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PHYSICAL AND MECHANICAL CHARACTERIZATION AND EXPERIMENTAL ANALYSIS SILICON CARBIDE, GRAPHITE AND MARBLE DUST REINFORCED OF ZA-27 ALUMINIUM ALLOY HYBRID COMPOSITE FOR BEARING MATERIAL APPLICATION

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ABSTRACT

In the recent years, among the major developments in the field of composites, the aluminium metal matrix composites are widely used for aircraft, automotive and aerospace industries because they have lightweight, high strength to weight ratio, corrosion resistance and high thermal conductivity. This paper describes the fabrication of Aluminium alloy (ZA-27) hybrid composite with three reinforced Silicon carbide (SiC) the wt. of SiC varies (0-6wt. %), Graphite (Gr) the wt.% of Gr is 2wt.% and Marble Dust (MD) the wt.% of MD is 2 wt.% by stir casting technique. The physical and mechanical properties of the fabricated hybrid composite determine by conduct the experiments for density measurement, hardness, and compressive strength and impact strength values. The wt. % of the reinforced increase in the composite leads to increase the experimental density of the composite and void content also increase with increase the wt. % of reinforced. The wt. % of filler content increase in the Hybrid Composite leads to increases the hardness value, compressive strength, and Impact strength of the fabricated hybrid composite.

Keywords: ZA-27 alloy, Stir casting Technique, Physical & Mechanical properties.

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1. INTRODUCTION

The aluminium metal matrix composites are widely used for aircraft, automotive and aerospace industries because they are lightweight, high strength to weight ratio, corrosion Resistance and workability. To day advance bearing materials are demands are more because during movements of the shafts minimum friction and multiple demands are fulfilled by advanced bearing materials. The Al based bearing materials are more because The fatigue Strength of Al-based bearing materials are more than the white material and the thermal conductivity aluminium alloy is higher so that Aluminium alloy have low cost, aluminium alloys are high corrosive resistance, Aluminium alloys have good fatigue Strength, aluminium alloys are lighter and workability. Aluminium alloys used for bearing application for many years.[1]Zhen gang Liu *et al.*[2] have taken pure Al as matrix, Mg, and the natural crystalline flake Graphite particles as reinforcement .The mesh size is 82µm nominal diameter. The wt. % of Mg is 0, 0.2, 0.4, 0.6, 0.8, and 1.0. The Composite specimen prepared by Stir Casting. Vickers hardness increases by 13% hardness value 67 with the increase of Mg content, the Highest tensile Strength 185 M Pa found at 0.6 wt. % Mg. Kart hick E *et al*.[3] manufactured a composite metal of AZ31with 95-87 wt. % take as base metal matrix.Al_2O_3 and SiC particles take as reinforcements. The alumina (Al_2O_3) take 5wt. % and SiC varied from 0-8 wt. % The samples prepare with the help of PM .the hardness increase with increase the wt.% of filler content. The hardness 16.47 % at 8 wt. % SiC filled AZ-31 alloy composite. Fei CHEN *et al.*[4] Have produced of ZA27the chemical composition as take as matrix and TiB_2 take as reinforcement the wt. % of TiB_2 (1%, 3% and 5%).the sample fabricated with the help of stir casting technique. The result showed that hardness and tensile Strength is significantly increase with increase the wt.% of TiB_2 The maximum Brinell hardness at 5 % TiB2 up to 128 and UTS of ZA-27 TiB_2 filled alloy composites at 5 wt.% have 434 M Pa respectively. A. Baradeswaran *et al.*[5] Fabricated a composite material aluminium alloy Al 7075 are taken as base metal matrix and B_4C powder take as the reinforcement. The filler content of Boron carbide B_4C as 5, 10, 15 & 20 vol. the particle size 16µm to 20 µm the specimen prepare with the help of stir casting .The result showed that, The Hardness, The ultimate tensile, wear resistance, The Flextural and compressive Strength are increase with increasing the B_4C filler content. [6]Fabricated done an experiment in which a composite metal of Aluminium alloy (AA6063) as base matrix and clay take reinforcement. The clay 5–30 wt. % of clay particles with Grain size 250 micron and specimen with the help of liquid stir casting route. The specimen prepared for the tensile, Vickers hardness and wear test. The Clay particles added in base metal which is improved the mechanical & wear performance of clay particles filled aluminium alloy composite. P.B. Pawar *et al.* [7] conducted an experiment in which pure Aluminium is taken as matrix and Silicon Carbide particulate taken as reinforcement. Metal matrix is prepared by stir casting. The wt. % of SiC were 0, 2.5, 5, 7.5, and 10 in wt. %. Different mechanical tests are done and result shows that there is enhancement in Hardness, material toughness. The maximum enhancement is shown in 10 % of SiC particulate sample.

