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Study on Tribological Behavior of ZA-27/Al_2O_3/Gr MMC

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ABSTRACT: The present study reveals the wear behavior of Zinc-Aluminium (ZA-27) alloy reinforced with Alumina (Al_2O_3) with graphite (Gr) particulate metal matrix composite. The composite is prepared using liquid metallurgy Technique. The pin-on disc wear test was employed to study the wear behavior of the ZA-27 alloy based composite. The sliding wear test is conducted for different normal load, sliding speed and sliding distance. The wear behavior was studied as function of mass loss. The microstructure was studied through optical image for determining the distribution of particles in MMC. The worn surface analysis was carried out in order to understand wear mechanism using optical image microscopy. The microstructure indicates that, nearly uniform distribution of particles was achieved through stir casting technique for fabrication of MMCs. The wear result reveals that mass loss of composite and alloy increased with the increase in wear parameters. It was found that the Al_2O_3 plays a vital role in determining the wear behavior of material. The worn surface reveals that, at lower percentage of Al_2O_3, the smeared layer was observed revealing the formation of tribo film due to presence of graphite. While at higher percentage (9%) of Al_2O_3 clustered Gr particles are observed instead of smeared surface layer, may be due to the fact that Al_2O_3 particles might have pulled out through ploughing mechanism and caused transition of dry sliding wear to three body abrasive wear mechanism.

Keywords: Composites; Al_2O_3 particles; Dry sliding wear; Microstructure; ZA-27 alloy;

I. INTRODUCTION

Wear can be defined as a process where interaction between two surfaces or bounding faces of solids within the working environment results in dimensional loss of one solid, with or without any actual decoupling and loss of material. Sliding wear is one of the most commonly observed phenomenon in many engineering applications. Nowadays, metal matrix composites (MMCs) are extensively used in such tribological applications due to their better mechanical and tribological properties compared to their parent alloy.

Zinc- Aluminium (ZA) based cast alloys are widely used in industrial applications due to their excellent castability, wear resistance and good mechanical properties. Some of the popular members of ZA alloy family are ZA-8, ZA-12, ZA-27. Zinc–aluminum alloys (ZA alloys) are occupying attention of both researchers and industries, as a promising material for tribological applications. Commercially available ZA alloys (especially ZA-27) have become the alternative material, primarily for aluminum cast alloys and bearing bronzes, due to good castability and unique combination of properties [1].

Babic *et. al.* [2] demonstrated that Zinc–aluminum (ZA) alloys are important bearing materials, especially suitable for high-load and low-speed applications. Due to good tribomechanical properties, low weight, excellent foundry cast ability and fluidity, good machining properties, high as-cast strength and hardness, corrosion resistance, low initial cost, energy-saving melting, environmental friendly technology and equivalent or even superior bearing and wear properties, the ZA alloys (mostly ZA-12 and ZA-27) are capable of replacing aluminum cast alloys and bearing bronzes. Ranganath *et. al.* [3] studied that ZA-27 is the high strength performer of the zinc alloys originally developed as a high strength gravity casting alloy and was suitable for thin wall die casting. It is also the lightest alloy and offers excellent bearing and wear resistance properties. Its friction and wear characteristics can compare to the standard bearing material of industrial SAE660 lead-tin bronze.

Marigoudar and Sadashivappa [4] have observed that the ZA-27 based MMCs possess excellent mechanical and tribological properties and are considered as potential engineering materials for various tribological applications.

Further, the increased percentage of reinforcements contributed in increased hardness and density of the composites. Sharma [5] stated that modulus of elasticity and ultimate tensile strength of the ZA based MMCs gradually increased with increasing volume fraction of the fiber, although the ductility decreased with an increase in volume fraction of the fibers. Sharma *et al.* [6] investigated the tribological effect of silicon carbide (SiC) reinforcement on the unlubricated sliding wear behavior of ZA-27 alloy. The authors have revealed that the composites exhibited a lower wear rate compared to the unreinforced alloy specimens in conditions of dry sliding.

Kumar *et. al.* [7] concluded that garnet particle reinforcement has significantly reduced the material loss due to sliding wear of ZA-27 composites. Further, friction coefficient of zinc-aluminium alloy metal matrix composite decreased with increase in percentage of reinforcement.

