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Effect of SiO_2 Nanoparticles on the Tribological Behavior of Balanites Aegytiaca (Desert date) Oil-Based Biolubricant

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Abstract
In view of the ecological problems associated with the pollution caused by vehicles and the degradation of the ecosystem due to the extensive use of synthetic oil. There is a need to find the fuel that can substitute mineral oil and, in addition, the fuel should be environmentally friendly. Balanites aegyptiaca (Desert date) oil has the potential to be a mineral oil option and is available in abundant quantities. Balanites aegyptiaca oil was used as a lubricant in this investigation to examine its potential for the friction and wear behavior of the contact surfaces. The quantity of nanoparticles to the biolubricant was evaluated on the basis of the previous work. Average load, sliding speed, specific nanoparticle blends and biolubricant are the parameters considered for investigation. The mixture of Balanites aegyptiaca oil and the silicon dioxide nanoparticles was prepared. The variety of silicon dioxide nanoparticles blended with balanites aegyptiaca oil was evaluated for tribological investigation. In the light of the investigation, 0.6% concentration of silicon dioxide nanoparticles demonstrated a crucial increase in the reduction of coefficient of friction (COF), wear rate, and improved surface morphology with synthetic oil correlation. The positive impact was observed when the amount of nanoparticles was added up to 0.6% to the Balanites aegyptiaca oil. The functioning of the BA + 0.6% blend is certainly having a potential impact on energy and natural concern as a lubricant.

Keywords Concentration · Balanites aegyptiaca oil · Wear · Silica nanoparticles · Friction

1 Introduction

Synthetic oils are appropriate for the implementation of various areas identified with the assembly industry, the automotive industry [1]. They are competent to act as a lubricant necessary to reduce friction and wear of the components in combination with a sliding motion. Synthetic oils are hydrocarbon-based products and are used with certain additives to enhance their application [2]. The usage of synthetic oils was harmful to the environment as they are having problems associated with their proper disposal.

Maneuver of such mineral oil is considerable across oil-based products owing to its use for lubrication purposes [3]. At present few ecological issues are involved with the utilization of mineral oil because they are responsible for marine contamination due to seepage after being used [4]. The obligatory to find another solution that could be utilized to substitute synthetic oil. In the perspective of this, the authors focused on the identification of a substitute for mineral oil.

Biolubricant has greater biocompatibility relative to oil-based mineral oil, but lacking advanced properties as with conventional lubricants [5].

Physicochemical characteristics became critical for the use of alternative oils like viscosity, flash point, and fire point, in order to enhance physicochemical properties, nanoparticles are among the correct chemical additives; numerous tests were carried out to determine the influence of nanoparticles on tribological features, whereas the vast majority of nanoparticles are accessible today [6–8]. Xie et al. [9] assessed the impact of silicon dioxide and molybdenum disulfide nanoparticles on engine oil tribology. The impact of the nanoparticle volume on the stress-bearing cap and the consistency of the oil film was illustrated. In general, molybdenum disulfide in lubricants is said to affect the load

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endurance capability and the density of the oil film. Peng et al. [10] also investigated the impact of the dimension of the silicon dioxide nanoparticles as just an additional element on the tribological implementation of paraffin oil. In the course of the investigation, experimental observations demonstrated that surface-modified silicon dioxide nanoparticles with an oleic acid diameter of 58 nm improved the tribological function of the oil. It is evident from the foregoing that nano-silicon dioxide has an immense ability to change the tribological performance of lubricating oil. Chaurasia et al. [11] introduced SiO_2 nanoparticles to Salt Oil for tribological analysis. The finding shows that a 0.5 per cent enrichment of silicon dioxide nanoparticles has shown a decrease in friction coefficient and wear rate. Sem micrographs also display improved surfaces when up to 0.5 percent amount of nanoparticles has been applied. Shi and Jiang [12] employed hybrid nano-particles consisting of graphene and copper and studied their tribological behavior. Findings indicated that the addition of hybrid nano-particles to lubricants greatly affects tribological performance and decreases the coefficient of friction and wear by 35 and 50%, respectively. Singh and Rahim [13] explored the role of CeO_2 nanoparticles additive to Michelia Champaca oil on tribological behavior. The findings show that 0.6% of CeO2 nanoparticles induce a substantial reduction in friction and wear coefficients. The SEM micrograph also indicated that 0.6% of CeO_2 nanoparticles in modified oil aid in improved surfaces as a result of successful surface film deposition. Ren et al. [14] investigated the effect of the hybrid nano-additive (ZnO + graphene) on the tribological behavior of lubricating oil. Research has indicated that the ZnO + graphene nanostructure provides a dynamic friction landscape. The authors further indicated that the inclusion of the proposed hybrid nanoparticles would increase the stability and load-bearing capability of the lubricating film would lead to improved tribological characteristics.

