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Tribological Behaviour of Biodiesel and Metal Oxide Nanoparticles as Alternative Lubricant: A Pin-on-Disc Tribometer and Wear Study

[1]V. Ram Babu, *[2]M. Jaya Krishna, [3]A. Lakshumu Naidu

[123]GMR Institute of Technology, Rajam, Andhra Pradesh

Abstract

Metals currently have a wide range of applications in which friction creation is a serious issue. Wear rate increases as a result of constant friction, causing metal deformation. The Pin on Disc equipment was used to test sunflower oil and additives (biodiesel and ZnO). The impact of vegetable oil lubricant, its biodiesel, and nanoparticle added lubricant on the wear of metallic surfaces was investigated. There are seven more lubrication conditions in addition to the dry state. Raw sunflower oil, Raw oil (80 percent) + B20, Raw oil (60 percent) + B40, Raw oil (80 percent) + B20 + Nano1 (0.5 percent), Raw oil (60 percent) + B40 + Nano1 (0.5 percent), Raw oil (80 percent) + B20 + Nano2 (0.2 percent), Raw oil (60 percent) + B40 + Nano2 (0.2 percent), Raw oil (80 percent) + B20 + Nano2 (0.2 percent), Raw oil (60 percent) + B40 A stainless steel disc and a brass pin were utilised in this experiment. At three loads (1, 3 & 5 kgf) and three speeds (300, 500 & 700 rpm), the wear rate, frictional force, and coefficient of friction for all lubricants are examined. Nanoscale particles added to lubricants were proved to improve tribological characteristics significantly. In dry circumstances, the wear rate, frictional force, and coefficient of friction are all increased. Because the presence of ZnO nanoparticles reduces the wear rate, frictional force, and coefficient of friction greatly when compared to basic oil and dry circumstances, nano lubricant has the lowest value.

Keywords: Sunflower oil, ZnO nanoparticles, Methanol, stainless steel disc, Brass rods.

1. INTRODUCTION

Every country has developed because of outstanding innovations that translate knowledge into applications in every sector in today's world, which is led by technology. Advanced internal combustion engines, vehicles, manufacturing industries, and refrigeration and air conditioning are only a few of the uses [1]. Different metals are used for different applications, and different metals come into touch with other metals. So, where there is contact, there is friction, and where there is friction, there is wear [2]. The lifetime of the product or service was reducing due to friction and wear, and it was also not performing efficiently. Lubricant is important in decreasing friction and wear [3]. Bio-lubricant contains animal fats and vegetable oils. These lubricants are biodegradable and environmentally benign, being freely accessible in nature and having strong anti-frictional and anti-wear qualities. Mineral oil or petroleum-based lubricants are best replaced with bio-lubricants. Bio-lubricants have excellent lubricating properties due to their high viscous nature and the fact that they are bio-lubricants, as the name implies. And, in order to improve the anti-frictional properties of the bio-lubricant, Iron oxides or Nano particles are used as an additive to improve the lubricant's properties [4-10]. Sunflower oil, soya bean oil, coconut oil, palm oil, olive oil, and cotton seed oil are some of the vegetable oils used in bio-lubricants, and nano particles such as ZnO, Cuo, Mos2, Tio2, and Al2o3 are used as additives to bio-lubricants to improve their properties [13].

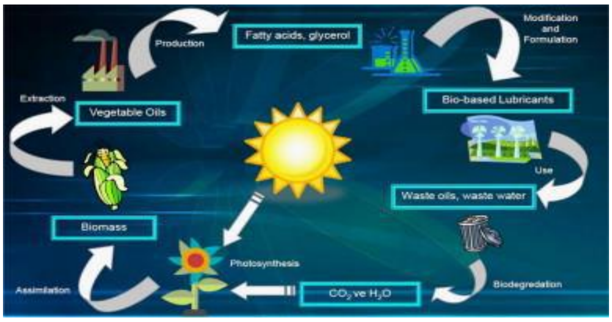


Fig1. *Bio Lubrication Process*

Nanotechnology was also developed, and it played an important role in improving applications in various fields, including lubricants. So, there is an alternative to integrate Nano technology in to the lubricants for manufacturing optimum lubricant for increasing anti-frictional and anti-wear features [12].

