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Original Article

Viscosity and Tribological Characteristics of Sunflower Oil with ZnO as Additive

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Abstract *- Vegetable oil bio-based lubricants are regarded as a suitable alternative to petroleum-based lubricants due to the increasing environmental concerns in past years. This study presents sunflower oil's viscosity and tribological properties with additions containing 0.25 to 1% weight percentage ZnO nanoparticles. The magnetic stirrer and ultrasonicator were used to prepare the samples of lubricants. The Redwood viscometer is used to measure the viscosity. The closed cup tester by Pensky-Martin is employed to measure flash and firing points. Using a four-ball tester, friction and wear characteristics such as wear scar diameter and coefficient of friction was determined. The outcomes are compared with those obtained using mineral oils and pure sunflower oil. Flash and fire points are significantly increased even though the modest rise in viscosity is not significant enough.*

Keywords *- Flash and Fire point, Magnetic stirrer, Tribo-film, Viscosity, Wear scar diameter.*

1. Introduction

Friction is also one of the factors that cause energy losses in a machine. Wear and lubrication are used to reduce the energy losses due to friction. By creating a friction-reducing film termed tribo-film, lubrication lessens wear and friction between moving surfaces that are in contact. The lubricant can be a fluid, solid, or plastic substance. Many different substances can be used to lubricate a surface. Oil and grease are the most common. Previously the most attention was given to the cost aspects of the lubricants used in the machine. But very little to no attention is given to biodegradability and its impacts on humans and the environment. Because of these reasons, Mineral oils have become the most common lubricants. All kinds of machines like Engines, differential assembly and gearboxes, hydraulic press, machine guideways, and a few mechanical moving components need lubrication. These are lubricated by petroleum-based lubricating oils. These petroleum-based lubricants prevent materials from being removed by abrasion and enhance sealing characteristics, low pour points, and film formation. [1]. These mineral oils are derived from Petroleum based crude oil, which releases lots of carbon by-products to the environment, which causes the greenhouse effect and global warming. Also, these mineral oils are non-biodegradable and cause soil and water pollution. But, recently, due to the rise in concerns towards the environment, the focus is shifted towards using vegetable oils as lubricants instead of Mineral oils.

2. Literature Review

Bio-based lubricant oils can be derived from palm, soybean, sunflower, jojoba, rapeseed, canola, coconut, jatropha, and mustard oils [2]. Vegetable oils comprise fatty-acid glycerides with better boundary lubrication performance [3]. But the drawback of vegetable oil is its poor-oxidation property which can be overcome by decreasing the number of free fatty acids [4]. In this research article, Sunflower oil is chosen because its production cost is reasonable and its wide availability, eco-friendliness, and renewability [5]. Compared to mineral oils, vegetable oils have a higher viscosity index, higher flash point, lower evaporation loss and enhanced lubricity, which leads to improved energy efficiency [6-7].

The properties of lubricant oils are improved by the use of additives. These include anti-wear additives, extreme pressure additives, film-forming additives, viscosity control additives, and deposit control additives [8]. Recently interest in nanoparticles is increased because of the recent advancements in nanotechnology and their unique properties. Nanoparticle additives have been proven to be excellent choices for additives because of characteristics such as the quantum-size effect, the small-size effect, and the interface and surface effects. [26]. Deploying nano-lubricants leads to a substantial friction coefficient reduction and load-bearing capacity improvement. Ball bearing effect [10], protective film effect, mending effect, rolling effect and polishing effect etc. [11-12] are the different lubrication mechanisms proposed for the suspension of Nanoparticles in Lubricating oil [13]. In addition to functioning as ball bearings between the friction surfaces, suspended nanoparticles will also provide film by coating the rough friction surfaces [14-15]. Nanoparticle-assisted abrasion also uses nanoparticles to lessen surface roughness and compensate for the mass loss (mending effect) (polishing effect) [16-17].

ZnO is employed as an additive in this work owing to its high surface energy, excellent dispersion characteristics, and distinctive electrical and thermal conductivity. The viscosity and tribological characteristics of the Sunflower oil with ZnO are studied using a viscometer and four-ball tester.