In the earlier investigation, neither of the work was performed while taking into the implementation of silicon dioxide nano-particles to balanites aegyptiaca oil. In the context of the above-stated literature, the authors have confirmed that the application of silicone oxide nano-particles with balanites aegyptiaca oil is appropriate for improving the lubrication characteristics of raw balanites aegyptiaca oil. The rationale behind this analysis is therefore to explore the tribological characteristics of silicon dioxide nano-particles as a balanitesa egyptiaca oil additive and to discover its characteristics as a substitute for untreated balanites aegyptiaca oil at varying speeds. The objective of this study is to examine the tribological behavior of mineral oil and silica oxide nanoparticles as an additive to the biolubricant. Also, this work seeks to give an overall perspective on the use of nano-added substances as conceivable, based on contact pressure, sliding speed and type of oil.

2 Materials and Methods

2.1 Lubricant Details

In order to make balanites aegyptiaca oil suitable for tribological evaluation, the process of transeterification is necessary to improve the characteristics of the oil. The desert date oil was obtained from the nearby seller Arbariya Organics, Foundry Nagar Agra, Uttar Pradesh, India. The balanites aegyptiaca oil contains a lot of unsaturated fatty acids that are appropriate for minimizing friction and wear of the components in contact. The assessment of unsaturated fatty acids is equally increasingly critical as they can form a fair protective cover within a limited capacity. The insights regarding the fatty acids can be acquired from the past investigations referenced in the literature [11]. The extent of the nano-particles considered amid this examination was 25 nm because of its favorable involvement for the minimization of friction and wear of materials during sliding.

The SiO_2 nano-particles were acquired from M/S Asstra Chemicals, Chennai, India and particular of the nano-particles size was given by the dealer. The ultrasonicator was used to blend SiO_2 nano-particles with balanites-aegyptiaca oil while maintaining the oil bath at 0–10 °C. The ultrasonicator was processed for one and half hour and the mixing possibilities of the lubricants using this process were assured. This assurance has been provided through the examination of the blended surfaces. The power supplied was 100 KW with a frequency of 40 kHz.

2.2 Physiochemical Properties

The evaluation of the property was necessary to decide the characteristics of the oil. Table 1 stated the physicochemical properties of the specimens used in the experiment.

Density was estimated utilizing benchtop density meters. Viscosity was assessed using a Redwood viscometer. The rheometer was used to estimate kinematic viscosity at 40 °C and 100 °C according to the ASTM benchmarks. The viscosity index was determined in the light of the kinematic viscosity data collected at specific temperatures.

2.3 Test Procedure

Pin-on-Disc (POD) Wear Tester TR-20LE supplied by DUCOM, India, was used for the tribological study of selected balanites aegyptiaca oil with silicon dioxide nano-particles as added substances. The material used for the study was Al-5% MgO metal matrix composite. The hardness of the chosen pin was 67 HRC. The parameters considered for the analysis of POD tribometer are: 40 to

Table 1 Physicochemical characteristics of raw balanites aegyptiaca oil and quantities of SiO_2 nanoparticles with oil

Characteristics	Density @ 15 °C (g/cm^3)	Kinematic viscosity @ 40 °C (mm^2/s)	Kinematic@ 100 °C (mm^2/s)	Viscosity index
Balanites aegyptiaca oil + 0.1%	0.9223	17.42	4.47	217
Balanites aegyptiaca oil + 0.3%	0.9231	17.68	4.58	224
Balanites aegyptiaca oil + 0.5%	0.9339	17.75	4.65	228
Balanites aegyptiaca oil + 0.6%	0.9349	17.82	4.71	232
Balanites aegyptiaca oil + 0.9%	0.9363	17.89	4.76	236

90 N; Temperature = 150 °C; Track diameter = 80 mm (for each condition); Sliding speed = 300 rpm; Sliding distance = 3000 mm. The same track diameter and the sliding distance were considered for each test performed on the Disc machine. The weighing machine with the least count 0.1 mg is used for accurate measurement of the weight of the plate. The acetone bath ultrasonic apparatus, which worked for about 15 min, was used to clean the surface of the pin. After the cleaning process, the pin was placed in the desiccators to dry it to avoid contact with the atmospheric dust available for a better examination of its surface.