Kiran *et. al.* [8] has studied the dry sliding wear behavior of as-cast and heat-treated zinc-aluminum (ZA-27) alloy, reinforced with silicon carbide and graphite particles. They have found that wear resistance was significantly improved with heat treatment of samples and composites exhibited better wear resistance compared to base alloy.

The literature survey reveals that, ZA-27 is of prime importance and studied by various researchers. However, influence of Al_2O_3 particulate reinforcement on ZA-27 hybrid metal matrix composites is less studied. Hence, an attempt has been made in the current study to investigate the wear behaviour of Al_2O_3/Gr/ZA-27 composites.

II. MATERIAL AND EXPERIMENTATION

Materials. In the present study, ZA-27 alloy is used as matrix material. The chemical composition is indicated in Table 1. The alumina (Al2O3) particles of 400 mesh size and graphite (Gr) powder are used as the reinforcement material. The composites were prepared through vortex stir casting technique. The details of samples prepared is shown in Table 2. The alumina percentage was varied in the composites prepared from 0 to 9%. While 3% constant amount of graphite was added to composite to impart self-lubricating behavior to it.

Table 1: Composition of ZA-27 alloy.

Composition	Al	Cu	Fe	Mg	Pb	Cd	Zn	Sn
Wt.%	25-28	2.0-2.5	0.075 max	0.01-0.02	0.006 max	0.006 max	bal	0.003 max

Table 2: Shows the ZA-27 Composites Specimen details.

ZA-27 weight %	Al_2O_3 weight %	Gr weight %
100	----	----
94	3	3
91	6	3
88	9	3

Dry sliding wear test. The dry sliding wear test was conducted according ASTM G99 standard using pin-on-disc set up. The specimen is rubbed against rotating hard steel disc without any lubricant. The studied parameters are applied load, sliding distance and sliding velocity. The velocity was varied from 1m/s to 5m/s, load is varied between 10N to 50N and sliding distance was varied from 200m to 1000m. Before and after testing, the specimen is cleaned using acetone and weighed using electronic mass balance having sensitivity of 0.1mg. The difference in mass was recorded as mass loss due to wear. Tests are conducted at normal room temperature. The principal objective of investigation was to study the effect of variation of normal load, sliding velocity and percentage Al_2O_3 on wear behavior.

III. RESULTS AND DISCUSSION

A. Microstructure

The optical microstructures of die-cast ZA-27 alloy and ZA-27/Al_2O_3/Gr with 0%, 3%, 6% and 9% Al_2O_3 and 3% Gr as constant reinforcement are shown in Fig. 1(a), 1(b), 1(c) and 1(d). Optical microscopy investigations illustrated that the aluminium oxide particle remained well bonded to the matrix despite the high residual thermal stresses induced by the large thermal expansion coefficient mismatch between the two phases, and a uniform distribution of the reinforcement phase exists.

Microstructures play an important role in the overall performance of the alloys as well as composites. As a result, there were large clusters of aluminium oxide within some areas of the matrix while other areas were entirely aluminium oxide depleted. The segregation was more pronounced in the 9% Al_2O_3 composites.

