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Research paper

Effect of Alumina NANOPARTICLES as Additive on the Friction and Wear Behavior of POLANGA based Lubricant

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Abstract

Environment degradation and non-biodegradability are the major problems associated with mineral-oil based lubricants. Non-edible vegetable oils are one of the suitable substitutes for the mineral oils. In this study, polanga oil was used as the lubricant to check its feasibility for the tribological behaviour. Alumina nanoparticles are added to the polanga oil on a weight-percentage basis. The variation of alumina (Al_2O_3) nanoparticles concentration with polanga oil was evaluated for the coefficient of friction and wear analysis. Minimum coefficient of friction and wear was observed at 0.075% % concentration which gets further increased at 0.1 % concentration. The smooth surface of the pin was observed at 0.075 % nanoparticles concentration with the comparison to base polanga oil. Maximum total acid number changes was obtained at 0.1% concentration.

Keywords: *Pin-on-disk; polanga oil; Al2O3 nanoparticles; Coefficient of friction; Specific wear rate.*

1. Introduction

Mineral oils are suitable for various applications including fields related to manufacturing, automobile industries [1,2]. They are capable to act as a lubricant required for the reduction of friction and wear of the metals in contact during sliding motion. Mineral oils are the petroleum products and added with some additives to improve their performance according to the applications [3]. But, they are having adverse effects on the environment especially, regarding their disposal. The aquatic environment gets polluted due to their disposal and the petroleum reserves are going to deplete in the upcoming future [4]. There is a need to find alternative which can be utilized for the replacement of mineral oil. Taking this point into consideration, the author focused on finding alternatives to mineral oil. Non-edible vegetable oils are one of the resources and play a vital role in enhancing the renewable resources, more economic and harmless to the environment where it is used [5,6]. Non-edible vegetable oils are having better biodegradability in comparison to petroleum-based mineral oils but they lag in technical properties with respect to the conventional lubricants [7]. Oxidation stability is less and the main problems have occurred at low temperature with a reduction in pour point and cloud point values [8]. Non-edible vegetable oils are having certain advantages like better equipment life, minimum emission into the atmosphere, better lubricity, improved anti-wear characteristics and high viscosity index [9]. For the further improvement of the physicochemical properties, nanoparticles are one of the suitable additives [10,11,12]. Various studies have been conducted related to the effect of nanoparticles for the tribological characteristics but most of them are regarding to their addition with synthetic or mineral oil. Chen *et. al.* [13] coated Cu-Ni bimetallic nanoparticles surface with dodecanethiol and investigated its tribological characteristics. Better dispersibility was observed with Cu-Ni bimetallic nanoparticles due to its hydrophobic nature. Cu-Ni nanoparticles performed well as an additive for reducing friction and wear of the surface during tribological investigation. Huang *et al.* [14] performed tribological characteristics of graphite nanosheets with an average diameter of 500 nm by stirring ball milling. Improvement in the antiwear characteristics of paraffin oil was improved by the addition of graphite nanosheets. Al_2O_3 nanoparticles have obtained considerable importance as they are suitable for reducing friction and wear of the material due to the mending mechanism or they are having the capacity of forming a sustainable protective film [15]. From the above reference survey, very few studies have looked at the effect of Al_2O_3 nanoparticles on the friction and wear characteristics of lubricant which have significant influence on the friction and the anti-wear mechanism. Based on the aforementioned literature survey, the author has determined that the addition of Al_2O_3 nanoparticles with polanga oil is suitable for the improvement of the lubrication characteristics of bare polanga seed oil. Therefore, the purpose of this study is to investigate the tribological characteristics of nanoparticles as a polanga oil additive and reveal its characteristics about its feasibility as an alternative to bare polanga oil at different sliding speeds.

2. Experimental Details

2.1. Lubricant Development

To obtain a uniform and stable disparity, nanoparticles were added to the polanga oil using ultrasonication technique. The ultrasonicator was used to perform mixing of Al_2O_3 nanoparticles with polanga oil. The duration of the test was 1.5 h and the concentration of the nanoparticles ranging from 0.025% to 0.1% (gap of 0.025%) was added to the polanga oil at ambient temperature. The addition of the nanoparticles to the polanga oil was designated as PO, PO+0.025%, PO+0.0.05%, PO+0.075% and PO+0.1% respectively.

2.2. Experimental Setup

The physicochemical properties of the PO, PO+0.025%, PO+0.0.05%, PO+0.075% and PO+0.1% was mentioned in Table 1.

