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# DRY SLIDING WEAR PROPERTIES OF ZA-ALLOY CONTAINING TRACES OF IMPURITIES WITH AND WITHOUT HEAT TREATMENT

**Gurunagendra G R [1], Ravikeerthi C[1], Dr. B R Raju[2]**

[1]Associate Professor, Department of Mechanical Engineering, Global Academy of Technology, Bangalore, India
Assistant Professor, Department of Mechanical Engineering, Academy of Technology, Bangalore, India
[2]Professor and Head Department of Automobile Engineering, TOCE Bangalore

## ABSTRACT

ZA-8,ZA-12,ZA-27 are the family of ZA alloys widely used as Low cost Bearing materials in High load and Low speed applications. These alloys with low cost, low energy requirement for shaping, excellent cast ability, and high strength properties are better than some bronze bearing alloys, but they still have restricted application especially due to the deterioration of mechanical and wear resistance properties at temperatures exceeding 100°C. Aluminium is one of the major alloying elements in Zn alloy systems where it imparts fluidity to the alloys. In practice, the amount of Al added to Zn-based alloys in order to attain good engineering properties varies over a wide range. Against this background, the present research work has been undertaken with an objective to explore the potential of ZA alloys as a bearing material and to investigate the effect of alloying elements at room temperature on the Tribological behaviour of the ZA alloy. Zinc and aluminium are low cost bearing materials compared to conventional bearing material and this work is an attempt to find a possible use of such economical materials which might gainfully be employed as low cost, high strength and wear resistant alloys.

***KEYWORDS*:** High load, Low speed, bearing materials

## 1. INTRODUCTION

The group of zinc-aluminium (ZA) alloys was developed in 1970s and became a substitute for brass and cast malleable iron to produce the wear-resistant parts. These alloys with low cost, low energy requirement for shaping, excellent cast ability, and high strength properties are equivalent or better than some standard bronze bearing alloys, but they still have limited application especially due to the deterioration of mechanical and wear resistance properties at temperatures exceeding 100°C. Aluminium is one of the major alloying elements in Zn alloy systems where it imparts fluidity to the alloys. In practice, the amount of Al added to Zn-based alloys in order to

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attain good engineering properties varies over a wide range. The effect of different Al contents (namely 8, 12, 20 and 27) on the microstructure and tensile properties of Zn based alloy has increased strength and wear resistance. Zinc-Aluminium alloys are known to possess excellent bearing properties particularly at high load and low speed. They have found increasing use for many applications and have competed effectively against copper, aluminium and iron-base foundry alloys. However, the elevated temperature (> 100°C) properties of zinc aluminium alloys are unsatisfactory and restrict their use in some applications. One promising approach to improve the elevated temperature properties was reinforcing the alloys with SiCfibers or particles, alumina particles and fibres, glass fibres etc.

All the zinc-aluminium alloys have excellent resistance to corrosion in a variety of environments. However, there has been a lack of specific corrosion data of zinc-aluminium based MMCs and their corrosion resistance to date, because of very limited use of zinc-aluminium alloys as matrix material for MMCs. Most of the commercial work on MMCs has focused on aluminium as the matrix metal. The combination of light weight, environmental resistance and favourable mechanical properties has made aluminium alloys very popular for use as a matrix metal. Aluminium and its alloys have been used as a matrix for a variety of reinforcements: continuous boron, Al2O3, SiC and graphite fibers, various particles, short fibers and whiskers. As a result, advanced metal matrix composites with improved mechanical, physical and tribological characteristics, were obtained. The ZA alloys are suitable for casting by sand, permanent mould, shell mould and high-pressure die casting methods. These alloys exhibit mechanical properties equal to or exceeding those of conventional zinc die casting alloys and those of cast iron, aluminium and copper alloys. In addition, they have excellent bearing properties, wear resistance and machinability. Advantage of cast properties include low melting temperatures and hence low melting energy consumption, increased die life and mould stability. They can be readily cast in thin sections in sand moulds .It is also appreciated that the microstructure of ZA alloys, as it is true for any alloy, is associated with various factors such as compositions of alloy, production techniques adopted etc., and that even a very small change in one of these factors can seriously affect the quality, performance of the material. Hence, this leads to the argument that the field of microstructure, phase formation and wear properties of ZA alloys with different compositions still remains open for investigation for various purposes in industry.