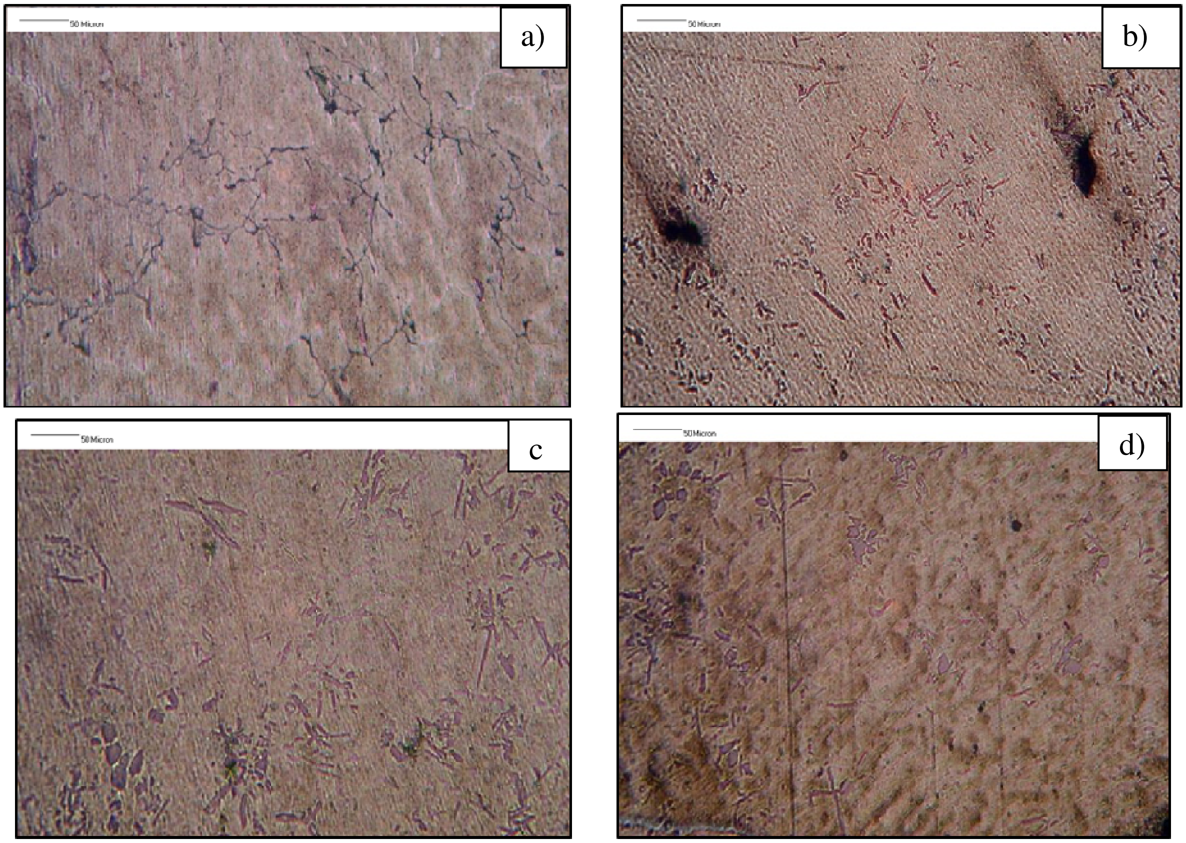


Fig. 1. Optical micrograph images of microstructure of (a) pure alloy (b)ZA27/3%Al_2O_3/3%Gr, (c) ZA27/6%Al_2O_3/3%Gr and (d) ZA27/9%Al_2O_3/3%Gr composites at 200X magnification.

B. Effect of Normal Load

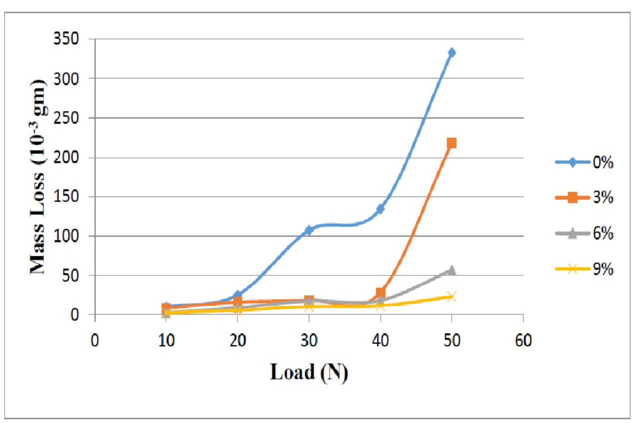


Fig. 2. Variation of mass loss with applied load.

The effect of applied normal load on the MMC with different Al_2O_3 reinforcement percentage and constant graphite percentage of 3% is shown in Fig. 2. In this study, for constant speed of 3 m/s and constant distance of 600m, load is increased in steps of 10N. The test is conducted for normal loads of 10, 20, 30, 40 and 50N. It is observed that wear of the composite specimen decreases with increase in Al2O3 percentage. Further, as the load is increased, the increase in wear is observed revealing the transition of mild wear to severe wear.