2. MATERIAL AND METHODS OF FABRICATION

2.1. Matrix Material

Aluminium alloy (ZA-27) have high Strength to weight ratio and desirable thermal conductivity. The aluminium alloy ZA-27 broadly used for structural application and bearing application. The chemical composition of ZA-27 alloy composite are (Al-25%, Cu-2%, Mg-0.01, Zn-% remainder).

2.2. Reinforcement Material

One of the important roles of reinforcement added in matrix material and produce a composite material is to improve the mechanical property. The cost of the particulate filled Composites (SiC, Graphite and Marble dust) are less than the fibre reinforced composites material, because the particles cost are less than fibre reinforcement.

2.2.1. Silicon Carbide (SiC)

SIC is a very hard ceramic particle and have low Density. The Sic powder added in to Matrix material to enhance overall mechanical properties of fabricated composite. The size SiC particle is 25 μm. Figure 1 (a) shows the image of SiC Micro powder.

2.2.2. Graphite particle (Gr)

Gr Graphite is a type of solid lubrication .Gr particle added in to Matrix material to enhance wear resistance of fabricated composite. The size Gr particle is 25 μm. Figure 1 (b) shows the image of Gr Micro powder.

2.2.3. Marble dust (MD)

MD is a very hard particle.MD added in to matrix material to enhance the overall mechanical and wear properties of fabricated alloy composite. The size MD particle is 25μm. Figure 1 (C) shows the image of Marble Dust Micro powder.

(a) (b) (c)

Figure 1 (a) SiC particle (b) Gr particle (c) MD Particle

2.3. Composition of Samples

The fabrication will be done by Stir casting process for fabrication matrix material will Take as ZA-27 alloy and reinforcement will take as Silicon carbide (SiC), Graphite and alumina (SiC$_)$.these materials are taken in different composition which are listed below

Table 1 Chemical composition of ZA-27 metal alloy hybrid composite

Designation of Sample	**Chemical Composition**
ZA-27-0%SiC	ZA-27+0 wt. % SiC+2 wt. % Gr +2 wt. % MD
ZA-27-2%SiC	ZA-27+2 wt. % SiC+2 wt. % Gr +2 wt. % MD
ZA-27-4%SiC	ZA-27+4 wt. % SiC+2 wt. % Gr +2 wt. % MD
ZA-27-6%SiC	ZA-27+6 wt. % SiC+2 wt. % Gr +2 wt. % MD

2.4. Stir Casting Fabrication Technique

The matrix material (ZA-27) is take in Graphite crucible and heated inside the electric furnace up to above its liquid temperature about 500°C and reinforcement SiC, Graphite and Marble dust are heated to 300°C in the respective crucibles then after the crucible contain ZA-27 alloy base metal matrix is heated 800°C and preheated powders are mixed with melt alloy of ZA-27.The electric furnace shown in Figure 2 (a). For the better mixing of reinforcement in the melt base matrix ZA-27 alloy stirring mechanism is used. Stirring mechanism consist a motor and a mechanical stirrer made of Graphite for 6 –8 minutes and heated again in furnace. Then crucible is taken out of the furnace and stirred again for 6-8 minutes and then poured into the Hardened steel die. The hardened steel die dimensions are 145 x 90 x 10 mm.

(a) (b)

Figure 2 (a) Electric Furnace and (b) Solidified composite plate

The solidified plate is shown in Figure 2(b).The mixture was then allowed to solidify for 2 – 3 minutes and then after the solidified Plate remove from the metallic die .The solidified plate of composite was suddenly quenched into cold water.

3. RESULT AND DISCUSSION

3.1. Influence of voids content on SiC filled ZA-27 alloy composites

The theoretical density of the SiC filled fabricated alloy composites is decide with the help Of rule-Of-mixture by Equation (1), while experimental density is evaluated using water immersion technique based on Archimedes' principle. Thereafter, void content's computed as per Equation (2).

$$\rho_{th} \quad = \frac{1}{\frac{W_m}{p_m}+\frac{W_{Sic}}{p_{Sic}}+\frac{W_{Gr}}{p_{Gr}}+\frac{W_{MD}}{p_{MD}}} \tag{1}$$