3 Results and Discussion

3.1 Coefficient of Friction Analysis

The friction force was generated due to the applied loads exerted on the pin and the average value was obtained from the setup monitor during the tribological characterization. Figure 1a and b show the impact of the application of nanoparticles on biolubricants at various sliding speeds and loads.

In the earlier parts, the load was connected from 40 to 90 N. The associated loads and sliding speeds contribute significantly to the analysis of the characteristics of fuel samples. There is a reduction in COF perceived when 40 N load is combined with an increase in sliding speed. With the use of biolubricant involving an introduction of 0.6 percent SiO_2 nanoparticles, the acquired COF was less. The decrease in COF measure was noted at the time when the quantity of the nanoparticles expanded past the volume of 0.6 percent to the biolubricant. The amount of COF acquired was higher than that of mineral oil in relation to the addition of more than 0.6% of nanoparticles. A similar trend was found with an increase of 90 N in the associated load. The COF calculation was based on a rise of about 14 to 20 per cent during the use of 90 N loads.

3.2 Wear Analysis

Figure 2 shows the wear scar diameter of the samples measure at **a** 40 N load and **b** 90 N load.

With the increment in sliding speed, a decline in the measure of wear has been seen and extreme has been acquired at low speed (100 rpm). The reason for getting the most extreme wear at 100 rpm has been added to the time accessible for the SiO_2 nano-particles to mingle with the surface. After 0.6% concentration, extra nano-particles amassed and causes wear of the surface.

The load was introduced from 40 to 90 N as expressed in the preceding sections. Connected loads and sliding speeds contribute significantly to the assessment of fuel samples. As the sliding rate rises, the friction coefficient decreases when