However the transition was more pronounced in alloy compared to composites. Perhaps the increase in reinforcement has resulted in the increased hardness and causes the surface barrier for the penetration of hard asperities into the surface. The minimum wear loss was observed for ZA27/9%Al_2O_3/3%Gr reinforcement compared to other materials studied at all different loads considered in the study.

C. Effect of Sliding Speed

The figure 3 depicts the effect of sliding speed on wear behavior of ZA-27 MMC. It is studied as a function of variation in speed from 1m/s to 5m/s in steps of 1m/s at constant load of 30N and constant sliding distance of 600m. The increase in speed has lead to the increase in wear loss of all composites. It can be observed that the wear loss increased gradually with the increase in speed from 1-3 m/s, further rapid increase in the wear loss was exhibited for increase in speed from 3-5 m/s. Perhaps, at low speed the formation of tribo layer has occurred due to the presence of graphite and decreased the wear loss in composites and prolonged till 4 m/s, while in increased wear loss was observed at 3m/s in pure alloy. However, at high speed the tribo layer might have broken, thus the rapid wear loss was the resulted.

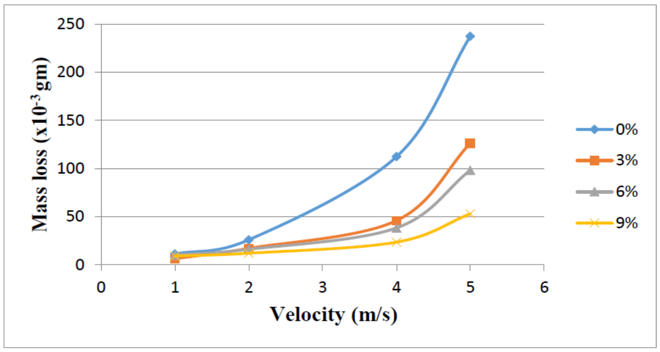


Fig. 3. Variation of mass loss with increasing sliding velocity.

D. Effect of Sliding Distance

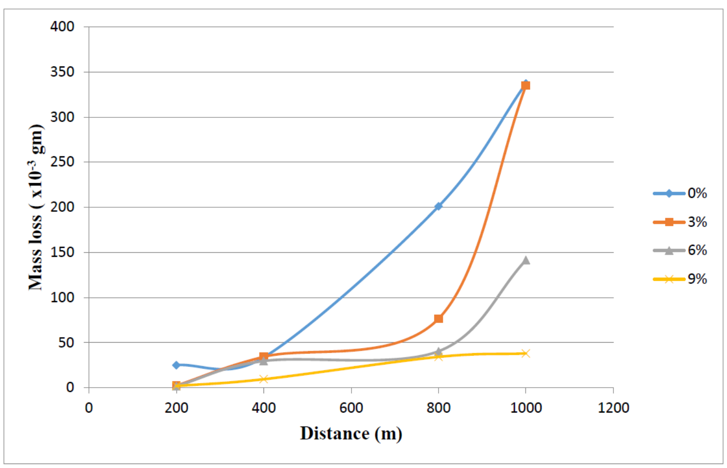


Fig. 4. Variation of mass loss with increasing sliding distance.

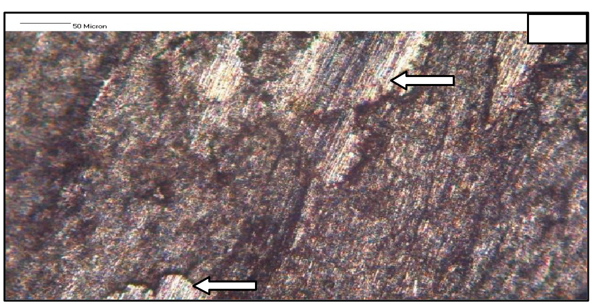
The effect of sliding distance on the wear behavior of MMC with different Al2O3 reinforcement percentage and constant graphite of 3% is shown in Fig. 4. In the current study, for constant speed of 3 m/s, constant load at 30N, the wear behavior was studied as a function of mass loss with variation in sliding distance from 200-1000m in steps of 200m. The mass loss due to wear was increased with the increase in sliding distance and decreased with increase in Al2O3 percentage. It may be due to the fact that increased sliding distance increases the interaction of pin and disc. In dry sliding mechanism the interaction of asperities of two sliding surfaces plays a vital role in governing the wear of material. Increased sliding distance would result in the increased interaction of asperities also. Thus, rubbing of counter parts also increases leading to increased removal of material. Furthermore, the increased Al2O3% has increased the hardness in hybrid MMC's, while the presence of graphite might have caused the mechanically mixed layer (MML) occurrence which possess relatively higher hardness than bulk composite.