3. Methodology

3.1. Sample Preparation

The Sunflower oil and ZnO nanoparticle blend are prepared using a Magnetic stirrer and Ultrasonicator [18]. Sunflower oil and ZnO NPs are mixed and stirred for about 1 hour at 1200 rpm and room temperature using a magnetic stirrer. For each sample, ultra-sonification was carried out for about 20 minutes to prepare a microemulsion preventing agglomeration of the nanoparticles by using a particle dispenser.

Fig. 1 Magnetic stirrer

Fig. 2 Ulrrasonicator

3 samples are prepared with various weight proportions of Sunflower oil and ZnO, as mentioned in the table below.

Table 1. Sample proportions

Sl. No	Weight percentage	
	Sunflower oil	ZnO
1	99	1
2	99.75	0.25
3	99.375	0.625

3.2. Viscosity Measurement

The samples' viscosity was assessed using a Redwood viscometer [27]. At varying temperatures (30–50 °C), the period of time required for 50cc of oil to flow through the orifice is noted.

The kinematic viscosity of the oil samples is calculated using the following formula,

$$\nu = (0.00247t-(0.65/t))$$

The mass density of the oil sample at the appropriate temperature is multiplied by the kinematic viscosity to determine the absolute viscosity.

Fig. 3 Redwood Viscometer

3.3. Flash and Fire point

The Pensky-Martin closed cup tester determines the flash and fire point [20]. A cup is poured with an oil sample. The oil in which the metre is submerged is heated. The test flame is passed over the cup every two degrees when the sample temperature rises.

The sample vapours rapidly ignite in the air at the flash point temperature. At least five seconds pass after the sample vapours begin to burn and it reaches the fire point temperature.

Fig. 4 Pensky Marten's closed cup tester

3.4. Tribological Characterizations

Testing was performed using a 4-ball tester manufactured by Magnum Engineers, Bangalore, India. SKF chrome steel balls with a diameter of 12.7 mm, HRC 64-66, and mirror finish were used. The test was performed at 1200 rpm with a load of 40 kg. At a temperature of 75 °C, the ZnO samples were used to study the wear resistance of sunflower oil. A four-ball tester was used to determine the coefficient of friction and moment of friction [21]. The wear scar diameter was measured under an optical microscope.

A high-resolution optical microscope with high magnification was used to investigate the steel ball bearing's wear characteristics after the experiment (1-hour run duration) was finished (50x). Micrographs were employed to estimate the wear scar diameters, and the average value of the diameters was calculated based on the ASTM D 4172 standard [22].

Fig. 5 Fourball tester

4. Results and Discussion

We compared the results of various tests with pure sunflower and mineral oil.

4.1. Viscosity

The results of analyzing the kinematic and absolute viscosities of sunflower oil containing ZnO are displayed in Table 2.

All investigated samples experienced a decrease in kinematic and absolute viscosity as the temperature rose. Compared to pure sunflower oil, the viscosity increased with adding ZnO. According to the International Organization for Standardization ISO, samples of sunflower oil containing ZnO reached the necessary level of kinematic viscosity. The viscosity values are comparable to ISO VG 32, SAE 15W and SAE 75W grade oils. Sunflower oil's kinematic viscosities are equivalent to the synthetic Renolin B10 gear lubricant, which has closed-gear lubricant qualities [23]. Sunflower oil with 0.625 weight percent of ZnO showed higher viscosity than other samples.

Viscosity variation with temperature for various samples and Viscosity grading system for standard oils is shown in Figure 6 and Figure 7, respectively.

4.2. Flash and Fire Point

Flash and fire points obtained from the Pensky-martin test are shown in Table 3.

The flash and fire point of sunflower oil with ZnO added anywhere between 220 and 230 °C, much higher than the flash and fire point of pure sunflower oil between 160 and 170 °C. Sunflower oil with ZnO added has a higher flash and fire point than Renolin B10 (205 C), a synthetic gear lubricant. Compared to other oil samples, sunflower oil enhanced lubricity performance and reduced the likelihood that lubricant thin films would break down [24].

