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A study on tribological behavior of rice bran and karanja oil-based Tio_2 nano bio-fluids

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ABSTRACT

In this present study, the wear rate and friction coefficient of base fluids (Rice bran and Karanja oils) with and without titanium oxide nanoparticles were studied. The friction and wear properties of base fluids were investigated by a pin-on-disc tribometer. During the investigation, sliding velocity and sliding distance were maintained at constant (2.06 m/s and 800 m), and applied loads were varied (20, 40, 60, and 80 N). The results demonstrated that Karanja oil with titanium oxide nanoparticles could remarkably improve the friction and antiwear properties of bio-based nano-fluids (base oil with nanoparticles). With increasing titanium oxide nanoparticle concentrations in base fluids, thermal conductivity qualities improved dramatically and the temperature causes kinematic viscosity to decrease.

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1. Introduction

Lubricants are utilized in a variety of applications around the world, ranging from small to huge industrial machinery units, and in a variety of operating situations. The release of harmful lubricants into the environment during use as a result of mishandling, spillages, leaks, evaporation, and other factors has raised environmental concerns [1]. Researchers are focusing on optional lubricants to change the use of petroleum-based oil [2]. There has been a surge in interest in the use of biodegradable materials in the last 30 years. Vegetable oils are prospective petroleum-based oil alternatives since they are not only environmentally friendly, renewable, and less hazardous, but they also have good lubricant qualities like a high viscosity index, lubricity, and low volatility [3,4]. Because of their strong interaction with lubricated surfaces, vegetable oils can be used as anti-wear additives and friction modifiers. Due to their amphiphilic character and the presence of polar groups in the vegetable oil molecule, they have an excellent film interaction [5,6]. As a result, vegetable oil-based lubricants are unique in that they can be used as both boundary and hydrodynamic lubricants [7,8].

Chemical additions are required for vegetable oils to execute all of their functions efficiently. Additives improve the lubricating capabilities of base oils by improving or adding desirable characteristics that are already present. For this reason, Additives are the most important component of contemporary lubricants. Many studies have found that lubricants with nanoparticles scattered in them are efficient at reducing wear and friction. Metals, organic, inorganic, and polymer materials, as well as metal nanoparticles, have been employed to make nano lubricants [9,10]. Because of their structure, size, and other features, nanoparticles have emerged as viable lubricant additives. Small amounts of nanoparticles are dispersed in the base oil to create bio-based nano lubricants. By dispersing modest amounts of nanoparticles in base oil stably and homogeneously, the thermal properties of the oil can be greatly enhanced [11,12]. Nanofluids show better thermal conductivity, viscosity, film coefficient, wettability, vital heat flux, etc. compared to usual fluids [13]. To increase the tribological performance of the base oil, a variety of nanoparticle additions have been studied [14]. The tribological behavior of LaF_3 nanoparticles as an oil additive was investigated, and the study proved that a film formed on the surface [15]. Lubricating oil with Zro_2/Sio_2 composite nanoparticle additions showed anti-wear and anti-friction performance. They also discovered a 0.1 wt% optimum concentration that resulted in a friction coefficient 16.2 percent lower than the

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base oil [16]. The thermal conductivity of a nano oil with CuO nanoparticle additions was investigated, and the results revealed a 6.2 percent increase in thermal conductivity with a 2 wt% nano additives combination. (Jaime Taha-Tijerina et al. 2012) Reported that an addition of 0.1 wt% Boron nitrate nanoparticles gave a 5% increase in the thermal conductivity of the base oil [17,18]. The ability of nanofluids comprised of ethylene glycol and single-walled carbon nanotubes to transmit heat was examined. The maximum increase in thermal conductivity was found to be 14.8 percent at 0.2 wt% volumetric concentration, according to their findings [19]. The tribological behavior of fullerene nanoparticles added to mineral oil was reviewed and analyzed. Their findings showed that the tribological properties of nano-oils improved when compared to oils that did not include carbon nanoparticles [20]. When Tio_2 nanoparticles were introduced to engine oil, the coefficient of friction was reduced by more than 85% when compared to the oil without Tio_2 nanoparticles at a concentration of 0.3 percent by weight of the oil [21]. As additions, Tio_2 nanoparticles significantly increased the load-bearing capacity of rapeseed oil, as well as its antiwear and friction reducing qualities [2]. The tribological and rheological characteristics of different vegetable oil were investigated in this work. Cuo and Tio_2 nanoparticles were added to various vegetable oils. The use of nanoparticles (Cuo and Tio_2) was improved anti-friction and anti-wear properties of vegetable oils. Keeping in view previous work reviewed above, the present study, tribological properties of the Biobased nano- fluids were evaluated with titanium oxide (Tio_2) nanoparticles using pin on disc tribometer as per the ASTM G 99 standards.

