Investigation of Tribological Characteristics of ZA 27 Alloy Under Various Lubrication Conditions

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***Abstract* - In the current engineering scenario, brass and copper alloys are important class of materials suitable for journal bearing applications. Owing to the environmental laws and the increase in cost of copper, it is found necessary to replace the copper based materials with alternate materials. Through the literature review it is found that ZA 27 is a suitable alternative. The wear rate has been reported to be very less when compared with copper based materials and it has been found to posses higher tensile strength, lower specific weight and easy machinability characteristics. Moreover, it has been established that the working life is four to five times longer than that of phosphor bronze. Nano lubricants are recently being used in order to improve further the tribological characteristics of bearings. A nano lubricant is a new kind of engineering lubricant made of nanoparticles, dispersant and base lubricant. Thus a lubricant with both the combined properties of both the liquid and solid can be obtained. The concept behind the use of nano lubricant is that the liquid lubricant provides damping and low friction, and the nano particle acting as a solid provides load supporting strength. In this paper, the tribological characteristics of ZA 27 alloy is proposed to be studied under dry condition, lubricated condition and when lubricated with nano lubricant. Sliding wear tests are to be performed using a pin-on-disc apparatus under various conditions of load and sliding speed.**

***Key words* - ZA 27 alloy, Pin on disc, Nano Oil Lubrication, Wear rate, Co efficient of friction**

I. INTRODUCTION

The zinc–aluminium (ZA) family of casting alloys is gaining a wide commercial importance as journal bearing materials suitable for heavy load and low speed applications. These alloys, most notably ZA-12 and ZA-27 are capable of replacing traditional bronze bearing at low cost [1-8].The ZA-27 alloy which is an important member of the ZA family of alloys with a high strength is reported to have properties equivalent to those of aluminium alloys. Abundant availability, good bearing and mechanical properties such as wear resistance, anti-seizure properties, yield and tensile strengths scored in favor of extensive use of these alloys for bearing applications. It was reported that the ZA alloys, when compared to bronze, have better anti-frictional properties, better emergency running properties, lower coefficient of friction, longer life and lower cost [1-6].

ZA 27 alloy is having the highest damping characteristics nearly ten times greater damping capacity than A380 aluminium or mild steel. Zinc's excellent casting fluidity permits thinner fin and cooling pin design to better dissipate heat. All zinc alloys particularly ZA-12 and ZA-27 demonstrates the excellent bearing and wear resistance qualities, high hardness and natural lubrication characteristics. The mechanical and physical properties of ZA 27 alloy is shown in Table 1.

Table 1 Mechanical and physical properties of ZA 27 alloy

Ultimate Tensile Strength N/mm^2	420-490
Yield Strength N/mm^2	378
Elongation %	2-8
Hardness BHN	90-120
Shear Strength N/mm^2	290-305
Creep Strength N/mm^2	70
Density gms/mm^2	0.0048
Stress to fracture N/mm^2	149
Co- efficient of friction	0.01-0.3

A. Nanolubrication Principle

A nano lubricant is a new kind of engineering lubricant made of nanoparticles, dispersant and base lubricant. Thus a lubricant with both liquid and solid properties can be obtained. The principle behind nanolubrication is liquid lubricant provides damping and low friction and the nano particle acting as solid provides load supporting strength. The addition of nanoparticles into lubricating oil significantly reduces the friction coefficient and increases the load bearing capacity of the friction parts in mechanical systems. A variety of mechanisms have been proposed to explain the lubrication enhancement of the nanoparticle suspended lubricating oil (i.e., nano-oil), including the ball bearing effect, protective film, mending effect and polishing effect.[1-10].

In this research work, the tribological behaviour of the ZA 27 alloy was examined using a Pin-on-Disc friction and wear tribotester [5, 6, 7, 8]. The Co efficient of friction and Sliding wear rate was studied at varying load, speed and sliding distance conditions. The same test was done with lubricating condition and also with nanolubrication.

II. EXPERIMENTAL

A. Specimen preparation

ZA 27 alloy is used as the specimen material in the present investigation and has the chemical composition as shown in Table 2. It is prepared through casting process. The melting process for ZA 27 alloy was carried out in the temperature controlled electrical crucible furnace.

Table 2 Chemical composition of the ZA 27

Aluminium	27%
Magnesium	0.02%
Copper	2.5%
Iron	0.075%
Lead	0.006%
Cadmium	0.006%
Zinc	Balance

The melted alloy was then cast into steel mould which was designed in the form of circular rod having the cavity of 15 mm diameter and 200 mm length. With the use of turning process it is turn in to 10mm diameter and 25mm length specimen.