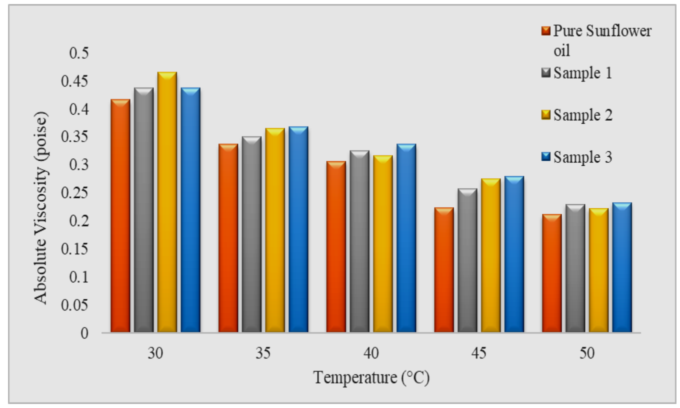

Fig. 6 Absolute viscosity vs Temperature chart

Table 2. Flash and fire point

Parameter	Pure sunflower oil	Sample 1	Sample 2	Sample 3
Flashpoint °C	162	220	220	220
Fire point °C	172	232	232	232

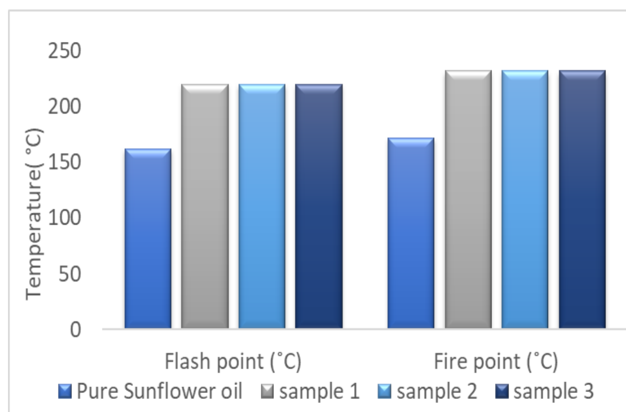

Fig. 8 Temperature vs Flash and fire point chart

Table 3. Kinematic and absolute viscosity

Temperature °C	Pure sunflower oil		Sample 1		Sample 2		Sample 3	
	ν poise	μ poise	ν poise	μ poise	ν poise	μ poise	ν poise	μ poise
30	0.45	0.42	0.5	0.44	0.49	0.47	0.49	0.44
35	0.37	0.34	0.4	0.35	0.38	037	0.41	0.37
40	0.33	0.31	0.36	0.33	0.33	0.32	0.37	0.34
45	0.24	0.22	0.29	0.26	0.29	0.28	0.31	0.28
50	0.23	0.21	0.25	0.23	0.23	0.22	0.26	0.23