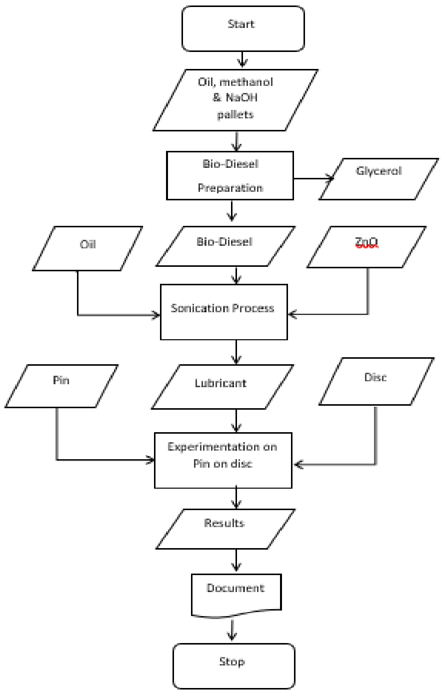
Oil Additives With Nanoparticles

The role of nanoparticles as additives in lubricating oil has gotten a lot of attention because of their excellent properties due to their high surface to volume ratio. Extreme pressure, anti-wear, friction modifier, antioxidant, and anti-corrosion additive properties vary across Nano-additives, which may be employed in a variety of tribological applications [14-20]. The key advantages of the Nano lubricant are its spherical form, which allows for a high surface to volume ratio, which improves dispersion stability, and its usage as an antioxidant and anti-corrosion agent [23]. It also has excellent anti-frictional characteristics .The Nano lubricant has the disadvantage of being expensive and complex to make.

2. Experimental Methodology

Brass was utilised as a pin in this experiment, and it was tested on a stainless-steel disc. Sunflower oil is chosen as a bio-lubricant, and its bio-diesel and metal oxide, Zno, are combined as an additive to increase lubricating characteristics, which will then be utilised to improve tribological properties. To prevent particle agglomeration, an ultrasonic machine was used for 1 hour of sonication [23]. It's time to make the Nano-bio-diesel lubricant. Taking speed and load at three distinct levels under constant time frames the combinations of process variables. These eight combinations are tested to determine tribological qualities like as wear, frictional force, and coefficient of friction [27]. The goal of this research is to look at how stainless-steel wears under the impact of Nano lubricants [28-29]. Speed and load are two of the changeable input factors. Friction and wear properties of stainless steel are investigated using a pin-on-disk tribo-tester under varied loads of 10N to 90N and rotational speeds of 100-900 rpm in a specified operating duration in the current research. The studies are carried out with a brass pin and a stainless-steel disc lubricated with Nano-bio-diesel lubricants, and the variation of wear and frictional force is investigated under varying input parameters such as load and speed.

2.1 Flowchart for Experimental Methodology:



2.2 Procedure For Preparation Of Biodiesel (From Sunflower Oil)

The manufacture of bio-diesel was covered in the following session. Blends that have undergone transesterification are appropriate for use in engines. The steps are depicted in

Figure 2.3. At 60°C, 1 L of raw oil is treated with 100 mL methanol and 2-3 mL sulphuric acid. The pulp is separated after three hours of setting in a decanter. At 60°C, sodium methoxide is added to the acid-treated oil. The glycerine is removed once it has settled for 6 hours. To obtain pure biodiesel, the base processed oil is water washed and then dehydrated at 110oC [3].

The Nano lubricant was made with an ultrasonic sonicator, and the lubricant had to be prepared before the ZnO and lubricant were sonicated [6-10]. Lubricant is made up of predetermined amounts of raw oil and biodiesel for certain situations. It was made by stirring for 30 minutes without using any heat and added ZnO particles fig2.2.

Fig 2.1: *Preparation Of Biodisel*

Fig 2.2 *Lubricant (After Sonication)*

2.3. LUBRICANT CONDITIONS FOR EXPERIMENT:

The following section discussed about lubricant conditions for experiment

1. Dry conditions

2. Raw oil

3. Raw oil (80%) +B20

4. Raw oil (60%) +B40

5. Raw oil (80%) +B20+Nano 1(0.3%)

6. Raw oil (60%) +B40+Nano 1(0.3%)

7. Raw oil (80%) +B20+Nano 2(0.2%)

8. Raw oil (60%) + B40+Nano 2(0.2%)

1. Dry Conditions:

Operating or doing experiment without lubricant.

2. Raw Oil:

Experimenting under lubrication conditions with sunflower oil as the basic material.

3. Raw Oil (80%) + B20:

Bio-diesel makes up 20% of the lubricant, which is made up of 80% raw oil and 20% bio-diesel. It was made by stirring for 30 minutes without using any heat.