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## 2. EXPERIMENTAL PROCEDURE OF WEAR TEST:

The Alloy was prepared using Liquid Metallurgy route using Pure Zinc (99% pure) and Aluminium (99% pure) using Weight method. Composition as shown in the Table 1.

| Obtained by optical emission spectrum with traces of Impurities. | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Composition | Zn | Al | Sn | Cd | Cu | Fe | Pb | Bi | Mg | Ag | Sb | Si |
| Percentage | 88.480 | 9.8 | 0.094 | 0.007 | 0.01 | 0.600 | 0.032 | 0.08 | 0.236 | 0.008 | 0.264 | 0.353 |

Dry sliding wear tests for different number of specimens was conducted by using a pin-on disc machine (Model: Wear & Friction Monitor TR-20) supplied by DUCOM is shown in Figure 1.

**SPECIFICATIONS**

**APPARATUS** : TRIBOMETER (DUCOM PVT LTDBANGALORE)

**DISC ROTATION SPEED** : 200-2000 RPM

**SLIDING SPEED** : 0.5-10 M/S

**TRACK DIAMETER** : 50-100 MM

**WEAR RANGE** : 1-2000 µ

**LOAD** : 5-200 N

**POWER** : 2KVA, 230V

**SPECIMEN STANDARD** : ASTM G99

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Figure 1: Pin on Disc Machine

The pin was held against the counter face of a rotating disc (EN31 steel disc) with wear track diameter 100 mm. The pin was loaded against the disc through a dead weight loading system. The wear test for all specimens was conducted under the normal loads of 1kg, 2kg and a sliding velocity of 2 and 4 m/s.

Wear tests were carried out for a total sliding distance of approximately 1250 m under similar conditions as discussed above. The pin samples were 30 mm in length and 6 mm in diameter. The surfaces of the pin samples were slides using emery paper (80 grit size) prior to test in order to ensure effective contact of fresh and flat surface with the steel disc. The samples and wear track were cleaned with acetone and weighed (up to an accuracy of 0.0001 gm using microbalance) prior to and after each test. The wear rate was calculated from the height loss technique and expressed in terms of wear volume loss per unit sliding distance.

In this experiment, the test was conducted with the following

Parameters:

- Load
- Speed
- Distance

In the present experiment the parameters such as speed, time and load are kept constant throughout for all the experiments. These parameters are given in Table.

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Table 2: Parameter taken constant during sliding wear test

| | |
|---|---|
| Pin material | ZA-alloy |
| Disc material | EN 31 steel |
| Pin dimension | Cylinder with diameter 6 mm height 30 mm |
| Sliding speed (rpm) | 400 |
| Normal load (kg) | 1, 2, 3 |
| Sliding distance (m) | 1250 |

## 3. PIN-ON-DISC TEST

In this study, Pin-on-Disc testing method was used for tribological characterization. The test procedure is as follows:

- Initially, pin surface was made flat such that it will support the load over its entire cross-section called first stage. This was achieved by the surfaces of the pin sample ground using emery paper (80 grit size) prior to testing
- Run-in-wear was performed in the next stage/ second stage. This stage avoids initial turbulent period associated with friction and wear curves
- Final stage/ third stage is the actual testing called constant/ steady state wear. This stage is the dynamic competition between material transfer processes (transfer of material from pin onto the disc and formation of wear debris and their subsequent removal). Before the test, both the pin and disc were cleaned with ethanol soaked cotton (Surappa et al 2007)

Before the start of each experiment, precautionary steps were taken to make sure that the load was applied in normal direction. Figure represents a schematic view of Pin-on-Disc setup.