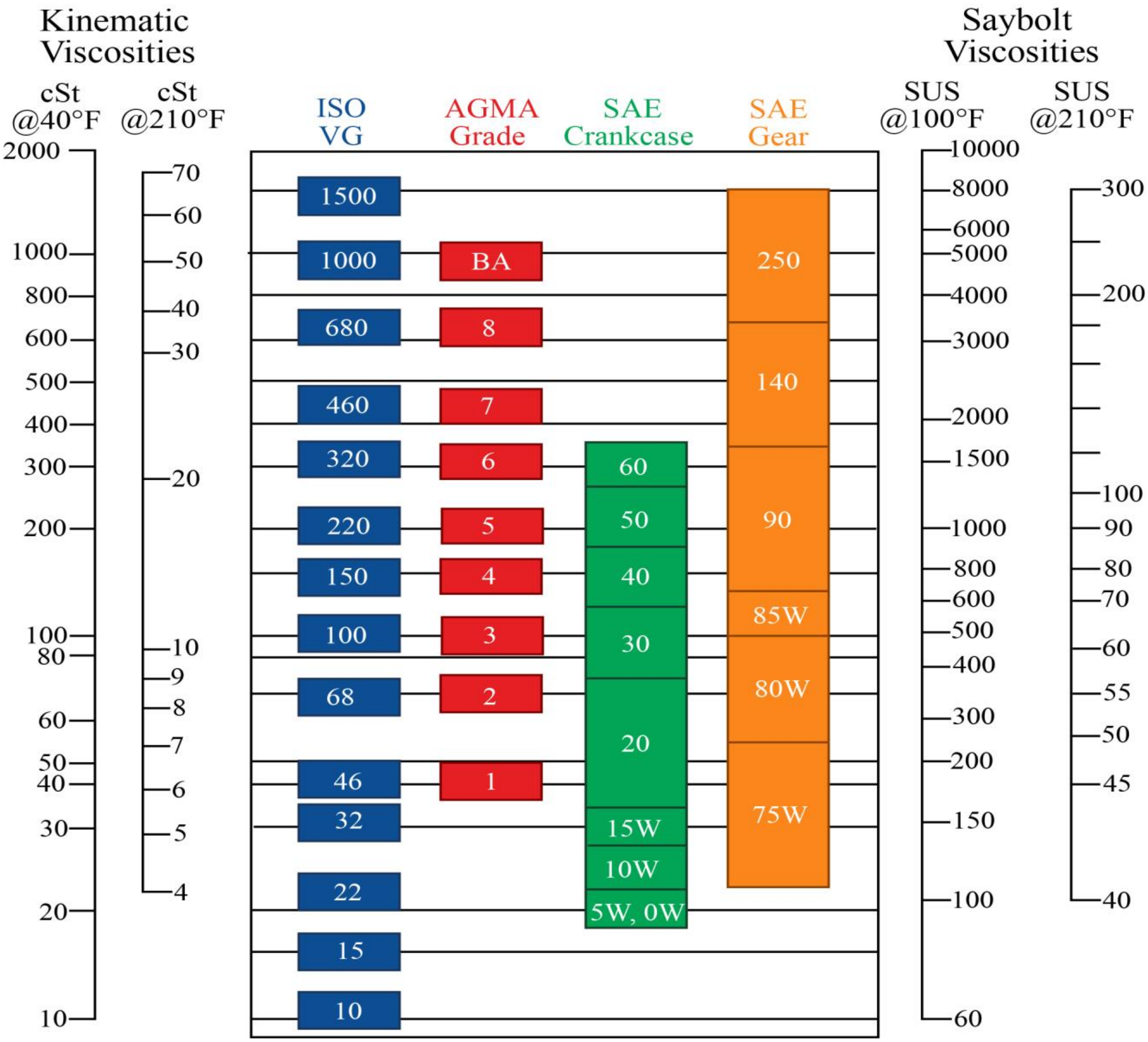

Fig. 7 Viscosity grading system

4.3. Friction Characteristics

The coefficient of friction is calculated using the following formula,

$\mu = F/N$

Where μ is the coefficient of friction, F is the frictional force measured by the Tribotester's built-in force sensor, and N is the applied normal force [25]. The average coefficient of friction came out to around 0.09572.

The frictional force is reported to be reduced by including ZnO nanoparticles. Nanoparticle addition also resulted in a reduction in the coefficient of friction. The friction coefficient of the prepared nano lubricant is 0.0957, which is lesser than the synthetic lubricant SAE20w40 (0.1009). Zinc Oxide based nano lubricant has the minimum coefficient of friction at normal operation conditions, followed by Copper Oxide and Zirconium Dioxide. The results obtained from the ZnO addition are comparable to the addition of TiO2 and CuO.

The torque produced when two objects in contact move and experience friction are referred to as frictional torque. Frictional torque has an impact on the bearing's ability to operate freely. Figure 10 depicts the Frictional Torque discovered using the Four-Ball Tester. The average Frictional torque obtained is around 0.1667 N m.