2. Materials and methodology

The specimen preparation process, the nanoparticle integrated bio-lubricant preparation method, and the experimental methods are all detailed in this section. The pin-on-disc tribometer is shown schematically in Fig. 1. The materials for the pin are steel and the disc material is EN 81 steel. Pin materials were machined into 25 mm length and 10 mm in diameter using a lathe machine.

Fig. 1. Schematic diagram of Pin-on-Disc Tribometer.

The specific wear rate was calculated by using Eq. (1). Tio_2 nanoparticles were in the range of 30–60 nm, delivered by Nano labs, Jharkhand, India. A probe-type ultrasonication was used to formulate nano bio-fluids in different combinations of nano bio-fluids in different weight percentages (0.1, 0.5 and 1) [24]. The thermophysical properties and kinematic viscosity were measured using the transient hot-wire method and redwood viscometer as per ASTM standards [2].

$$Specific\ \ wear\ \ rate = \frac{wear\ \ volume}{load\ \ x\ \ sliding\ \ distance} \tag{1}$$

3. Results and discussions

3.1. Kinematic viscosity and thermal conductivity

The viscosities of base fluids with titanium oxide nanoparticles have been calculated at 40 to 80 °C temperatures, and it can be observed in Fig. 2 that the value of viscosity obtained for base fluids with titanium oxide nanoparticles is less than that of base fluids at any temperature. However, the viscosity of base fluids varies less with temperature than base fluids containing titanium oxide nanoparticles. It shows that Karanja oil containing titanium oxide nanoparticles has a greater viscosity index than selected fluids. One of the most important features of fluids is their high heat conductivity. The thermal conductivity of base fluids with 0.1, 0.5, and 1% Tio_2 nanoparticles was measured. All the thermal conductivity of base fluids with nanoparticles was detected at different temperatures ranging from 40 to 80 °C. Fig. 3 shows the thermal conductivity of base fluids and base fluids with titanium oxide nanoparticles at various weight percentages. In comparison to the base fluids, all base fluids with titanium oxide nanoparticles exhibit greater thermal stability. The results show that base fluids with Tio_2 nanoparticles are found to have high thermal conductivity enhancement at a much lower fraction of Tio_2 nanoparticles. A maximum of 0.174w/mk thermal conductivity can be observed concerning Karanja + 1 %Tio_2 base fluids. Thermal conductivity and viscosity also can increase as nanoparticle concentration rises [22]. Furthermore, when the temperature increases, the Brownian motion of nanoparticles grew more intense, allowing for a much faster heat flow between particles, resulting in an increase in thermal conductivity [23].

3.2. Wear rate and coefficient of friction

When the normal load is increased from 20, 40, 60, and 80 N the wear rate decreases as well. Fig. 4 represents wear rate at varying loads vs nano biofluids. The results reveal that even at low concentrations of 0.1%, titanium oxide nanoparticles may Anti-wear performance has been greatly improved the characteristics of the base fluid. The value of wear rate diminished as the concentration of nanoparticles increased from 1% base fluids containing titanium oxide nanoparticles have a considerably lower wear rate. The friction coefficient is a measure of how much energy is lost as a result of friction. When titanium oxide nanoparticle compositions are increased with increasing load and weight percentages of titanium oxide nanoparticles, the friction coefficient decreases, according to the test results. The friction coefficient at varying loads vs nano biofluids is presented in Fig. 5. The minimum value of friction coefficient of rice bran oil containing titanium oxide nanoparticles drops to 0.033, indicating that titanium oxide nanoparticles operate as lubricant additives with good friction-reducing properties. The titanium oxide nanoparticles function as a protective layer and produce a thin film between the contact region and the wear

