A Review on Processing, Characterization and Erosion Wear Response of Filled Metal Alloy Composites

Anurag Shrivastava[1], Rajiv R Lal[2], Brijesh Gangil[3]
[1]SR Group of Institute, Lucknow, (U.P.) India.
[2]Rabindranath Tagore University, Bhopal (M.P.) India.
[3]Associate Professor, NIT, Pauri Garhwal (Uttarakhand) India.

ABSTRACT

Metal matrix composites they were mainly included in structural engineering components where only a typical failure mode becomes solid particle erosion. That research throughout this article focuses also on manufacturing and classification of silicon carbide (SiC) reinforced metal matrix compounds (MMCs) at various weight percentages ranging from 0 to 9 percent by weight in phase 3. Also reported the% of each and their response to erosion wear of the solid particles. A simple and widely used liquid metallurgy technique called stir casting technique is used to produce these composite materials. The erosion tests are carried out according to the experimental design based on the Taguchi L16 orthogonal matrix. It describes the primarily important factors that control that wear rate. The findings suggest how this compound's erosion wear rate was most determined than other influences even by impact rate and fill material, meanwhile. This also illustrates the strong filling properties of both the SiC particles because as wear rate declines throughout the matrix material with increasing filler content.

I INTRODUCTION

Metal matrix composites they has several advantages over monolithic metals, such as for a higher specific module, significantly higher weight, improved elevated temperature properties, and even a lower thermal expansion coefficient. Because of certain properties, for even a large variety of uses, viz., metal matrix composites are considered. Nozzle chamber combustion (in rockets, space shuttles), housings, pipes, cables, heat exchangers, structural elements, etc. Metal matrix composites (MMCs) Thanks to a combination of superior mechanical properties, including such strengthened elastic modulus, tensile strength, high temperature stability or wear resistance relative to master matrix alloys, they also increasingly became candidates of vital structural applications.. Designers benefit from MMCs as they would be especially ideal for mobile that need good tolerance to high temperatures, good structural rigidity, dimensional flexibility but light weight. The new trend is really for the healthy the use MMC components in car engines that mainly work in high pressure and temperature conditions. [1]. The increasing demand towards lightweight, rigid but solid materials having contributed to the growth of ceramic dispersion reinforced MMC. This MMCs have exceptional mechanical characteristics and thus are deemed possible engineering components of different wear-related applications. Several researchers experimented upon this MMC sliding wear system reinforced particles such as SiC, Al_2O_3 which garnet particles, etc., but instead found an increase in resistance to wear including abrasion [2]. Zinc casting alloys are advanced materials that really are flexible. The combination of strength, durability, rigidity, bearing efficiency but economical casting capability is not provided by any other alloy method. Due to its excellent bearing but wear properties, lower casting temperatures but lower costs [3], zinc alloys become critical matrix materials. Zinc-aluminum (ZA) alloys containing a limited quantity of copper has proved to have been expense but energy-efficient replacements for such a number with ferrous and non-ferrous alloys because of the higher strength, improved wear resistance, [4]. ZA alloys become appropriate bearing materials, perfectly appropriate with applications with high loads with low speeds [5]. Thanks towards good tribomechanical properties, low weight, significant and positive effect to melt and flow, good processing characteristics, high strength characteristics including such castings, good corrosion resistance, low initial cost, casting energy saving, ZA alloys (mainly ZA-12 and ZA-27) are likely to substitute cast aluminium alloys and bearing bronzes [5] with environmentally safe technology including properties with equal or perhaps even greater bearing but wear. That cost savings of 25 percent to 50 percent to 40 percent to 75 percent, relative to aluminium and brass alloys, overall, is really a significant thing that determines these alloys desirable. [6]. That being said, some lower compressive strength at elevated temperatures and dimensional instability near temperatures beyond 100 C [3,4] are the key drawbacks of the alloy device. The strong strength of these alloys is Alloy ZA-27, and corresponds to both the ZA alloy family, that is used as a substitute for bronze bearings in bearing which bushing implementations. [7,8] Because of its lower cost with equal or higher efficiency. It's indeed incredibly common throughout the markets for bearings, wear-resistant parts, valves, pulleys and pulleys, throughout addition to using it with thin-walled casts and also in components like electrical, automotive or industry and agriculture machinery. [9]. Stir casting becomes widely agreed as both an especially promising route[10] among the variety of production processes available with MMC batches. The benefits are its convenience, versatility and applicability to something like a vast amount of manufacturing and this is also the cheapest of all MMC routes available.. [10]. Throughout this technique, these are shook vigorously to shape a swirl on the surface of both the melt because after matrix material was already melted, and then the reinforcement material is applied to the side of the swirl. These are noted that throughout stirring, the formation of the vortex becomes useful and for movement of particles to both the molten matrix, because the change in temperature here between melt's inner and outer surface sucks the ions into liquid [11]. No consideration has been paid to the tribological traits of Zn-based CMMs. Researchers working on specific Zn-Al strengthened alloys [12, 13] recently confirmed that now the addition of reinforcing particles greatly increases the abrasive, slipping wear resistance. In