4. Raw Oil (60%) + B40:

Bio-diesel makes up 40% of the lubricant, which is made up of 60% raw oil and 40% bio-diesel. It was made by stirring for 30 minutes without using any heat.

5. Raw Oil (80%) + B20 + Nano 1(0.3%):

Bio-diesel makes up 20% of the lubricant, which is made up of 80% raw oil and 20% bio-diesel. It was made by stirring for 30 minutes without using any heat. After that, 0.3 percent ZnO was added to the lubricant (in terms of weight percentage). The dispersion of Nano was achieved by employing an ultrasonic probe machine and a sonication procedure for 1 hour at a frequency of 20-25Hz.

6. Raw Oil (60%) + B40 + Nano 1(0.3%):

Bio-diesel makes up 40% of the lubricant, which is made up of 60% raw oil and 40% bio-diesel. It was made by stirring for 30 minutes without using any heat. After that, 0.3 percent ZnO was added to the lubricant (in terms of weight percentage). The dispersion of Nano was achieved utilising an ultrasonic probe machine and a sonication operation lasting 1 hour at a frequency of 20-25Hz.

7. Raw Oil (80%) + B20+Nano 2(0.2%):

Bio-diesel makes up 20% of the lubricant, which is made up of 80% raw oil and 20% bio-diesel. It was made by stirring for 30 minutes without using any heat. After that, 0.2 percent ZnO was added to the lubricant (in terms of weight percentage). The dispersion of Nano was achieved utilising an ultrasonic probe machine and a sonication operation lasting 1 hour at a frequency of 20-25Hz.

8. Raw Oil (60%) + B40+Nano 2(0.2%):

Bio-diesel makes up 40% of the lubricant, which is made up of 60% raw oil and 40% bio-diesel. It was made by stirring for 30 minutes without using any heat. After that, 0.2 percent ZnO was added to the lubricant (in terms of weight percentage). The dispersion of Nano was achieved utilising an ultrasonic probe machine and a sonication operation lasting 1 hour at a frequency of 20-25Hz.

3. Pin On Disc:

The pin on disc wear testing machine is simple and easy to use. This is used for both wear testing and coefficient of friction measuring[19]. This device allows for the investigation of friction and wear characteristics in sliding circumstances under various settings. The sliding takes place between the stationary pin and the revolving disc. To fit our studies, we may change the usual load, rotating speed, and track diameter. The following are the various components of a wear testing machine, and the experimental setup is depicted in Fig3

Fig.3. Pin On Disc Setup

3.1. Dimensions of pins and disc : Pins of required dimensions are made using CNC machine.

The dimensions of pins and disc are as follows.