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Table 3: Process parameters and levels

| Sl no. | Load (N) | Sliding Speed, S (rpm) | Sliding Distance, D (m) |
|---|---|---|---|
| 1 | 10 | 400 | 1250 |
| 2 | 20 | 400 | 1250 |
| 3 | 30 | 400 | 1250 |

**WEAR TEST**

Dry sliding wear tests for the ZA have been conducted using pin-on-disc Tribometer(m/s Ducom Bengaluru). The test have been conducted in air. Wear test have been conducted using cylindrical sample (ϕ12mm*30mm) that had flat surface in contact region and the rounded corner. The pin is held stationary against counterface of 100mm diameter rotating disc made of En-32 steel having HRC65.

The wear test have been conducted under three normal loads 1kg, 2kg, 3kg and at fixed sliding speed of 2.094m/s. Each wear test have been carried out for the sliding distance of 1.8km. Tangential force has been monitored continuously. Height was is measured from graph using slope and converted to volume loss data and wear rate is determined.

## 4. WEAR CALCULATION

1. Area, Cross sectional Area=$A = \frac{\pi d^2}{4}$
2. Volume loss,
Volume loss = Cross sectional Area x Height loss
3. Wear rate
Wear rate = Volume loss / Sliding distance
4. Wear resistance,
Wear resistance = 1/ Wear rate
5. Specific wear rate,

Specific wear rate = Wear rate/load

**Table 4:** Wear rate Results at as Cast condition

| Sl No | Load | | Height Loss | | | Time | Distance covered | Wear Rate | Friction Force | Coefficient of Friction |
|---|---|---|---|---|---|---|---|---|---|---|
| | Kg | N | $H_1$ µm | $H_2$ µm | $H_1$-H2 µm | Sec | m | (mm³/m) $\times 10^{-3}$ | N | |
| 1 | 1 | 10 | 53.5 | 49.7 | 3.85 | 50 | 104.71 | 1.03 | 2.98 | 0.298 |
| 2 | 2 | 20 | 51.08 | 38.26 | 12.82 | 50 | 104.71 | 3.46 | 10.1 | 0.505 |
| 3 | 3 | 30 | 88.44 | 77.95 | 10.49 | 50 | 104.71 | 2.83 | 14.27 | 0.475 |

| Load(N) | Wear resistance (m /mm³) |
|---|---|
| 10 | 970.87 |
| 20 | 288.91 |
| 30 | 353.09 |

| Load(N) | Specific wear rate $\times 10^{-4}$ mm³/ N m |
|---|---|
| 10 | 1.03 |
| 20 | 1.73 |
| 30 | 0.943 |

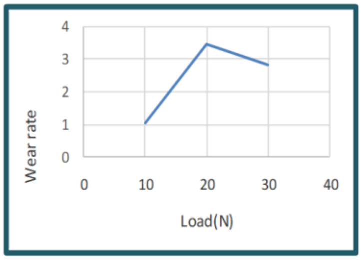


Figure 1: Load vs Wear Rate

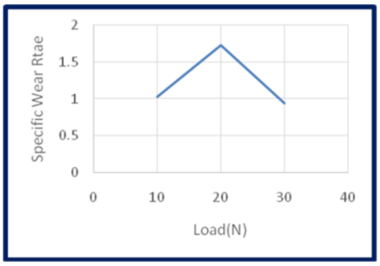


Figure 2: Load vs Specific Wear rate

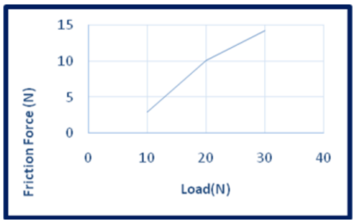


Figure 3: Load vs Friction Force

**Table 5:** Wear rate Results after Heat Treatment

| Sl No | Load | | Height Loss | | | Time | Distance covered | Wear Rate | Friction Force | Coefficient of Friction |
|---|---|---|---|---|---|---|---|---|---|---|
| | Kg | N | $H_1$ µm | $H_2$ µm | $H_1$-$H_2$ µm | Sec | m | (mm³/m) $\times 10^{-3}$ | N | |
| 1 | 1 | 10 | 44.78 | 42.22 | 2.56 | 50 | 104.71 | 0.691 | 4.72 | 0.21 |
| 2 | 2 | 20 | 58.96 | 43.92 | 15.04 | 50 | 104.71 | 4.06 | 8.71 | 0.22 |
| 3 | 3 | 30 | 93.85 | 70.52 | 23.33 | 50 | 104.71 | 6.29 | 13.62 | 0.22 |
| | | | | | | | | | | |