general, the development of major ceramic particles including such SiC, Al2O3, tends to increase the resistance to corrosion (two bodies including three bodies) and MMC erosion corrosion dependent on either a matrix of ZA alloys. Throughout the manufacturing, automobile and defence industries, CMMs are commonly used. Carbide tips containing hard tungsten carbide particles throughout are often constructed from the tough cobalt matrix. Any tank fittings may even be constructed of composite metal matrix components, likely reinforced steel with boron nitride. MMC can be used for some vehicle disc braking. And for its high basic thermal but thermal conductivity, modern high-performance sports cars, like those manufactured through Porsche, utilize carbon fibre rotors inside a silicon carbide matrix. Ford gives technical improvement to both the composite driveshaft metal matrix. The MMC driveshaft comprises of the aluminum mould reinforced with boron carbide that helps the driveshaft's critical speed to still be improved through reducing inertia. In many of its engines, Honda has been using aluminum matrix composite cylinder liners, along with the B21A1, H22A and H23A, F20C but instead F22C, and the C32B used in the NSX. And since, Toyota has been using metal matrix compounds, such as the Toyota Matrix of the very same name, and in Yamaha-designed 2ZZ-GE engine which is used in later iterations of the Lotus Elise S2, as well as in Toyota car models. In the Boxster and 911, Porsche often employs MMC to improve the engine's cylinder liners. And for structural portion of both the aircraft's landing gear, the F-16 Fighting Falcon uses monofilament silicon carbide fibres in either a titanium matrix. Wear are characterized when damage to something like a solid surface that, despite the relative movement here between surface one and or maybe more substances throughout contact, typically implies a progressive loss between materials. [14]. That is a material reaction to external stimuli which could in essence be mechanical or chemical. The influence of wear mostly on durability of industrial products becomes widely known and also the cost of wear has indeed been identified as being very high. While wear was already clinically analysed thoroughly, wear problems in industrial applications continue. Currently, which shows the difficulty of both the phenomenon with usury [15]. In most plants and equipment, wear is really a typical phenomenon and is always a phase that's also gradual but progressive [2]. Among the most noticeable phenomenon of wear is erosion. These are attributed to the effect of contaminants on the surface of materials deposited in a current of gas or liquid. This one in essence, in several manufacturing applications, limits their life of both the mechanical components included. Based on erosion forms including damage processes, there are many various groups of erosion wear, including such pulp erosion, strong particle erosion, liquid affect erosion, including cavitation erosion. [16]. Strong Particle Erosion (SPE) is a mechanism of atmospheric deterioration wherein the substances interfere with the surface and facilitate the loss of material. A particle holds momentum and kinetic energy throughout travel, that will dissipate attributable to it's own collision with the a target surface through contact. [17]. SPE is indeed a useful phenomena in the some situations, including such blasting but abrasive high-speed water jet cutting, but in other infrastructure processes, namely steam & jet engines, pipes and valves who hold particulate matter and valves, that is a significant issue fluidized bed combustion systems (FBC) [18]. For all of this cause, this article examines that impact of the implementation and quality of silicon carbide (SiC) particles on the ZA-27 alloy's erosion resistance potential. The effect of further only one parameter over erosion wear of SiC-filled ZA-27 alloy metal matrix compounds has been experimentally explored and in experimental portion of this research. In order to research the influence of different operating parameters [19], an easy-to-use and therefore less time-consuming experimental programme suggested by Taguchi was implemented. This experimental design suggested through Taguchi having subsequently been gradually added to a large range of MMCs in order to evaluate the parametric evaluation throughout the friction method. [20-27]. ASTM chemical composition of the alloy: The B86-13 ingot configuration is seen in Table 1. Throughout this group of zinc-aluminum alloys, ZA-27 is the lightest alloy and thus has greater wear resistance property. Therefore, The whole material is commonly used for the bearings and is now used in many automobile components including such "clutches, brake rotor, connecting rods, exhaust valves," etc. due to it's own light weight, increasing vehicle fuel economy. This material might be used for power lines as a lightweight heart. Filling material. Filling materials are generally discontinuous, stronger and harder than matrix materials. Improving electrical, mechanical or tribological properties seems to be the primary purpose of all these filling materials. About either the compound. Silicon carbide is often used as either a filler substance composed of silicon tetrahedra but atoms of carbon through solid crystal lattice bonds. Which creates a substance that would be very hard and solid. Low density, high strength and high strength are also the main properties, Thermal expansion is low, thermal conductivity is high , hardness is high. SiC forms at 1200 °C a protective film of silicon oxide and in air which can be used up to 1600 °C. That high temperature due to low thermal expansion and high resistance makes these material outstanding thermal shock resistance characteristics. Some typical uses of silicon carbide are in stationary and mobile turbine components, gaskets, bearings, heat exchangers, etc. 2.3. Composite fabrication in this process, And use the muffle furnace, the melting of both the matrix alloy ZA-27 becomes done independently at around 800 C, beyond its melting point. The total amount of filler particles (0, 3, 6 and 9 percent by weight) preheated from around 400 C after melting, are added to Ta