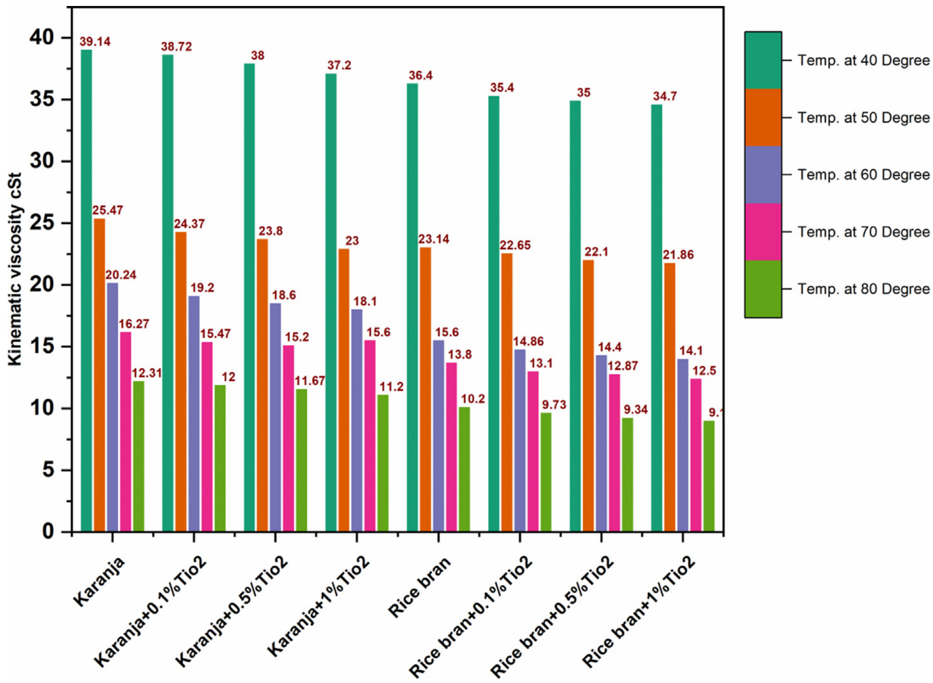

Fig. 2. Kinematic viscosties at varying temperatures.

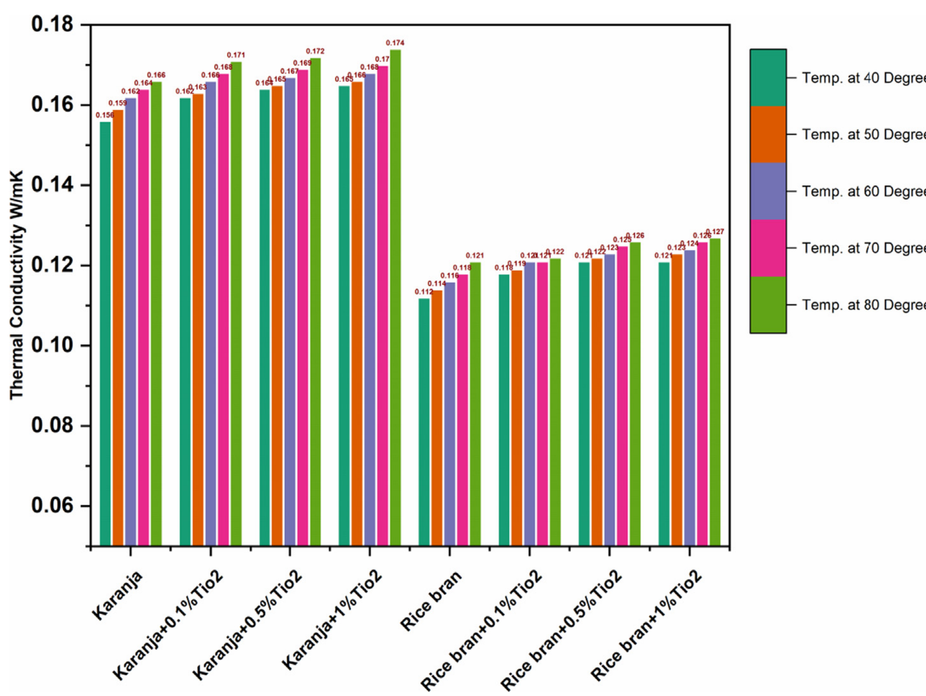

Fig. 3. Thermal conductivity at varying temperatures.

rate in the contact area is reduced as a result of the thin film creation [25].

4. Conclusion

The tribological and thermophysical properties of base fluids (Karanja and rice bran oils) with and without titanium oxide nanoparticles are evaluated and the results were compared with each other. This study led to the following conclusions:

(i) The tribological properties of base fluids and base fluids with titanium oxide nanoparticles were assessed, and the wear rate of Karanja oil with titanium oxide nanoparticles was found to be lower than that of other selected fluids, while the friction coefficient of rice bran oil with titanium oxide nanoparticles was found to be lower than that of other selected fluids.
(ii) Karanja oil with and without nanoparticles has a greater viscosity index between 40 °C and 80 °C, When compared to the selected fluids.