Table 1: Physicochemical properties of bare polanga oil and nanoparticles concentrations with the polanga oil.

S. No.	Properties	Viscosity (cSt) 40 °C	Viscosity (cSt) 100 °C	Flash point (°C)	Fire point (°C)
1.	Polanga oil	243.15	18.19	271	257
2.	Polanga oil+0.025%	245.13	18.26	272.3	261
3.	Polanga oil +0.05%	246.32	18.37	272.7	265
4.	Polanga oil +0.075%	246.59	19.48	272.9	272
5.	Polanga oil +0.1%	247.69	19.59	273.1	281

A pin-on-disk machine was used to perform the friction and wear test according to the ASTM standards D4172 and G99 [16,17]. The material of the pin used for the study was a combination of Al-7%Si alloy and EN31 steel. The hardness of the EN31 steel was 60 HRC. The details about the operating conditions during the experiment was illustrated in Table 2. The flow rate of about 5 ml/min was maintained during the experiment for the operating conditions. The flow rate was calculated by flowing the oil into the measuring flask and the time was determined according to the flow for filing the flask. The material loss of the pin was calculated by the difference in the weight of the pin before and after performing the experiment. Shimadzo weighing machine was used for the weighing purpose of the pin with having an accuracy of ±0.1 mg. The acetone was used to clean the pin surface with ultrasonic bath apparatus operated at 65°C temperature for around 15 minutes.

Table 2: Operating conditions during the test

S. No.	Operating parameters	Value
1.	Normal loads applied on the pin	50 N
2.	Track length used during the test	80 mm
3.	Sliding speed, rpm	200-800 (with a gap of 200)
4.	Total sliding distance	3000 m

3. Results and Discussion

Test with the bare polanga oil was used as the reference for the COF characteristics and wear behavior.

3.1. Coefficient of Friction Analysis

An overview of the coefficient of friction for different sliding speed at particular load of 50 N is compiled in Fig. 1. The sliding speed was varied from 200 rpm to 800 rpm with a gap of 200 rpm . With an increase in sliding speed, the coefficient of friction decreases having a minimum coefficient of friction at 800 rpm. With an increase in speed, the duration of the contacts between the sliding parts decreases resulting in a reduction of coefficient of friction.

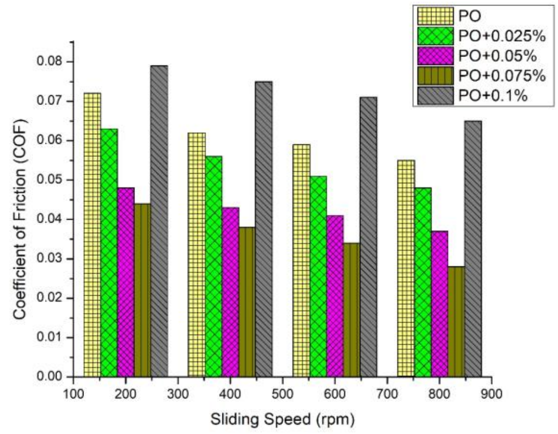

Figure 1: Coefficient of friction with sliding speed

Fig. 2 shows the effect of the concentration of copper nanoparticles on the coefficient of friction at various sliding speeds with 50 N load. With an increase in the amount of concentration of nanoparticles, minimum coefficient of friction was obtained up to the limit of 0.075% concentration and a further increase in the value of the coefficient of friction was obtained at 0.1 % concentration at each sliding speed ranging from 200 rpm to 800 rpm.

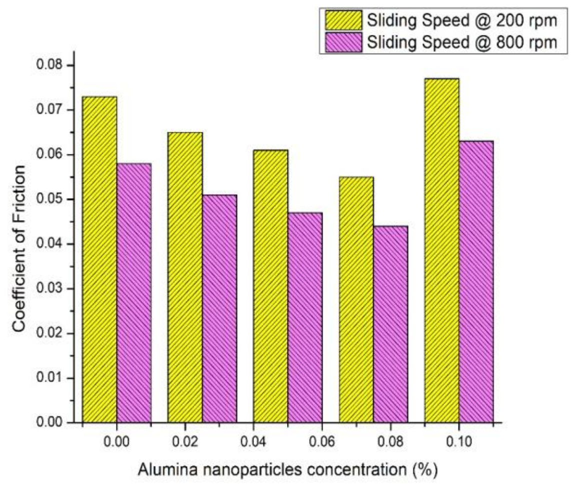

Figure 2: Effect of nanoparticles concentration on COF.