Table 1
Chemical composition of ZA-27 alloy. Materials

Material	Al	Cu	Mg	Zinc
Wt%	25-28	2-25	0.01-0.02	Balanced

But use an electric stirrer, the molten metal is constantly stirred. In order to guarantee a uniform mixing of filler particles and in matrix material, the stirrer becomes rotated at a speed of 450 rpm for 2-3 minutes. In order to improve wett ability throughout stirring, There are minimal concentrations of magnesium that have been added to both the melt. That molten metal would then be poured into some kind of permanent shape of 120 χ 305 mm2 cast iron with inter-laminar shearing. Usage of the very same UTM.

Casting and the temperature are then slowly decreased. The castings are extracted after solidification.

Form and height criteria (25 χ 25χ 5 mm3) for the erosion test.

II DENSITY AND VOID FRACTION

In different weight sensitive uses, density is now a structural property of both the utmost significance. It depends on either the proportional proportion of the components with in composite of reinforcement and matrix. There still is a disparity between such a composite material's theoretical or observed density values consistent with neither voids nor pores becoming present. Any of the mechanical properties but even the efficiency of composites is influenced greatly by all these voids.

Porosity measurement is performed using the image analysis technique. The polished top layers are held under a microscope (Neo-mate) equipped with a CCD camera (JVC, TK 870E). To produce a scanned shape of the specimen, which device was being used. The scanned image becomes transmitted through VOIS image recognition programme to something like a computer. The programme will reliably measure the total area covered through, or a percentage of, its microscope objective. The total area each area occupied either by pores then is separately calculated as well as the porosity of both the surface being analysed is assessed.

(a) Micro-hardness - The micro hardness calculation is carried out along with the micro hardness of a Leitz. A diamond indenter becomes inserted under load F, shaped like it's a straight pyramid with such a square base but an angle and 136 between opposite sides, into another material. That measured load and also its arithmetic mean L are the two diagonals X and Y of the notch which exist also on surface of the sample following removal. The load assumed is F = 49.08 N with in current thesis and even the Vickers hardness number becomes determined using following equation[28], where L has been the sample segment volume. P seems to be the maximum load; b and t are also the sample's width but thickness, respectively.

(b) Impact strength - By breaking the V-notched specimen with the pendulum hammer, evaluating the expended energy but comparing it to the cross section of the specimen, the pendulum impact testing machine (ASTM: D256) ascertains another notch pressure power of the material. The machine becomes calibrated such that the blade on the free-hanging pendulum scarcely reaches the specimen (zero position). The specimens become clamped in either a square support and thus are struck by the 5 mm diameter hemispherical bolt at the centre point.