| Load | Wear resistance (m /mm³) |
|---|---|
| 1 | 1447.17 |
| 2 | 246.3 |
| 3 | 158.98 |

| Load | Specific Wear rate $\times 10^{-4}$(mm³/Kg-m) |
|---|---|
| 1 | 0.691 |
| 2 | 2.03 |
| 3 | 2.09 |

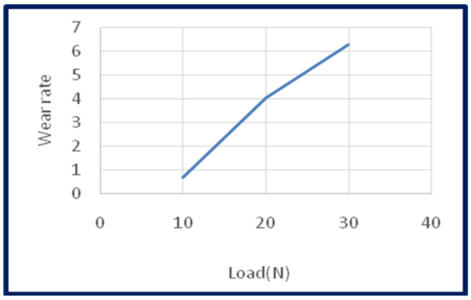

Figure 1: Load vs Wear Rate

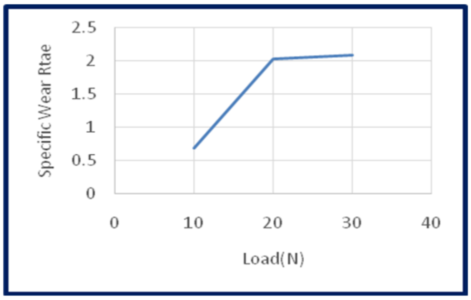

Figure 2: Load vs Specific Wear rate

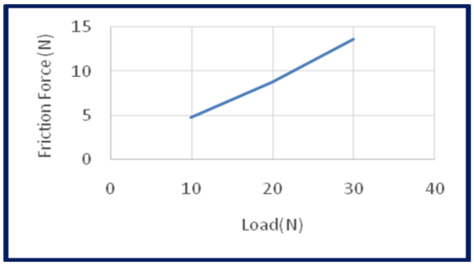

Figure 3: Load vs Friction Force

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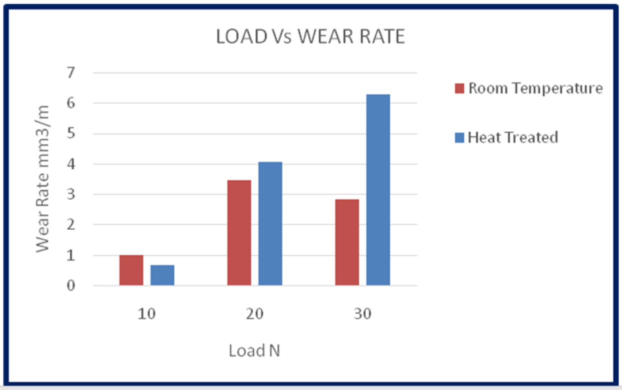
**COMPARISON CHART:**




## 5. CONCLUSION

ZA alloy is a competitive Bearing alloy that shows improvement in both Mechanical and Tribological properties compared with phosphor bronze, SAE 660 alloy and Cast Iron. As a First step towards developing a new material for the tribological applications for component used in various industrial applications.

Finally, at the end of completing the dry sliding wear test on the developed Low Aluminium and High Zinc alloy (ZA) there is a very low wear rate observed for heat treated alloy when compared to room temperature for Normal load of 10N, but wear rate increases at higher loaded for heat treated alloy.

There is more scope for further research by changing the process of fabrication of alloy and also Reinforcing with hard phase Reinforcements like Sic, $Al_2 0_3$, graphite, $MoS_2$etc.

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