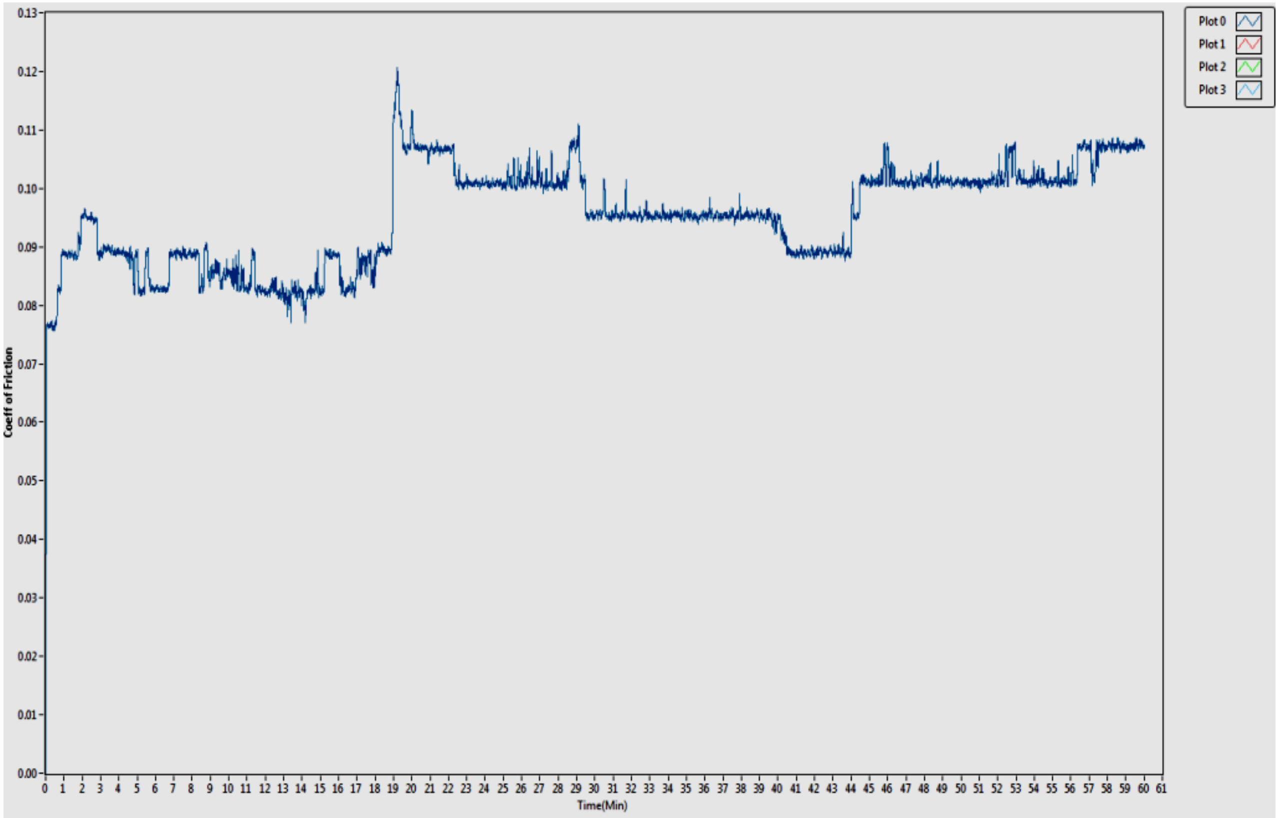

Fig. 9 Coefficient of friction

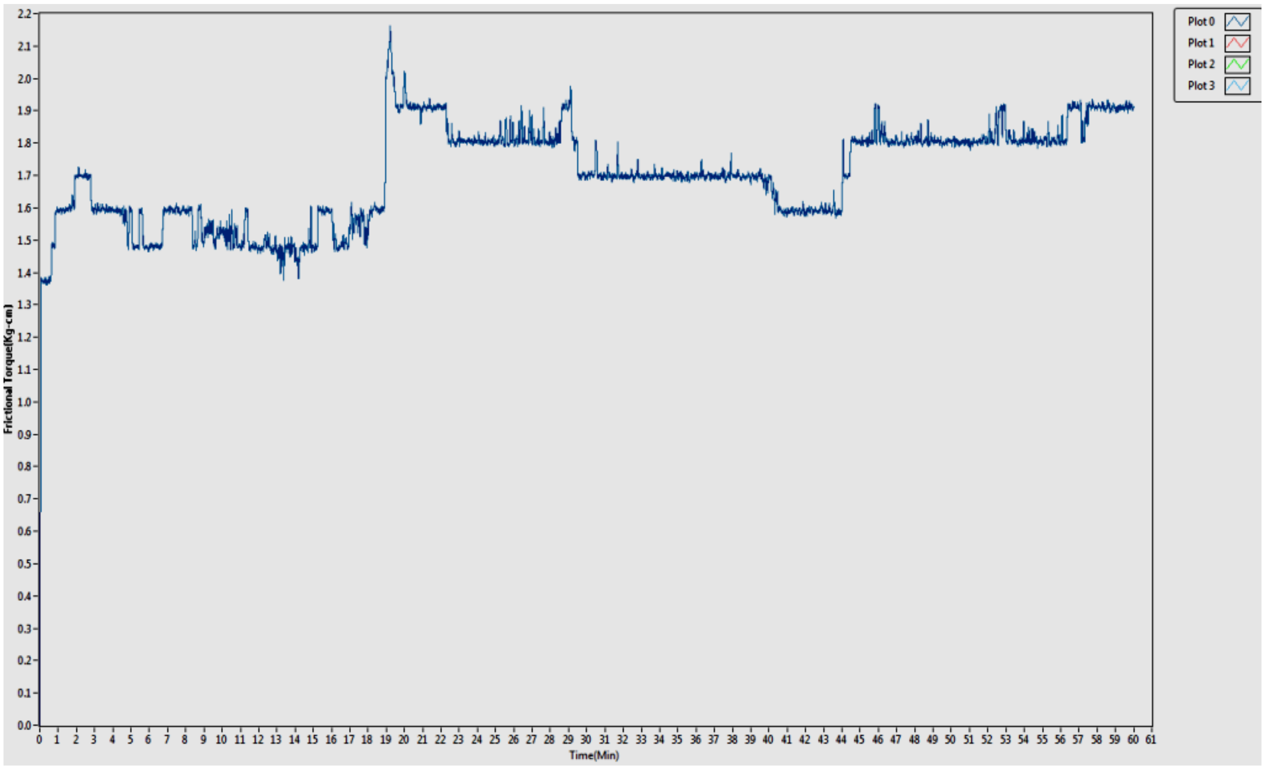

Fig. 10 Frictional torque

4.4. Wear Scar Diameter

Wear scar diameters of different samples are shown in the table below.

Table 4. Wear scar diameter

Wear scar diameter (µm)	Sample 1	Sample 2
Ball 1	750	658
Ball 2	627	712
Ball 3	794	740
Average Diameter	738.66	703.33

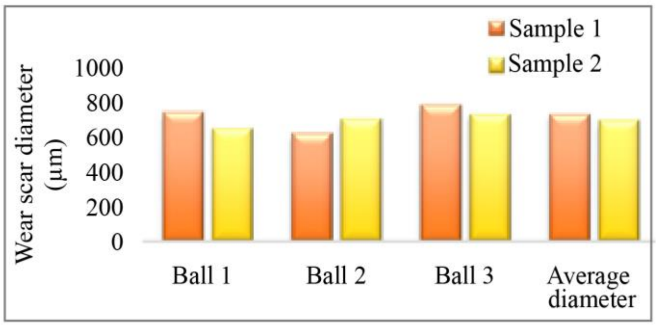

Fig. 11 Wear scar diameter bar chart.

Fig. 12 WSD of sample 1

Fig. 13 WSD of sample 2

The following explains how nanoparticle additives prevent wear. In addition to the asperity level contacts bearing the load, when the lubricant film between interacting surfaces gets thinner, and the lubrication regime is mixed or boundary, the nanoparticles also bear a portion of the load. During the interaction between the surfaces, a tribofilm may be formed due to the chemical action between the lubricant particles and the surface material. This tribofilm formed between the surfaces reduces the metal-to-metal contact. This, in turn, prevents adhesion, thus reducing the wear. It has been generally accepted that tribofilm formation is aided by temperature. The tribofilm may not form in the case of nanoparticles evaluated at ambient temperature, leading to the higher level of wear shown by ZnO during room temperature testing. Therefore, the wear scar diameter of Sample 2, with 0.25 wt % of ZnO, is lower than Sample 1, which has 0.625 wt % of ZnO.