(c) Scanning electron microscopy - According to any JEOL JSM-6480LV scanning electron microscope, both surfaces both of composite specimens are routinely inspected. Until studying by SEM, these specimens were immersed cautiously in chloroform. Those composite samples are placed as well as the eroded and uneroded surface with stubs are examined.

(d) Erosion test - Strong particle erosion experiments are undertaken in conjunction with ASTM G76 that used a standard air-jet erosion test rig. Using this set-up, although that's capable of creating erosive conditions, the erosion wear tolerance of such composite samples could be tested. Mainly comprising of an air compressing machine, an air-drying unit, which set-up, an air-drying unit, a conveyor belt type particle feeder,

(e) Tensile strength - Probably, the tensile testing is done on flat specimens. The dog-bone type and the straight side variety with end tabs are indeed the widely encountered tensile test specimens. A single axial load will be applied through several ends of the line mostly during procedure. The ASTM basic test system with metal matrix composite tensile properties seems to have the designation ASTM: D3552/D3552M the tensile testing is applied also on Instron 1195 Universal Measuring Machine (UTM) and also the results was analyzed to determine that composite sample tensile power.

(f) **Flexural strength -** The short beam shear (SBS) tests to determine the importance of flexural power, the composite samples was maintained constant. It is a 3-point bend test that usually promotes failure particles to both the mixing chamber while regulating the frequency of both the conveyor belt drive motor through varying. The compressed but dried air throughout the mixing chamber became combined with the eroding particles and afterwards accelerated through moving the mixture thru a tungsten carbide convergent nozzle with such an internal diameter of 3 mm and a length of 80 mm. Without perpendicular to the change of erodent movement, that erodent particles hit its sample surface from various angles varying around 15-90 and this angle with impingement could be varied through putting the samples horizontally within various sampling holders providing inclined faces 0-75. The velocity of both the erodent particles' effect is measured and use the double-disc process [29,30].

Dry silica sand with such an average particle size of 450 lm will be used as erodent throughout this current job. In order to conduct erosion experiments, the composite sample are cut to both the scale of (25χ25χ5) mm3. Samples were washed, dried then weighted with acetone and used an appropriate weight measurement tool with such a precision of ±0.001 mg during degradation for weight loss assessment. Otherwise the ratio with weight loss due to erosion to both the weight of a erodent inducing that loss were determined for a non-dimensional erosion rate. Each test run becomes repeated 3 times as well as the mean outcome becomes taken into account for any further erosion estimation.

And in regions near their wear surface, micro-constituents. Micro-cracking too is found in the top layer of both the subsurface region and yet another characteristic is really the movement of micro-constituents throughout the direction of eroding flow throughout the closest vicinity of both the wear surface.

III EROSION WEAR RESULTS AND TAGUCHI ANALYSIS

Performing different lab conditions, the corrosion wear rates of SiC strengthened ZA-27 metal matrix composites. Experimental results are translated into ratios of signal-to-noise (S/N). In truth, last and column reflects the S/N erosion rate ratio of an average of three replications. The research is carried out using common technologies primarily used for creation of experimental application known as MINITAB 14.

The S/N ratio reaction, through which it could be inferred that friction coefficient is now the most significant factor of any and all variables, accompanied with filler material, stand-off distance & impingement angle, whilst the eroding temperature does have the least or negligible importance for the erosion rate of these ZA-27 metal matrix composites filled with SiC. Other researchers like Mishra