B. Nano oil preparation

The nanolubricant was prepared by adding graphite nanoparticles in lubricant oil. The concentration of the graphite nanoparticle additive in the nanolubricant was 5 wt. %. In overall 5 liters of oil is used with 250 grams of graphite particle to conduct the experiment. The nanolubricant was prepared by thorough mixing (severe hand stirring using a glass rod for 2 hours) of graphite nanoparticles in lubricating oil.

C. Sliding wear tests

The Pin-On-Disc machine is a versatile unit designed to evaluate the wear and friction characteristics of materials exposed to sliding contacts in dry or lubricated environments. The sliding friction test occurs between a stationary pin stylus and a rotating disk. Normal load, rotational speed, and wear track diameter had been varied in this research work. Electronic sensor is used to monitor wear and the tangential force of friction as a function of load, speed, lubrication or environmental condition. These parameters as well as the acoustic emissions at the contact are measured and displayed graphically utilizing the Tribo DATA software package. The sliding wear test was performed in this machine under dry, base oil and nano oil condition at different working environment like various pressures and sliding velocity in order to determine the frictional force and wear rate.

The wear tester consists of a speed control unit, an electric motor having 3 kW power, disc, specimen holder, loading arm, friction force measurement unit, data storage system and abrasive oil mixture feeding system. A schematic representation of the test apparatus is shown in Fig. 1. The disc was polished by emery sheets prior and after conducting the wear tests. The wear tests were carried out in dry and lubricated conditions using a wear track diameter of 120 mm. The specimens were loaded against the disc by a cantilever mechanism. The parameters used for this paper is indicated in Table 3.

The specimen was fixed on the holder and the wear rate, frictional force were noted by varying the above specified parameters. For conducting wear test under lubricated conditions, base oil and oil with graphite lubricant mixtures was used. The nano lubricant was prepared by thoroughly mixing the graphite particles in 5 wt. % with the oil lubricant. This was done in order to examine the effects of graphite as a solid lubricant on the performance of the oil lubricant towards controlling the wear characteristics of the samples. Prior to initiating the actual tests, the disc was immersed in the lubricant and allowed to rotate at the speed of 600rpm for 10sec to spin off the excess lubricant from the disc surface with a view to create conditions closer to boundary lubrication.

TABLE 3 Parameters Used for Experiments

S. No	Load (N)	Speed (rpm)	Distance (m)
1	19.62	400	1000
2	29.43	500	1500
3	39.24	600	2000
4	49.05	700	2500
5	58.86	800	3000

Wear rates were computed by a weight-loss technique. The specimens were thoroughly cleaned and weighed prior to and after the wear tests. The friction force between disc and specimen was noted using a measurement unit.

Fig. 1 Pin-on disc type wear tester

III. RESULTS AND DISCUSSION

Based on the measurements recorded during the experimentation, the effect of following parameters on the wear rate and the coefficient of friction were carried out:

- Applied load (pressure)
- Sliding speed
- Sliding distance

A. Wear Rate

Wear rate is defined as the ratio of volume loss and sliding distance or volume loss with time of experiment. In this paper wear rate is indicated as volume loss (mm^3) per sliding distance (m)

The changes in the wear rate at various load (pressures) were presented in Fig. 2.The wear rate is increased with the increase in the applied load at dry lubrication condition. When the applied pressure is 250kN/m^2, the wear rate produced in the material in dry lubrication is 1.361E-06 mm^3/m whereas it is reduced to1.25E-07 mm^3/m for oil lubrication condition. In case of nano lubrication, it is further reduced to 4.167E-08 mm^3/m. It is observed that the oil lubrication reduces wear up to 80% and nano lubrication reduced the wear rate up to 90% while compared to dry lubrication state.

Fig. 3 shows the changes in the wear rate of ZA 27 material for varying velocities at three methods of lubrication.

It explains that the wear rate is indirectly proportional to sliding velocity in all three methods of lubrication. It also indicates the reduction in wear rate is observed with varying velocity in oil lubricated condition. For the sliding velocity of 5m/s, the wear rate in dry lubrication is 1.347E-06 and it is reduced to1.111E-07 mm^3/m in oil lubrication. The wear rate is further reduced to 5.556E-08 mm^3/m. It shows the reduction in the wear rate up to 90% in nano lubrication compared to dry lubrication conditions.