5. Conclusion

All investigated samples experienced a decrease in kinematic and absolute viscosity as the temperature rose. Compared to pure sunflower oil, adding ZnO enhanced viscosity, which increases the thickness of the oil coating and lessens contact between the ball surfaces. The addition of nanoparticles significantly increased Sunflower oil's flash and fire points significantly. Higher FTP values were observed with sunflower oil than with mineral oil, implying that when sunflower oil containing ZnO nanoparticles is employed as a lubricant, the likelihood of lubricant thin films breaking down will decrease and that lubricity performance will enhance in contrast to other oil samples. Nanoparticle addition also resulted in a decrease in the coefficient of friction. The wear scar diameter of Sample 2, with 0.25 wt % of ZnO, is lower than that of Sample 1, which has 0.625 wt % of ZnO. So, adding a higher wt % of nanoparticles has resulted in greater wear and thereby reduced the anti-wear properties.

References

[1] Bheemappa Suresha et al., "Role of Graphene Nanoplatelets on Tribological Behaviour of Madhuca Indica Oil," *AIP Conference Proceedings*, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[2] Manoj K. Gaur et al., "Experimental Investigation of Physical and Tribological Properties of Engine Oil with Nano-Particles Additives," *Advances in Design, Simulation and Manufacturing, DSMIE 2018*, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[3] Nobuyoshi Ohno et al., "High Pressure Rheology of Environmentally Friendly Vegetable Oils," *Tribology Letters*, pp. 273–280, 2012. [CrossRef] [Google Scholar] [Publisher Link]

[4] N.J. Fox, and G.W. Stachowiak, "Vegetable Oil-Based Lubricants—A Review of Oxidation," *Tribology International*, vol. 40, no. 7, pp. 1035–1046, 2007. [CrossRef] [Google Scholar] [Publisher Link]

[5] Mohammed Hassan Jabal et al., "Experimental Investigation of Tribological Characteristics and Emissions with Nonedible Sunflower Oil as a Biolubricant," *Journal of the Air & Waste Management Association*, vol.69, no. 1, pp. 109–118, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[6] Behrooz Zareh-Desari, and Behnam Davoodi, "Assessing the Lubrication Performance of Vegetable Oil-Based Nano-Lubricants for Environmentally Conscious Metal Forming Processes," *Journal of Cleaner Production*, vol.135, pp. 1198–1209, 2016. [CrossRef] [Google Scholar] [Publisher Link]

[7] Leslie R. Rudnick, *Lubricant Additives: Chemistry and Applications*, Second Edition (2nd Ed.), CRC Press, 2009. [CrossRef] [Google Scholar] [Publisher Link]

[8] Sobahan Mia et al., "High Pressure Tribological Behavior of Vegetable Oils as Lubricants," *Proceedings of the International Conference on Mechanical Engineering* 2007 (ICME2007), pp. 1-5, 2007. [Google Scholar] [Publisher Link]

[9] Szemruch, C et al., "Electrical Conductivity Test for Predict Sunflower Seeds Vigor," *SSRG International Journal of Agriculture & Environmental Science*, vol. 6, no. 4, pp. 118-127, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[10] Vicente Cortes et al., "The Performance of Sio_2 and Tio_2 Nanoparticles as Lubricant Additives in Sunflower Oil," *Lubricants*, vol. 8, no. 1, pp. 1-13, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[11] Z.S Hu et al, "Preparation and Tribological Properties of Nanometer Magnesium Borate as a Lubricating Oil Additive," *Wear* , vol. 252, no. 5-6, pp. 370–374, 2002. [CrossRef] [Google Scholar] [Publisher Link]

[12] R.B Rastogi, M Yadav, and A Bhattacharya, "Application of Molybdenum Complexes of 1-Aryl-2,5- Dithiohydrazodicarbonamides as Extreme Pressure Lubricant Additives," *Wear*, vol. 252, no. 9-10, pp. 686–692, 2002. [CrossRef] [Google Scholar] [Publisher Link]