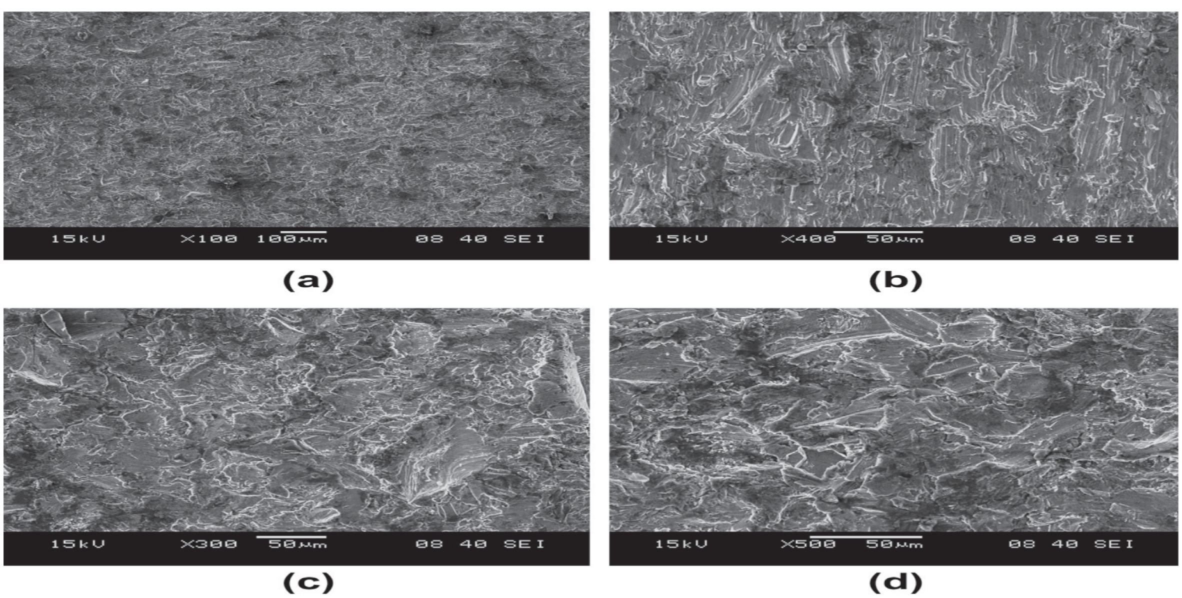

Fig. 1. SEM micrographs of the uneroded and eroded surfaces of the ZA27 metal matrix composites filled with 9 wt% SiC.

This kind of outcome is also recorded in another research. The consequence of the various signal-to-noise ratio control factors shown in Fig. 1 therefore points to the result that it the minimum corrosion wear rate of the mixture component.

IV CONCLUSION

The following basic findings contributed towards this theoretical and experimental research on particulate filled metal alloy.

(a) This composites do have low porosity and enhanced micro-hardness, tensile strength or force of effects. These show significantly lower flexural capabilities than that of the pure alloy ZA-27, though.

(b) It also is possible to actually evaluate the corrosion properties of these composites and use the Taguchi experimental design scheme. That Taguchi approach offers a clear, comprehensive and efficient technique for maximizing control factors. The successful application of both the signal-to-noise service elements recognises essential factors that influence the erosion rate of composites.

(c) The most significant aspects for the erosion rate of ZA-27 metal matrix composites filled with SiC filler are considered to be effect velocity and filler content amongst the variables.

REFERENCES

[1] Ranganath G, Sharma SC, Krishna M. Dry sliding wear of garnet reinforced zinc/ aluminium metal matrix composites. Wear 2001;251:1408–13.

[2] Kumar MP, Adashivappa K, Prabhukumar GP, Basavarajappa S. Dry sliding wear behaviour of garnet particles reinforced zinc–aluminium alloy metal matrix composites. Mater Sci (Medzˇ iagotyra) 2006;12(3):209–13.

[3] Tjong SC, Chen F. Wear behavior of as-cast ZnAl27/SiC particulate metal matrix composites under lubricated sliding condition. Metall Mater Tran A 1997;28a:1951–5.

[4] Chen T, Yuan C, Fu M, Ma Y, Li Y, Hao Y. Friction and wear properties of casting in situ silicon particle reinforced ZA27 composites. China Foundry 2009;6(1):1–8.

[5] Babic M, Slobodan M, Dzunic D, Jeremic B, Ilija B. Tribological behavior of composites based on ZA-27 alloy reinforced with graphite particles. Tribol Lett 2010;37:401–10.

[6] Dominguez C, Morenolopez MV, Rios-jara D. The influence of manganese on the microstructure and the strength of a ZA-27 alloy. J Mater Sci 2002;37:5123–7.

[7] Ranganath G, Sharma SC, Krishna M, Muruli MS. A Study of mechanical properties and fractography of ZA–27/titanium–dioxide metal matrix composites. JMEPEG 2002;11:408–13.

[8] Sharma SC, Girish B, Kamath MR, Satish BM. Graphite particles reinforced ZA-27 alloy composite materials for journal bearing applications. wear1998;219:162–8.

