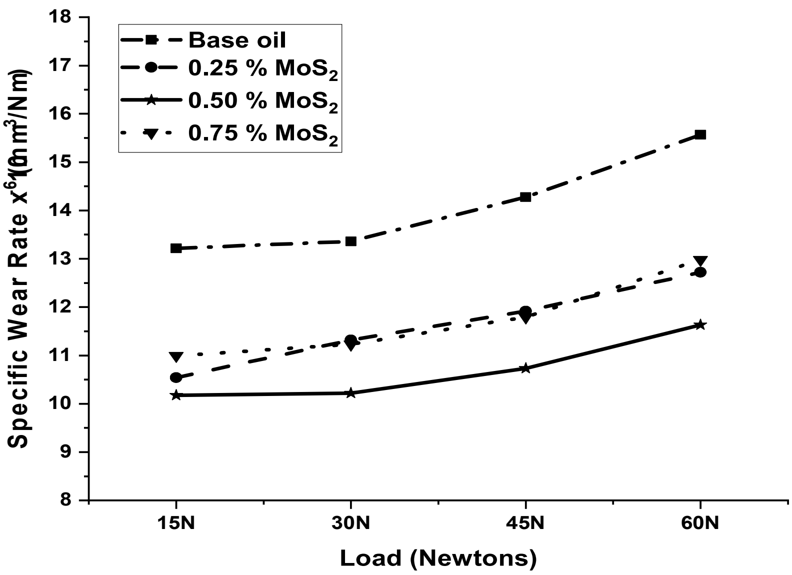

Fig. 2. Specific wear rate values recorded at various testing conditions.

3.3 Wear scar Analysis

Fig 3(a) and Fig 3(b) shows optical microscopy image of wear scars on steel disc and steel ball respectively when lubricated with base jatropha oil. A number of deep grooves and furrows can be seen in the Fig 3(a) which clearly depict the high roughness of the surface when lubricated with pure base oil. The sliding direction can be easily seen and both the adhesive and abrasive wear mechanisms were followed. Fig 3(b) reveals the formation of pits on the surface of steel ball during sliding in presence of base oil as lubricant. Heavy pitting and metal removal can be seen in Fig 3(b). Fig 4(a) and Fig 4(b) correspond to the wear scars of steel disc and steel ball respectively when lubricated with base oil + 0.5% MoS_2. As evident from the Fig 4(a), the surface is fairly smooth with minimum damage occurred as compared to Fig 3(a). Some small rubbing marks are present on the surface suggesting mild abrasion. As seen from the Fig 4(b), the heavy pits are absent and less damage is occurred as compared to Fig 3(b). From the wear scar analysis, it can be drawn that the addition of MoS_2 nanoparticles to base jatropha oil has eminently boosted its wear reducing capabilities. These results are in complete agreement with the wear analysis.

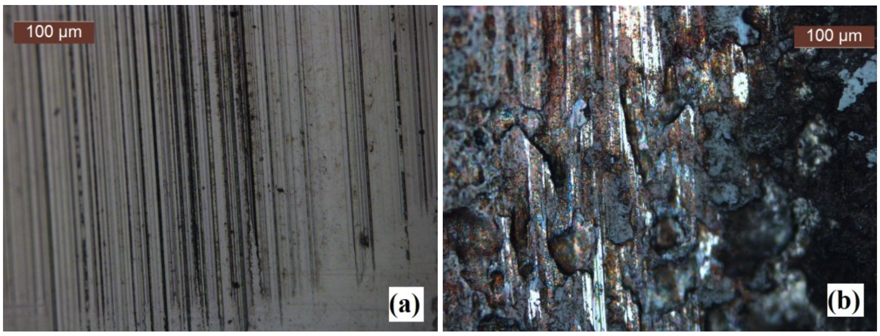

Fig. 3. Optical images of the wear scars of tribo pair when lubricated with base jatropha oil: (a) Steel disc (b) 52100 steel ball.

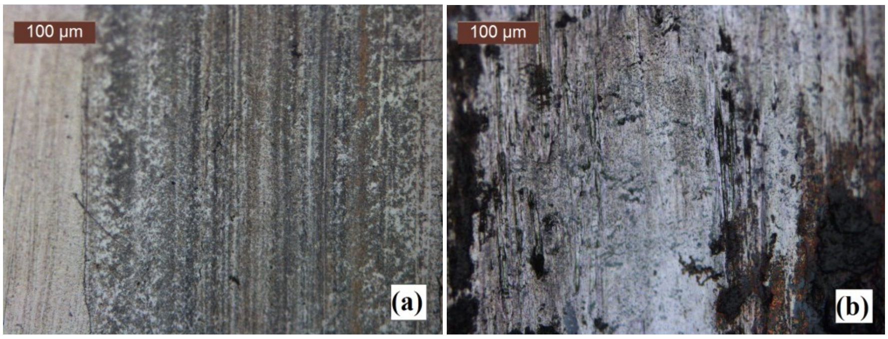

Fig. 4. Optical images of the wear scars of tribo pair when lubricated with base jatropha oil + 0.5% MoS_2: (a) Steel disc (b) 52100 steel ball

4 Conclusion

Ball-on-disc reciprocating tribological tests were undertaken. Jatropha oil with and without MoS_2 nanoparticles were used to lubricate the steel-steel tribo-pair to analyze the friction and wear. Following conclusions were compiled.