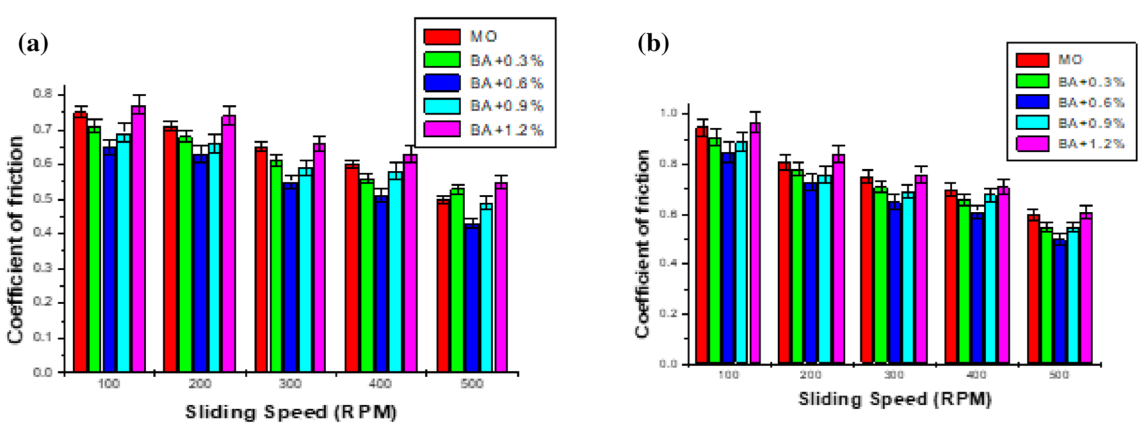

Fig. 1 Friction coefficient measured at normal load of **a** 40 N and **b** 90 N

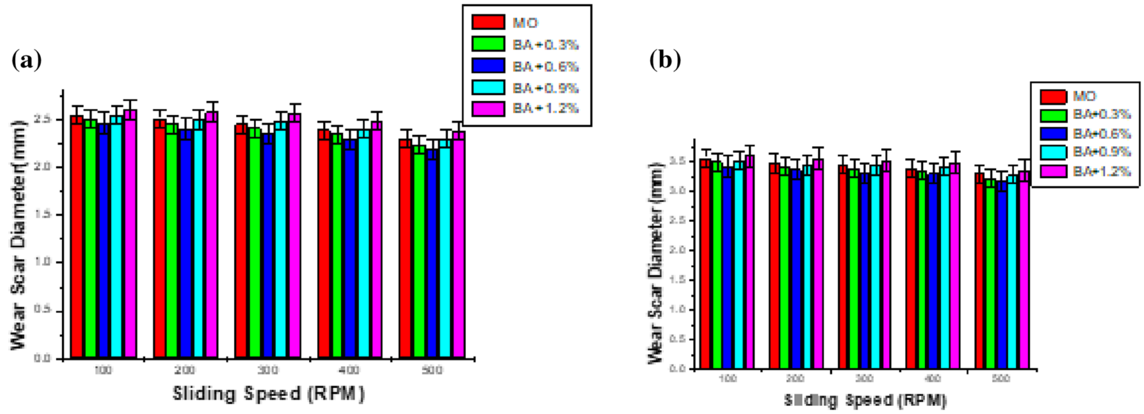

Fig. 2 Wear scar diameter at **a** 40 N and **b** 90 N load for all specimens

45 N loads are associated. The COF obtained was found to be lower with the addition of a biolubricant containing 0.6 per cent SiO_2 nanoparticles. At a time when the inclusion of nanoparticles to the biolubricant increased past the 0.6% concentration, an increase in the COF was observed. The COF was found to be higher compared to mineral oil in relation to an increase of 0.6% in nanoparticles. A similar trend has also been discovered with an increase of 90 N in the associated load. Approximately 15 to 25% of the COF value was added during the utilization of 90 N load.

3.3 Analysis of Viscosity

The noticeable change in viscosity depends on the temperature. The characteristics of the lubricants used have been determined by their viscosity. Figure 3a and b individually reveal the variety of kinematic and dynamic viscosity at different temperatures. In the course of this investigation, three preliminary tests were carried out to obtain a precision level and the mean value of the data acquired was subsequently used to illustrate the plots. From the graph, it can be seen that the viscosity reduces with the rise in temperature. No significant changes were seen at low temperatures particularly in comparison to elevated temperatures. After 60 °C of temperature, a substantial improvement in the measurement of viscosity was discovered. It was also noted that the decrement in the density of the oils was an important determinant of substantial alterations in the viscosity at different temperatures [15].

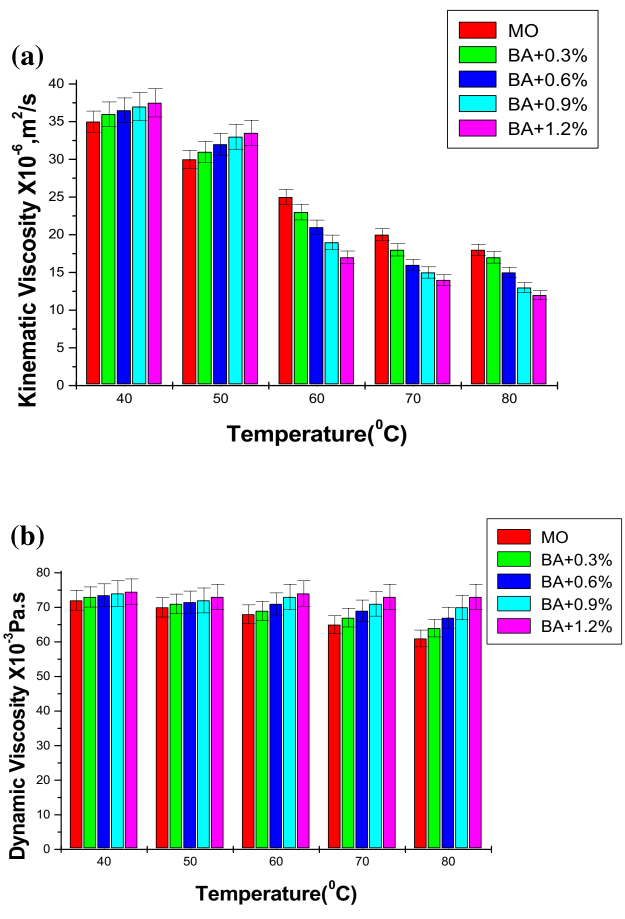

Fig. 3 Changes in the viscosity of biolubricant with temperature

3.4 Surface Roughness Analysis

Figure 4a demonstrates the surfaces perceived during the utilization of mineral oil. More profound small scale pores are shaped superficially. Figure 4b indicates the worn surface when 0.6% of SiO_2 nanoparticles are introduced to the lubricant over which the superior surface finish was acquired with correlation with the mineral oil. Hardly any smaller pores are superficially formed. It demonstrated the testimony of SiO_2 nanoparticles during sliding contact on the worn surface. With this evidence, it seems to be argued that for the more drawn out, BA + 0.6% of SiO_2 will form a protective oil film that stays the same during sliding surface contact.