[9] Li Y, Ngai TL, Xia W, Zhang W. Effects of Mn content on the tribological behaviors of Zn–27% A1–2% Cu alloy. Wear 1996;198:129–35.

[10] Hashim J, Looney L, Hashim MSJ. Metal matrix composites: production by the stir casting method. J Mater Process Technol 1993;92–93:1–7.

[11] Girot FA, Albingre L, Quenisset JM, Naslain R. Rheocasting Al matrix composites. J Metals 1987;39:18–21.

[12] Prasad BK. Investigation into sliding wear performance of zinc-based alloy reinforced with SiC particles in dry and lubricated conditions. Wear 2007;262:262–73.

[13] Modi OP, Rathod P, Prasad S, Dixit AK. The influence of alumina particle dispersion and test parameters on dry sliding wear behaviour of zinc-based alloy. Tribol Int 2007;40:1137–46.

[14] Stolarski TA. Tribology in machine design. UK: Heiman Newnes; 1990.

[15] Päivi Kivikytö-Reponen. Correlation of material characteristics and wear of powder metallurgical metal matrix composites. Doctoral Theses in Materials and Earth Sciences. Helsinki University of Technology. Laboratory of Materials Science. Espoo, 2006.

[16] Acharya SK, Dikshit V, Mishra P. Erosive wear behaviour of redmud filled metal matrix composite. J Reinf Plast Compos 2008;27(2):145.

[17] Mishra SC, Das S, Satapathy A, Ananthapadmanabhan PV, Sreekumar KP.Erosion wear analysis of plasma sprayed ceramic coating using the Taguchi technique. Tribol Trans 2009;52:401–4.

[18] Sahu SP, Satapathy A, Mishra D, Patnaik A, Sreekumar KP. Tribo-performance analysis of fly ash–aluminum coatings using experimental design and ANN. Tribol Trans 2010;53:533–42.

[19] Kranthi G, Satapathy A. Evaluation and prediction of wear response of pine wood dust filled epoxy composites using neural computation. Comput Mater Sci 2010;49(3):609–14.

[20] Dharmalingam S, Subramanian R, Somasundara VK. Analysis of dry sliding friction and wear behavior of aluminum–alumina composites using Taguchi's techniques. J Compos Mater 2010;44(18).

[21] Basavarajappa S, Chandramohan G. Wear studies on metal matrix composites:a Taguchi approach. J Mater Sci Technol 2005;21(6).

[22] Basavarajappa S, Chandramohan G, Davim JP. Application of Taguchi techniques to study dry sliding wear behaviour of metal matrix composites. Mater Des 2007;28:1393–8.

[23] Sahin Y. The prediction of wear resistance model for the metal matrix composites. Wear 2005;258:1717–22.

[24] Sahin Y. Optimization of testing parameters on the wear behaviour of metal matrix composites based on the Taguchi method. Mater Sci Eng, A 2005;408:1–8.

[25] Sahin Y. Tribological behaviour of metal matrix and its composite. Mater Des 2007;28:1348–52.

[26] Mamatha TG, Patnaik A, Biswas S, Kumar P. Finite element modeling and development of SiC-filled ZA-27 alloy composites in erosive wear environment: a comparative analysis. J Eng Tribol 2011;225(11):1106–20.

[27] Patnaik A, Mamatha TG, Biswas S, Kumar P. Damage assessment of titania filled zinc–aluminium alloy metal matrix composites in erosive environment: a comparative study. Mater Des 2011.

[28] William FH. Mechanical behavior of materials. UK: Cambridge University Press; 2005.

[29] Mishra SK, Biswas S, Satapathy A, Patnaik A. Erosion wear Analysis of Al2O3 particles reinforced ZA-27 alloy metal matrix composite using ANN. Int J Mater, Manufact Des 2012;1(1):65–76.

[30] Mantry S, Behera D, Mishra SK, Debasish D, Jha BB, Mishra BK. Erosive wear analysis of plasma-sprayed Cu Slag–Al composite coatings. Tribol Trans 2013;56:196–202.

[31] Patnaik A, Satapathy A, Biswas S. Investigations on three-body abrasive wear and mechanical properties of particulate filled glass epoxy composites. Malaysian Polym J 2010;5(2):37–48.)