[13] G. Liu et al., "Investigation of the Mending Effect and Mechanism of Copper Nano-Particles on a Tribologically Stressed Surface," *Tribology Letters*, vol.17, pp. 961–966, 2004. [CrossRef] [Google Scholar] [Publisher Link]

[14] L. Rapoport et al., "Mechanism of Friction of Fullerenes," *Industrial Lubrication and Tribology*, vol. 54 no. 4, pp. 171-176, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[15] F. Chin˜as-Castillo, and H. A. Spikes, "Mechanism of Action of Colloidal Solid Dispersions," *Journal of Tribology*, vol. 125, no. 3, pp. 552–557, 2003. [CrossRef] [Google Scholar] [Publisher Link]

[16] De-Xing Peng et al., "Side Effects of Sio2 Nanoparticles as Oil Additives on Tribology of Lubricant," *Industrial Lubrication and Tribology*," vol. 62, no. 2, pp. 111–120, 2010. [CrossRef] [Google Scholar] [Publisher Link]

[17] Xu Tao et al., "The Ball-Bearing Effect of Diamond Nanoparticles as an Oil Additive," *Journal of Physics D: Applied Physics*, vol. 29, pp. 2932–2937, 1996. [CrossRef] [Google Scholar] [Publisher Link]

[18] Marcio Loos, "Processing of Polymer Matrix Composites Containing CNTs," *Carbon Nanotube Reinforced Composites*, , pp. 171-188, 2015. [CrossRef] [Google Scholar] [Publisher Link]

[19] Putu Hadi Setyarini et al., "Evaluation of Rubber Seed Oil as Cutting Fluid Using Minimum Quantity Lubrication in the Turning Process of AA6061," *International Journal of Engineering Trends and Technology*, vol.69, no.1, pp. 198-204, 2021. [CrossRef] [Publisher Link]

[20] Neelameagam Periyasamy et al., "Viscosity Measurement Using Microcontroller to Study the Thermal Degradation of Edible Oil," *Sensors & Transducers*, vol.102, no. 3, pp. 45-50, 2009. [Google Scholar] [Publisher Link]

[21] Mohammed Hassan Jabal et al., "Performance Features of the Sunflower Seed Oil as a Hydraulic Bio Fluid Under Various Normal Loads," *Jurnal Teknologi*, vol. 82, no. 2, p. 1-6, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[22] Ibrahim et al., "Comparison Between Sunflower Oil and Soybean Oil as Gear Lubricant," *Applied Mechanics and Materials*, vol. 699, pp. 443-448, 2014. [CrossRef] [Google Scholar] [Publisher Link]

[23] Mohammed Hassan Jabal et al., "Experimental Investigation of Tribological Characteristics and Emissions of Nonedible Sunflower Oil as a Bio-Lubricant," *Journal of the Air & Waste Management Association*, vol. 69, pp. 109-118, 1995. [CrossRef] [Google Scholar] [Publisher Link]

[24] P. M. Anil et al., "A Comparative Study on the Tribological Performance of Lubricating Oils With Zro2, Cuo and Zno Nanoparticles as Additives," *International Journal of Applied Engineering Research*, vol.10, no. 91, 2015. [Google Scholar] [Publisher Link]

[25] Y.Y. Wu, W.C. Tsui, and T.C. Liu, "Experimental Analysis of Tribological Properties of Lubricating Oils With Nanoparticle Additives," *Wear*, vol. 262, pp. 819-825, 2007. [CrossRef] [Google Scholar] [Publisher Link]

[26] S. Baskar, G. Sriram, and S. Arumugam, "Experimental Analysis on Tribological Behavior of Nano Based Bio-Lubricants Using Four Ball Tribometer," *Tribology in Industry*, vol. 37, pp. 449-454, 2015. [Google Scholar] [Publisher Link]

[27] Silvia Daniela Romano et al., "Methanol Content in Biodiesel Estimated by Flash Point and Electrical Properties," *Bioethanol: Production, Benefits and Economics*, pp.135-146, 2009. [Google Scholar] [Publisher Link]