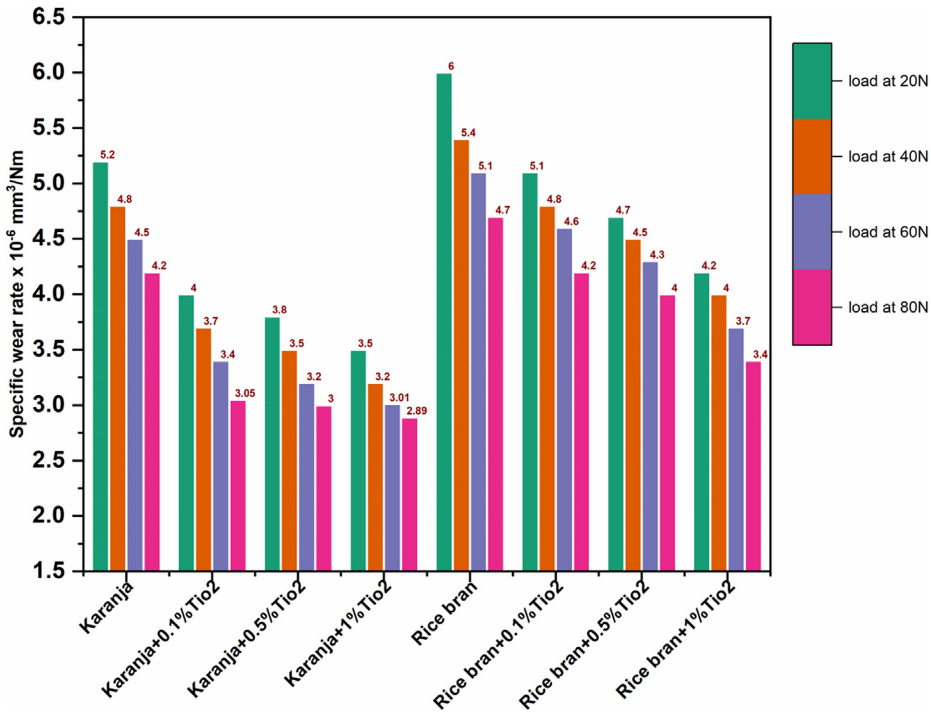

Fig. 4. Wear rate at varying loads vs nano bio fluids.

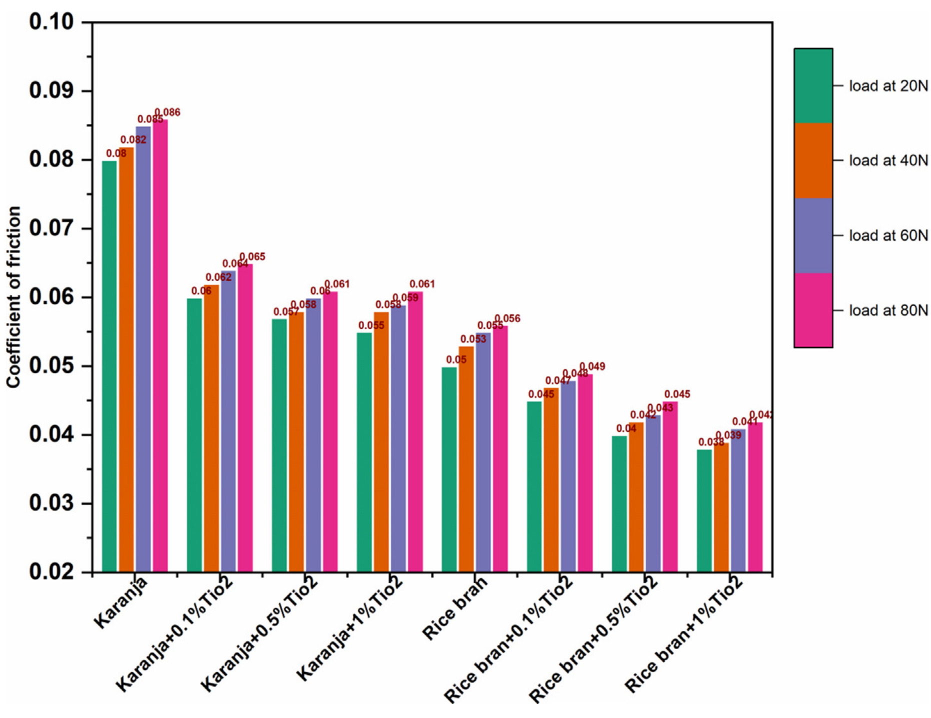

Fig. 5. Friction coeffcient at varying loads vs nano bio fluids.

(iii) Karanja oil with and without nanoparticles had a higher thermal conductivity than rice bran oils with and without nanoparticles.

CRediT authorship contribution statement

C. Rajaganapathy: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft. **T.V. Rajamurugan:** Writing – review & editing. **A. Dyson Bruno:** Project administration. **S. Murugapoopathi:** Supervision, Validation. **M. Armstrong:** Project administration.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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