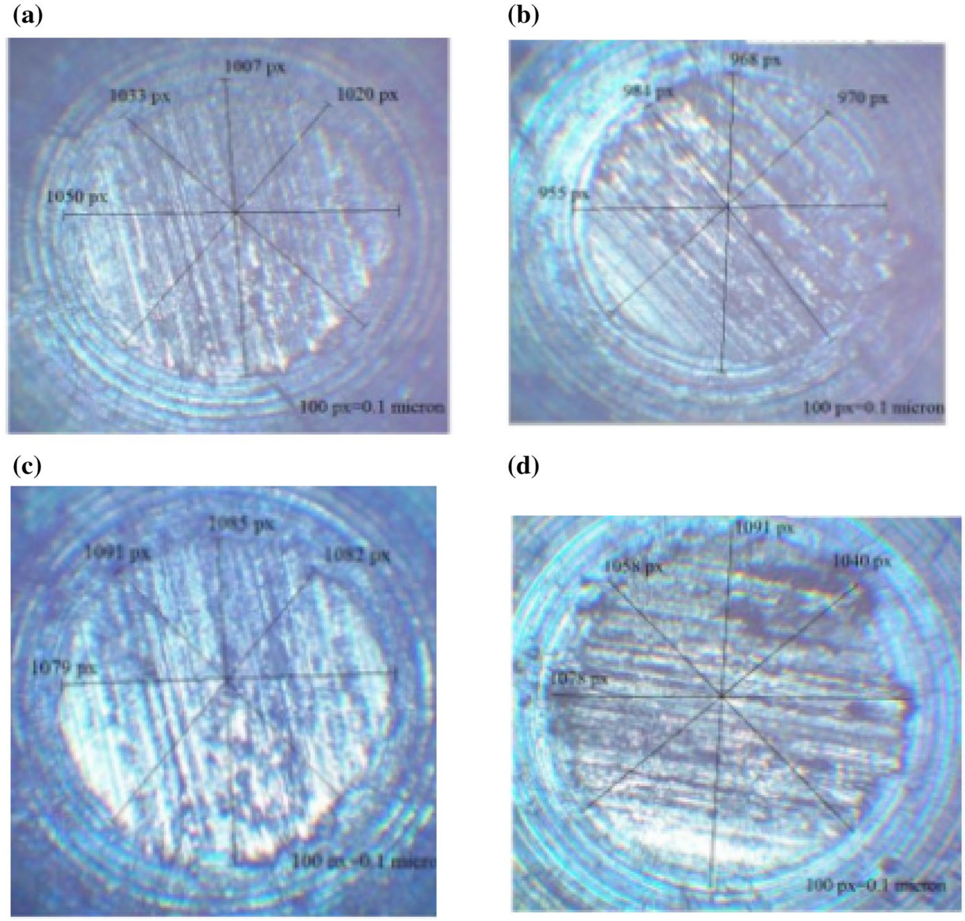

Fig. 4 Images obtained at 90 N and 300 rpm speed **a** MO **b** BA + 0.6% **c** BA + 0.9% **c** BA + 1.2%

Furthermore, irregular and deep grooves were found on the surface when the quantity of nanoparticles increased to 0.9% and 1.2% as shown in Fig. 4c and d. The particles are cut off on the surface of the formed valleys, resulting in a higher concentration of stress on the contact surfaces. Such behavior contributes to rough surface wear and results in increased COF and wear rates.

4 Conclusions

In view of the test circumstances, an enhancement in the tribological performance of the biolubricant is accomplished by taking into account the addition of nanoparticles of silicon dioxide. The influence of the concentration of silicon dioxide nano-particles was investigated to investigate the tribological conduct of the surface furnished with Balanites aegyptiaca oil. The following conclusions are drawn from this work:

- Occupancy of SiO2 nanoparticles to the biolubricant increases the effectiveness of the biolubricant in terms of decreased COF, wear rate and improved worn surface. The concentration of 0.6% nanoparticles allows for better tribological characterization.
- The friction minimization characteristics of Balanites-aegyptiaca oil have been improved to a certain degree by the use of SiO2 nano-particles.
- The friction coefficient was found to be lower when the optimum percentage contribution of SiO_2 nano-particles in the blend was 0.6%.
- Enhancement in the measurement of kinematic and dynamic viscosity has been seen with a rise in SiO_2 nano-particles.
- The impact of the use of SiO_2 nano-particles with Balanite aegyptiaca oil was observed at the surface morphology spectrum, which showed a better surface when compared to mineral oil.
- In view of the results obtained, the introduction of nanoparticles to a threshold of 0.6% has the potential to improve the tribological efficiency of the biolubricant. The use of this form of biolubricant, which is environmentally friendly, could also help to save energy.

Compliance with Ethical Standards

Conflict of interest There is no conflict of interest.

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