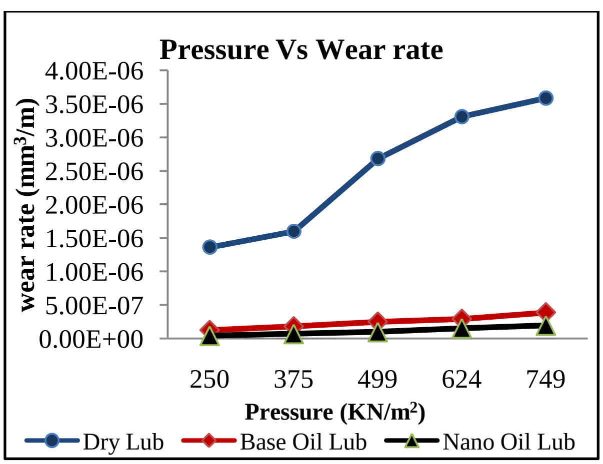

Fig. 2 Wear rate is plotted to various pressure in dry, base oil, nano oil lubrication.

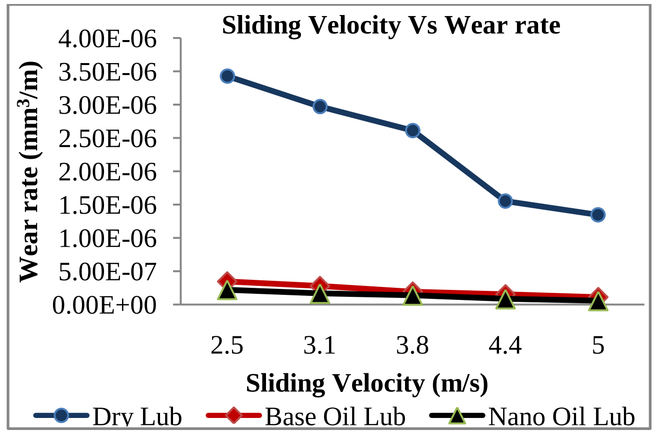

Fig. 3 Wear rate at various lubrication conditions as a function of sliding velocity

The Fig. 4 highlights the relationship between the wear rate and displacements at three lubrications conditions. The wear rate observed in the dry lubrication conditions for 1000m sliding distance is 1.917E-06 mm^3/m and where as it is reduced to 1.458E-07 mm^3/m in oil lubrication conditions. In case of nano oil lubrication, the wear rate observed is 6.25E-08 mm^3/m which confirms that the nano lubrication reduces the wear rate up to 90% while comparing to dry lubrication.

B. Co efficient of friction

Co efficient of friction is the ratio of frictional force to applied force. The coefficient of friction of ZA 27 material is increased as the load increases which is shown in Fig 5. The coefficient of friction measured at dry lubrication condition for a load of 250 kN/m^2 is 0.132518 whereas in oil lubrication state, due to less friction the coefficient of friction is reduced to 0.0255. In nano lubrication condition it is further reduced to 0.0051. The experimental result shows that the coefficient of friction is reduced up to 80% with the nano lubrication while comparing to dry lubrication state.

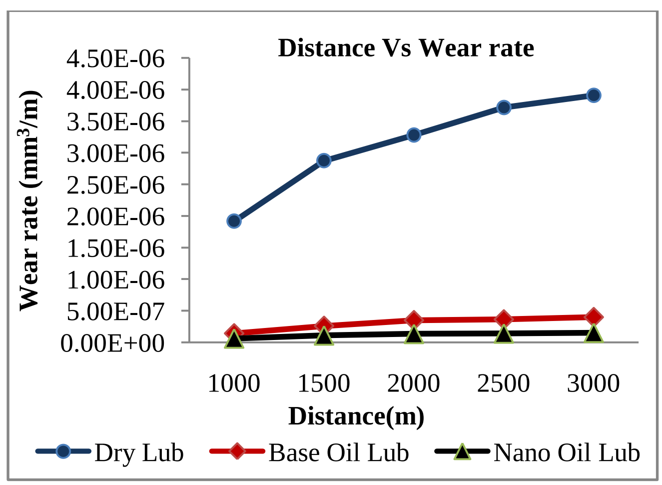

Fig. 4 Wear rate as a function of various distance in dry, base oil, nano oil lubrication.