Thus, the formation of work hardened layer between pin and the disc reduced the wear in the composites compared to pure alloy.

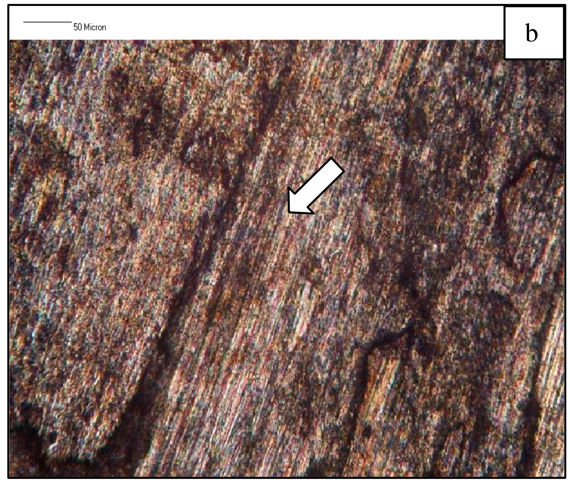
E. Worn Surface Analysis

The worn surface micrographs are shown in the figure 5. The micrographs of the specimen tested at load of 30 N, sliding distance of 600m and sliding speed of 3m/s. Figure 5(a), 5(b), 5(c), and 5(d) are worn surfaces of pure matrix and 3% Gr with 3%, 6% and 9% Al2O3 incorporated composites respectively. From the figure it can be illustrated that there was a severe delamination with large plastic deformation was observed in unreinforced alloy. While in case of the composites presence of grooves and craters can be observed due to the removal of particulates from the surface. The smeared surface layer can be observed in the composite, which reveals the existence of thin tribo film layer during the sliding action. Hence, it can be interfered that the presence of graphite has contributed towards enhancing the wear resistance of material. However, in 9% Al2O3 incorporated composites the graphite particles are broken and sprawled over the surface. This may be due to the fact that increased Al2O3 percentage has been more pronounced and contributed relatively greater extent compared to other composites.

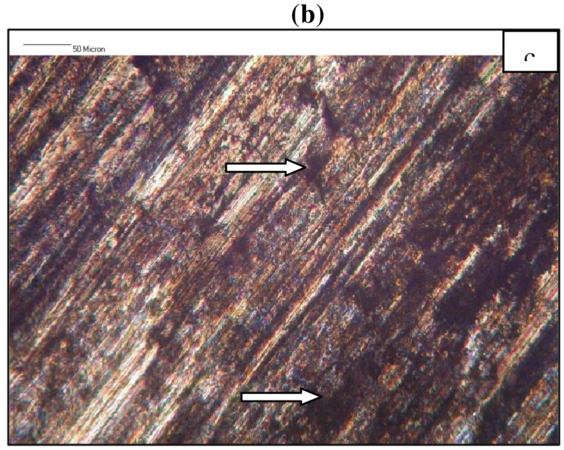
In 9% Al2O3 incorporated composite specimen, clustered Gr particles are observed instead of smeared surface layer. It may be due to the fact that the Al2O3 particles might have pulled out through ploughing mechanism and entrapped between the pin and disc resulting in the transition of dry sliding wear to three body abrasive wear mechanism. The graphite particles which are softer has been worn out easily without allowing the formation of tribo film. Hence, graphite particles are observed clearly in Fig. 5(d) compared to other specimen. Further, the increased wear resistance of higher percentage Al2O3 composite is due to the hard filler than the existence of graphite. Thus it can be conclude that the graphite addition is more lucrative when hard filler percen0tage is lower in hybrid MMC's.