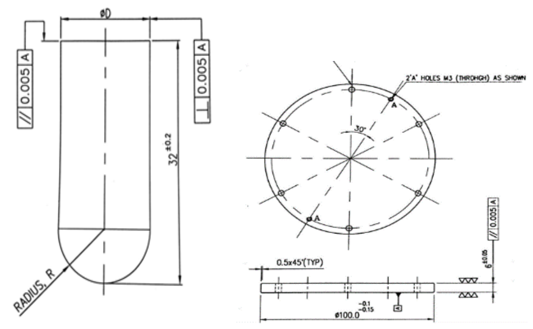


Fig 3.1: *Dimensions Of Pin And Disc*

Fig 3.2: Specimen Pin and Disc

4. Results And Discussions

The Pin on disc device was used to test sunflower oil and additives (biodiesel and ZnO). The impact of vegetable oil lubricant, its biodiesel, and nanoparticle added lubricant on the wear of metallic surface was studied using dry tests and base oil with/without addition. The wear rate, frictional force, and coefficient of friction for all lubricants are shown in Fig. 4.1-4.9, which also shows the wear rate, frictional force, and coefficient of friction for three loads (1, 3 & 5kgf) and three speeds for comparative purposes (300, 500 & 700 rpm). The performance of the lubricant was studied both without and with additives. According to Fig. 4.1, raising the speed for lubrication conditions increased the wear rate. This is quick surface area contact. The dry lubricant condition (LC1) has the highest wear rate among the eight situations. The raw oil (LC2) has a lower wear rate than the dry state but a greater wear rate than the Nano lubricant condition. In comparison to raw oil lubricant conditions, the Nano lubricant conditions LC5 (Raw oil (80%) +B20+Nano 1(0.5%)) have delivered reduced wear rate than all circumstances, with 43 percent less under low speed and 50 percent less under high speed. According to Fig. 4.2 (at 1kgf), a similar pattern of wear rate with regard to speed was found. Out of the eight conditions, the dry lubricant condition (LC1) had the highest wear rate, as expected; however, raw oil (LC2) had a lower wear rate when compared to the other lubricant conditions. When compared to dry lubrication conditions, LC2 had a 29 percent and a 26 percent lower wear rate at low and high speeds, respectively. According to Fig. 4.3, the dry lubricant condition (LC1) has the highest wear rate among the eight circumstances, while the raw oil condition (LC2) has a lower wear rate than the dry condition but is greater than the Nano lubricant condition. The LC8 (Raw oil (60%) +B40+Nano 2(0.2%)) has a lower wear rate than any other circumstances. Under low-speed conditions, it is 60% lower, and under high-speed conditions, it is 56% lower (LC7 (Raw oil (80%) +B20+Nano 2(0.2%)). This is due to the greater amount of Nano additive. The frictional force was raised by raising speed for lubrication conditions, as shown in Fig 4.4. This is quick surface area contact. The dry lubricant condition (LC1) has the highest frictional force among the eight situations. The frictional force of raw oil (LC2) was smaller than that of dry condition but more than that of Nano lubricant condition. When compared to raw oil lubricant conditions, the Nano lubricant conditions LC5 (Raw oil (80 percent) +B20+Nano 1(0.5 percent)) have given less frictional force than all conditions and comparatively giving 83 percent less under low speed and LC7 (Raw oil (80 percent) +B20+Nano 2(0.2 percent), raw oil have given the same frictional force under high speed. According to Figure 4.5 As previously stated (at 1kgf), a similar pattern of frictional force with respect to speed was found. Out of the eight conditions tested, the dry lubricant condition (LC1) produced the highest frictional force. The frictional force of raw oil (LC2) was smaller than that of dry condition but more than that of Nano lubricant condition. When compared to raw oil lubricant conditions, the Nano lubricant conditions LC6 (Raw oil (60 percent) +B40+Nano 1(0.5 percent)) has given less frictional force than all circumstances, yielding 70% less at low speed and 76% less at high speed. According to Fig. 4.6, the dry lubricant condition (LC1) has the highest frictional force among the eight circumstances, while the raw oil condition (LC2) has a lower frictional force than the dry condition but is greater than the Nano lubricant condition. The LC6 (Raw oil (60%) +B40+Nano 2(0.5%)) has a lower frictional force than all other circumstances. It is 82 percent less at low speeds and 50 percent less at high speeds. This is due to the greater amount of Nano additive. According to Fig. 4.7, the dry lubricant condition (LC1) has the highest coefficient of friction of the eight conditions. The raw oil (LC2) has a lower coefficient of friction than the dry condition but a higher coefficient of friction than the Nano lubricant condition. In comparison to raw oil lubricant conditions, the Nano lubricant conditions LC5 (Raw oil (80 percent) +B20+Nano 1(0.5 percent)) has given a lower coefficient of friction than all conditions and a 91 percent lower coefficient of friction under low speed and a 73 percent lower coefficient of friction under high-speed condition. According to Fig. 4.8, the dry lubricant condition (LC1) has the highest coefficient of friction, while raw oil (LC2) has a lower coefficient of friction than the dry condition but a higher coefficient of friction than the Nano lubricant condition. When compared to raw oil lubricant conditions, the Nano lubricant conditions LC8 (Raw oil (60 percent) +B40+Nano 2(0.2 percent)) has given a lower coefficient of friction than all conditions, giving 72 percent less under low speed and 62 percent less under high-speed condition. According to Fig. 4.9, the dry lubricant condition (LC1) has the highest coefficient of friction, followed by raw oil (LC2), which is lower than the dry condition but higher than the Nano lubricant condition. In comparison to raw oil lubricant conditions, the Nano lubricant conditions LC7 (Raw oil (80 percent) +B20+Nano 2(0.2 percent)) has offered a lower coefficient of friction than all circumstances and comparatively giving 38 percent less under low speed and 56 percent less under high-speed condition. This is due to the greater amount of Nano additive. The wear rate, frictional force, and coefficient of friction are all high, especially in dry conditions. While doing the lubrication test. Because of its viscous nature, base oil (sunflower oil) has a lower value than dry circumstances due to reduced frictional force and coefficient of friction. Because of the presence of ZnO nanoparticles, the wear rate, frictional force, and coefficient of friction of nano lubricant are much lower than in base oil and dry circumstances.