This may be attributed to the deposition of nanoparticles to the pin surface resulting in a strong protective film between oil, nanoparticles and surfaces [17,18]. With increase in concentration of nanoparticles behind the optimum concentration limit i.e. 0.075 %, deep interaction of the alumina nanoparticles with the surface promoted to the increase in coefficient of friction.

3.2. Wear Analysis

Effect of sliding speed on the specific wear rate of bare polanga oil and concentration of Al_2O_3 nanoparticles is shown in Fig. 3. With an increase in sliding speed, a decrease in the amount of wear was observed and maximum wear was obtained at 200 rpm. The reason of obtaining the maximum wear at low speed was contributed to the time available for the nanoparticles to interact with the surface. After 0.075 % concentration, more nanoparticles gets accumulated and results in the wear of the surface. This was due to the concentration increase in the amount of nanoparticles.
Fig. 4 shows the effect of concentration of nanoparticles on specific wear rate at 50 N load. With an increase in concentration of nanoparticles, specific wear rate was reduced up to the limit of 0.075 % concentration and a further increase in the amount of wear rate was observed at 0.1 % concentration.

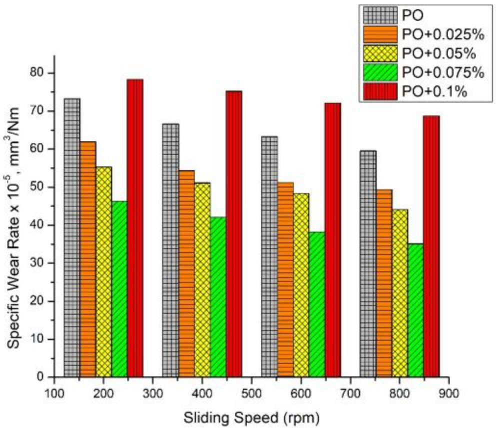

Figure 3: Effect of sliding speed on specific wear rate

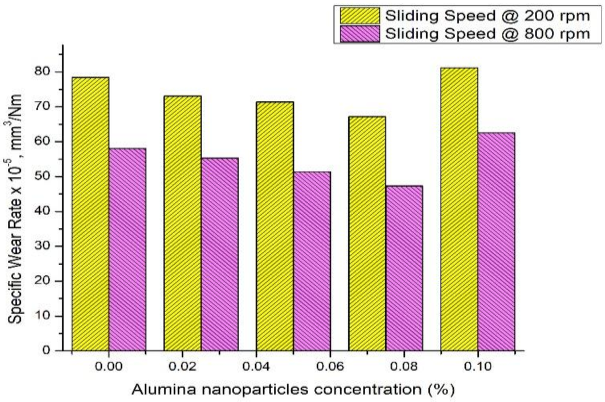

Figure 4: Nanoparticles concentration on specific wear rate.

3.3. Total Acid Number

Fig. 5 shows the total acid number obtained at different concentrations of nanoparticles in comparison to the bare polanga oil. The test was performed at 800 rpm sliding speed and 50 N load. Maximum changes in the total acid number was obtained at 0.1% concentration of the alumina nanoparticles. This was due to the more accumulation of the nanoparticles on the surface resulting in the increase in the difference of the total acid number.

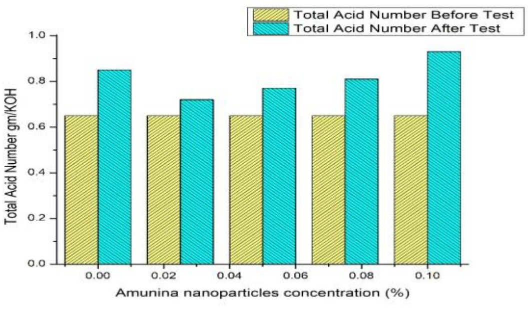

Figure 5: Total acid number with different alumina concentration percentage

4. Conclusions

The effect of Al_2O_3 nanoparticles concentration was investigated to check the tribological behavior of surface equipped with macadamia oil. Friction reduction properties of the polanga oil were improved by using Al_2O_3 nanoparticles up to a certain level. Minimum wear was obtained at the optimum copper concentration of 0.075 %. Minimum total acid number changes was obtained at 0.075% concentration in comparison to the bare polanga oil.

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