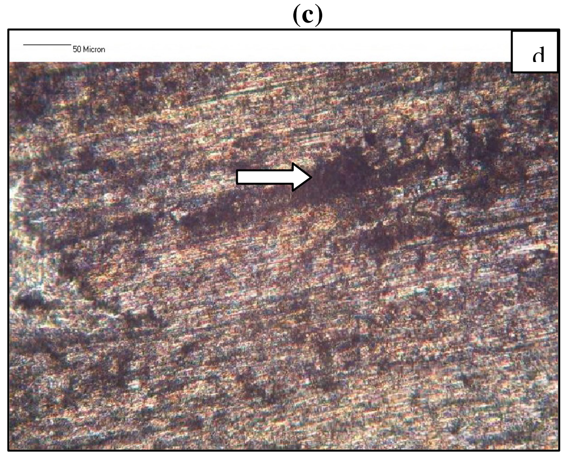
(a)



(b)



(c)



(d)

Fig. 5. Optical micrograph images of worn surface of (a) pure alloy (b) ZA27/3%Al_2O_3/3%Gr, (c) ZA27/6%Al_2O_3/3%Gr and (d) ZA27/9%Al_2O_3/3%Gr composites at 200X magnification.

IV. CONCLUSIONS

In the present study the sliding wear behavior of Aluminium hybrid MMC has been stated. Based on the obtained results the following conclusions were drawn:

- The particulate reinforcement plays a vital role in improving the wear resistance of MMC. The increase in the hard particulate reinforcement (Al_2O_3) exhibited a drastic improvement in the wear resistance.
- The highest wear resistance was found to be for the hybrid MMC with combination with 9% Al_2O_3 and 3% Graphite.
- The increase in the load has significantly influenced on the weight loss of the material. The severe wear was found to be for Aluminium alloy at 50N
- The increase in the distance has resulted in the increased wear loss.
- The worn surface analysis demonstrates that, at lower percentage of Al_2O_3, the smeared layer was observed revealing the formation of tribo film due to presence of graphite.
- While at higher percentage (9%) of Al_2O_3 clustered Gr particles are observed instead of smeared surface layer, may be due to the fact that Al_2O_3 particles might have pulled out through ploughing mechanism and caused transition of dry sliding wear to three body abrasive wear mechanism.

REFERENCES

[1]. J. P. Pandey, B. K. Prasad, Yegneswaran, "Effects of Al_2O_3 particle reinforcement on the lubricated sliding wear behavior of ZA-27 alloy composites", material science, 1998, **36**, 1121-1129.

[2]. M. Babic, M. Slobodan, D. Dzunic, B. Jeremic, and B. Ilija, "Tribological Behavior of Composites Based on ZA-27 Alloy Reinforced with Graphite Particles", *Tribology Letters*, 2010, **32,** 401-410.

[3]. G. Ranganath, S. C. Sharma, M. Krishna, and M. S. Muruli, "A Study of Mechanical Properties and Fractography of ZA-27/Titanium-Dioxide Metal Matrix Composites," Journal of Materials Engineering and Performance, 2002, 11, 408-413.

[4]. R. N. Marigoudar and K. Sadashivappa, "Dry Sliding Wear Behaviour of SiC Particles Reinforced Zinc-Aluminium (ZA43) Alloy Metal Matrix Composites", Journal of Minerals & Materials Characterization, 2011, **10**, 419-425.

[5]. S.C. Sharma "Elastic Properties of Short Glass Fiber-Reinforced ZA-27 Alloy Metal Matrix Composites", sliding wear, 1999, **10**, 468–474.

[6]. S. C. Sharma, G. Ranganath, M. Krishna, "Dry sliding wear of garnet reinforced zinc/aluminium metal matrix composites", Wear, 2001, 251, 1408 – 1413.

[7]. M. P. Kumar, K. sadashivappa, G. P. Prabhukumar, and S. Basavarajappa, "Dry Sliding Wear Behaviour of Garnet Particles Reinforced Zinc-Aluminium Alloy Metal Matrix Composites", Materials Science, 2006, **12**, 209-213.

[8]. T. Kiran, M. Prasannakumar, S. Basavarajappa, B. Viswanatha, "Effect of heat treatment on tribological behavior of zinc aluminum alloy reinforced with graphite and SIC particles for journal bearing", *Industrial Lubrication and Tribology*. **67** (2015) 292–300.