Result Graphs:

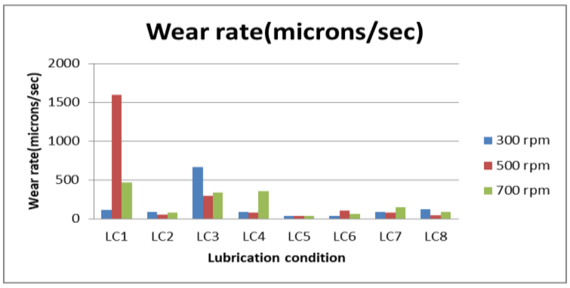


Fig 4.1 *Wear rate (microns/sec) at 1kgf*

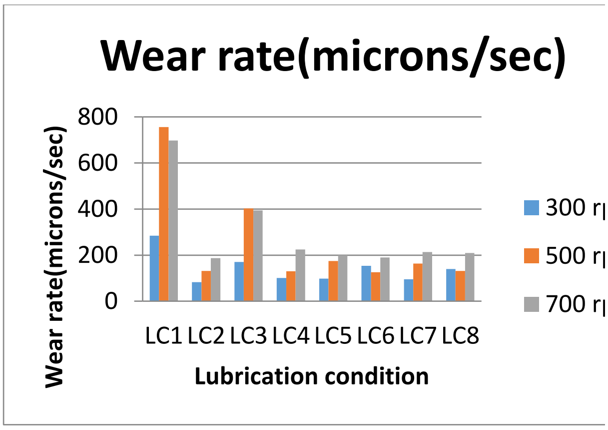


Fig 4.2 *Wear rate (microns/sec) at 3kgf*

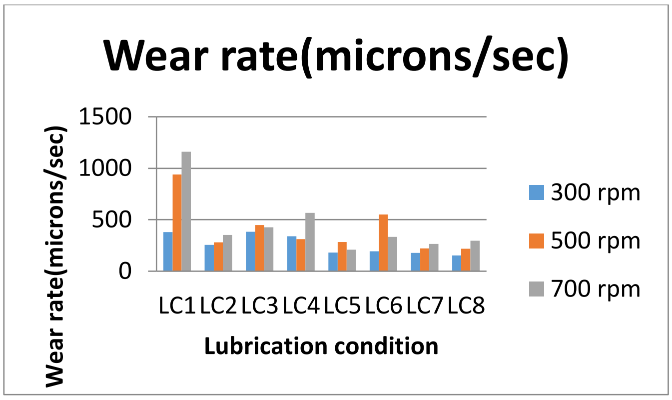


Fig 4.3 *Wear rate (microns/sec) at 5kgf*

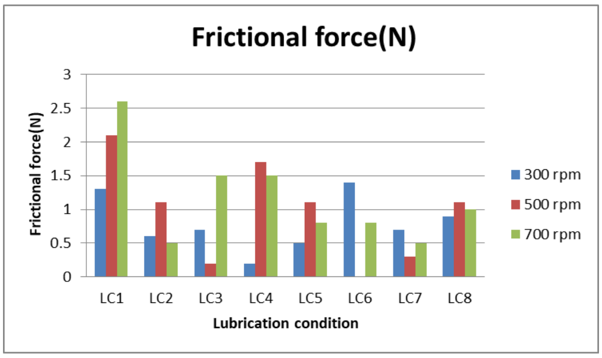


Fig 4.4 *Frictional force (N) at 1kgf*

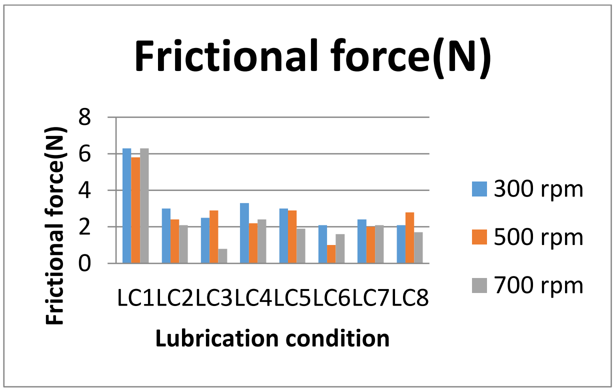


Fig 4.5 *Frictional force (N) at 3kgf*

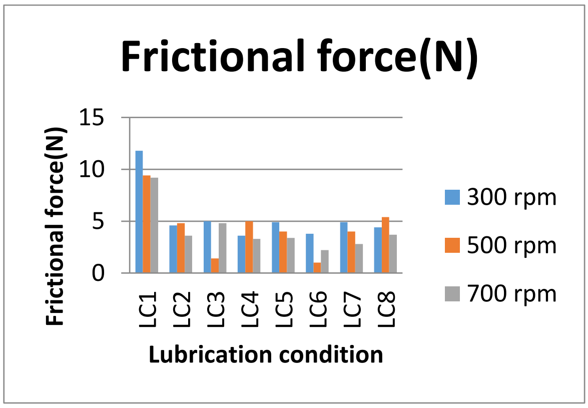


Fig 4.6 *Frictional force (N) at 5kgf*

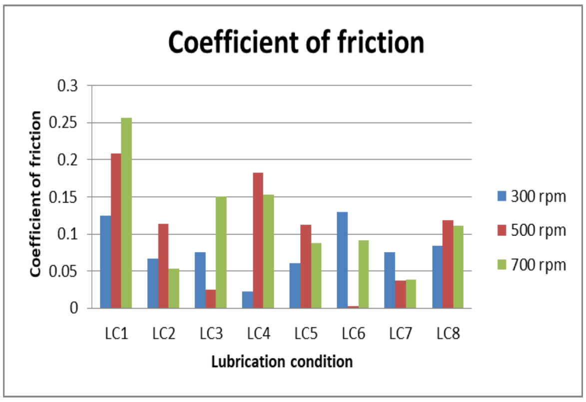


Fig 4.7 *coefficient of friction at 1kgf*

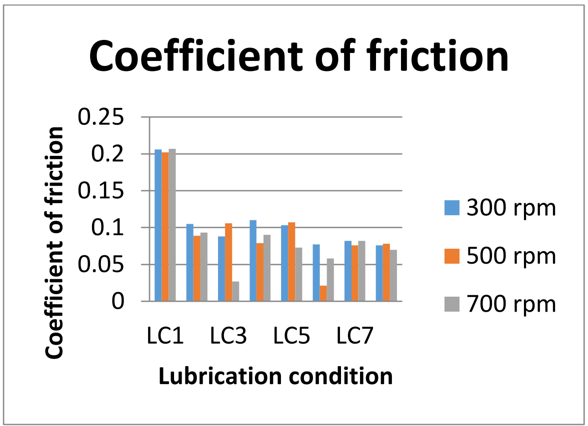


Fig 4.8 *coefficient of friction at 3kgf*

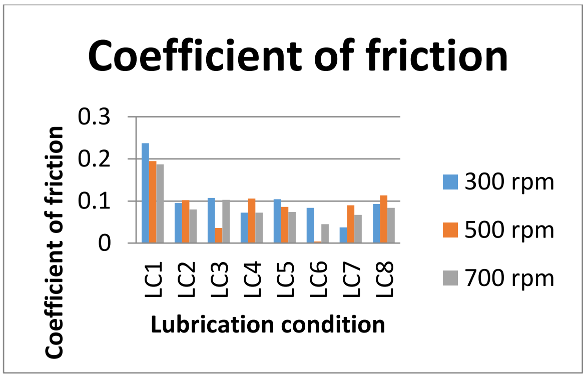


Fig 4.9 *coefficient of friction at 5kgf*

Conclusions

The current study's goal is to look into the influence of a bio-Nano lubricant on wear and frictional qualities. The investigations are conducted out on a POD Tribometer using Stainless Steel as the disc material and Brass as the pin material. The following conclusions are drawn from the outcomes of these experimental investigations [1-11]. Wear rate rises as speed and load increase. Because of its viscous nature, base oil (sunflower oil) has a lower wear rate than dry conditions [2-16]. This is due to the lower frictional force and coefficient of friction. Because of the presence of ZnO nanoparticles, nano lubricant has a lower wear rate than base oil and dry lubricant [26]. From Nano LC5 is giving least wear rate under low load and both low and high-speed conditions. And LC8 is giving less wear rate under high load and low speed condition and LC7 is giving less wear rate under high load and high-speed condition [24]. Frictional force increases as speed and load increase. The base oil (sunflower oil) has the least amount of friction. Because of the presence of ZnO nanoparticles, nano lubricant has a lower value than base oil and dry lubricant. The Nano LC5 provides reduced frictional force under low load and low speed conditions, whereas the Nano LC7 provides less wear rate under low load and high-speed conditions. And LC6 has the lowest frictional force at high load and at both low and high speeds. The coefficient of friction is not affected by speed or weight, but by the kind of surface.

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