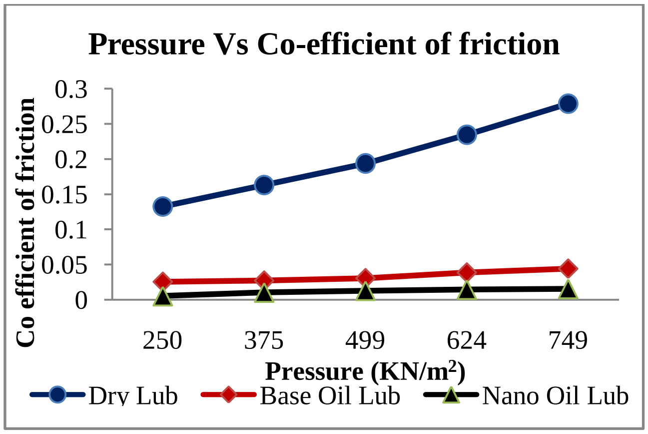

Fig. 5 Co efficient of friction of various lubrication conditions as a function of pressure

The coefficient of friction of ZA 27 for varying sliding velocity is shown in the Fig. 6. When the speed is increasing, the coefficient of friction is decreased. The nano oil supplied is reduces friction between the contact surfaces while compared to other lubrication methods.

The coefficient of friction in dry lubrication for a velocity of 800 m/s is 0.135066 but in case of oil lubrication condition, it is reduced 0.0153 due to reduction in friction. In nano oil lubrication condition, it is further reduced to 0.0051 because of very less contact between disc and specimen.

The effect of variation in sliding distance on coefficient of friction of ZA 27 is shown in Fig. 7. It shows that the coefficient of friction is increased when the distance is increased in both dry, base oil, nano oil lubrication conditions. While comparing all the lubricating conditions, nano lubrication condition gives very less coefficient of friction. When the sliding distance is 1000m, the coefficient of friction in dry lubrication is 0.137615 and in oil lubrication state it is reduced to 0.0102. In case of nano lubrication, it is reduced up to 0.0051which shows the reduction in the friction of more than 75%.

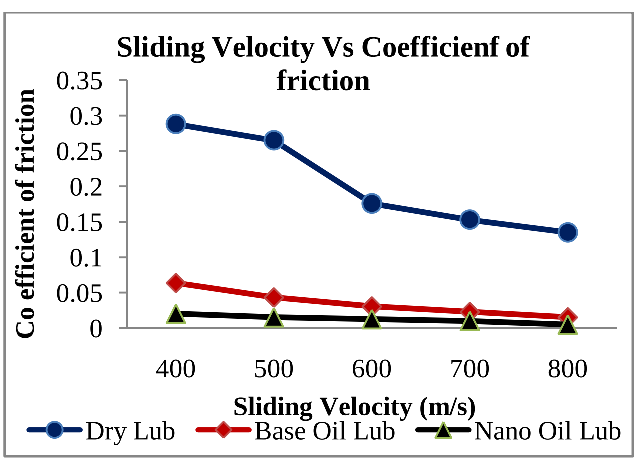

Fig. 6 Co efficient of friction of various lubrication conditions as a function of sliding velocity

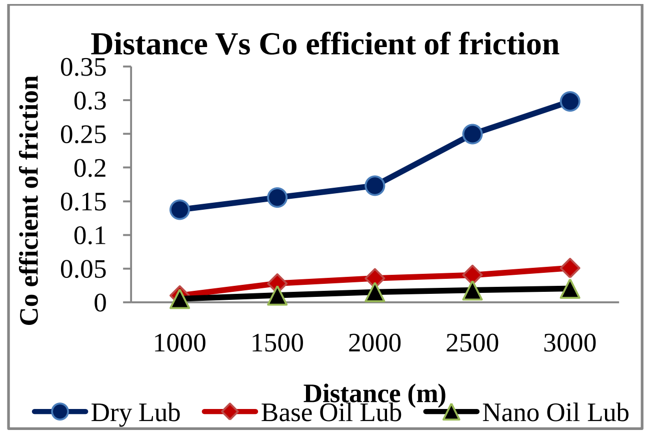

Fig. 7 Co efficient of frictionis plotted by various distances under different lubrication conditions

IV. CONCLUSION

From this experimental work, the wear rate and coefficient of friction of ZA 27 is analyzed at different input conditions. The result shows that the value of wear rate and coefficient of friction is very less in base oil and nano oil lubrication. In dry lubrication the wear rate is high upto 90% when compared to nano lubricating conditions.

In base and nano oil lubrication, the coefficient of friction is reduced up to 80% due to less friction between the contacting surfaces. When comparing the nano oil lubrication and oil lubrication there is very less reduction in co efficient of friction in nano oil lubrication.

From the above results, it is understood that ZA 27 material is most suitable for bearing applications due to very low amount of wear rate and coefficient of friction in dry, base, and nano lubrications.

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