1. MoS_2 nanoparticles were found to be very effective in curtailing both friction and wear rate. This was attributed to the formation of protective layer on the surfaces of tribo-pair thereby restricting the metal-to-metal contact.
2. The optimum weight ratio of MoS_2 nanoparticles for least friction and wear rate was observed to be 0.5%. The Cof and wear rate reduced by 63% and 35% respectively.
3. After increasing the concentration of nanoparticles to 0.75%, friction and wear rate started to increase due to their presence in exorbitant quantity.
4. The Cof decreased and the specific wear rate increased with respect to increase in load.

It was concluded that jatropha oil has outstanding lubricating characteristics which can be made better by addition of MoS_2 nanoparticles. It can be a good option as lubricant to substitute for mineral oils and contribute to sustainable and less polluted environment.

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References

1. Zainal, N.A., Zulkifli, N.W.M., Gulzar, M., Masjuki, H.H.: A review on the chemistry, production, and technological potential of bio-based lubricants. Renewable and Sustainable Energy Reviews. 82, 80--102 (2018)
2. Moniruzzaman, M., Yaakob, Z., Khatun, R.: Biotechnology for jatropha improvement. Renewable and Sustainable Energy Reviews. 54, 1262--1277 (2016)
3. Tzanakis, I., Hadfield, M., Thomas, B., Noya, S.M., Henshaw, I., Austen, S.: Future perspectives on sustainable tribology. 16, 4126--4140 (2012)
4. Nagendramma, P., Kaul, S.: Development of ecofriendly/biodegradable lubricants: An overview. Renewable and Sustainable Energy Reviews. 16, 764--774 (2012)
5. Panchal, T.M., Patel, A., Chauhan, D.D., Thomas, M., Patel, J.V: A methodological review on bio-lubricants from vegetable oil based resources. Renewable and Sustainable Energy Reviews. 70, 65--70 (2017)
6. Darminesh, S.P., Sidik, N.A.C., Najafi, G., Mamat, R., Ken, T.L., Asako, Y.: Recent development on biodegradable nanolubricant: A review. International Communications in Heat and Mass Transfer. 86, 159--165 (2017)
7. Desari, B.Z., Davoodi, B.: Assessing the lubrication performance of vegetable oil-based nano-lubricants for environmentally conscious metal forming processes. Journal of Cleaner Production. (2016)
8. Shahabuddin, M., Masjuki, H.H., Kalam, M.A., Bhuiya, M.M.K., Mehat, H.: Comparative tribological investigation of bio-lubricant formulated from a non-edible oil source (jatropha oil). Industrial Crops and Products. 47, 323-330 (2013)
9. Menkiti, M.C., Ocheje, O., Agu, C.M.: Production of environmentally adapted lubricant basestock from jatropha curcas specie seed oil. Int J Ind Chem. 8, 133--144 (2017)
10. Koshy, C.P., Rajendrakumar, P.K., Thottackkad, M.V.: Evaluation of tribological and thermo-physical properties of coconut oil added with MoS_2 nanoparticles at elevated temperatures. Wear. 330-331, 288--308 (2015)
11. Xu, Y., Geng, J., Peng, Y., Liu, Z., Yu, J., Hu, X.: Lubricating mechanism of Fe_3O_4@MoS_2 core-shell nanocomposites as oil additives for steel/steel contact. Tribology International. 121, 241--251 (2018)
12. Alves, S.M., Barros, B.S., Trajano, M.F., Ribeiro, K.S.B., Moura, E.: Tribological behavior of vegetable oil-based lubricants with nanoparticles of oxides in boundary lubrication conditions. Tribology International. 65, 28--36 (2013)
13. Rapoport, L., Leshchinsky, V., Lapsker, I., Volovik, Y., Nepomnyashchy, O., Lvovsky, M., Biro, R.P., Feldman, Y., Tenne, R.: Tribological properties of WS_2 nanoparticles under mixed lubrication. Wear. 255, 785--793 (2003)
14. Xie, H., Jiang, B., He, J., Xia, X., Pan, F.: Lubrication performance of MoS_2 and SiO_2 nanoparticles as lubricant additives in magnesium alloy-steel contacts. Tribology International. 93, 63--70 (2016)
15. Katpatal, D.C., Andhare, A.B., Padole, P.M.: Performance of nano-bio-lubricants, ISO VG46 oil and its blend with Jatropha oil in statically loaded hydrodynamic plain journal bearing. Journal of Engineering Tribology. 0, 1--15 (2019)

16. Singh, Y., Singla, A., Singh, A.K., Upadhyay, A.K.: Tribological characterization of Pongamia pinnata oil blended bio-lubricant. Biofuels. (2017)