Where-

W_m and $p_m$wt. % of ZA-27 alloy and density of ZA-27 alloy

W_{SiC} and p_{SiC} wt. % of SiC Micro Powder and density of SiC Micro Powder

W_{Gr} and p_{Gr} wt. % of Gr Micro Powder and density of Gr Micro Powder

W_{MD} and p_{MD} wt. % of Gr Micro Powder and density of Gr Micro Powder

$$\text{Void contents} = \frac{\text{Theortcal density } (\rho_{th}) - \text{Experimental density } (\rho_{exp})}{\text{Theortcal density } (\rho_{th})} \tag{2}$$

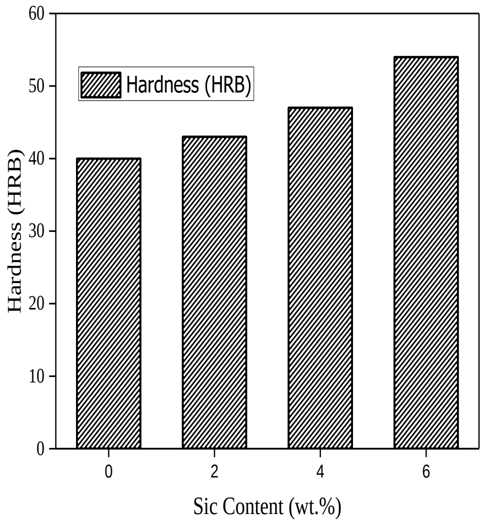
The variation in void content in the metal fabricated alloy composites may be due to the Presence of air bubble during mechanical mixing of filler materials in the alloy Composite During fabrication. The voids content produce the adversely Influence on the wear and mechanical Properties of alloy composites. The porosity reduce with the application of pressure, the pressure applied after the casting of specimen and improve the bonding force between filler materials and Al alloy. The similar Result found in aluminium alloy Al_2O_3 filled composite material. The density of the aluminium alloy with particulate filled composite alloy increase with increase the wt.% of filler content and particle size and the porosity of the aluminium alloy particulate filled composite alloy increase with decreasing the size and increasing the wt.% of particles. [8]

Table 2 Void fraction of SiC mixed ZA-27 alloy Composite

Composites System	Theoretical Density (gm./cc)	Experimental Density (gm./cc)	Void fraction (%)
ZA-27-SiC 0 %	4.62	4.59	0.48
ZA-27-SiC 2 %	4.57	4.51	1.22
ZA-27-SiC 4 %	4.55	4.53	0.32
ZA-27-SiC 6 %	4.51	4.47	0.99

3.2. Influence of Hardness on SiC metal powder-filled ZA-27 alloy composites

Figure 3(a) Indicates the Rockwell HV of the ZA-27 alloy composites metal filled with various weight percentage of SiC metal powder filler content.



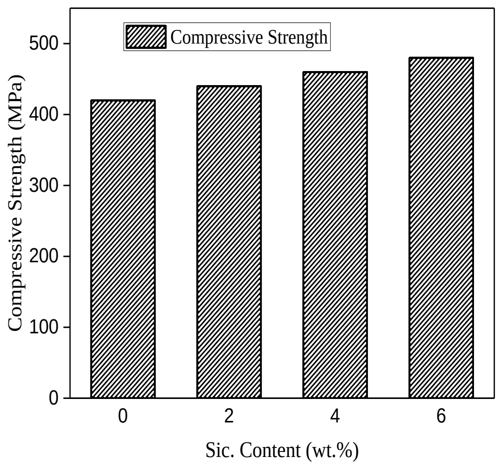
(a) (b)

Figure 3 (a) Hardness variation with wt. %of Sic contents (b) Specimens of hardness Test

It is revealed that the addition SiC powder filler increase the hardness significantly (Rock well Hardness tester with 10 Kgf. Minor Load on 'B' scale) of the specimen samples prepared 10×10×30 mm as shown in figure 3 (b). Hardness determine with the help of Rockwell Hardness test On SiC mixed ZA-27 metal alloy composite. The neat alloy have 40 HV and the addition of 2 wt.-% filler content material (SiC) leads to an increase in hardness by 7.5% to 43 HV. Furthermore, increment of 4 wt.-% over unfilled reinforced alloy composite leads to an increase in hardness by 17.5 % to 47 HV. Furthermore, addition of 6 wt.-% particulate content an increase in hardness by 35% to54 HV. Similar behaviour found in Silicon carbide mixed ZA-27 metal alloy composite the hardness increase with increase wt. % of SiC [10].

3.3. Influence of compressive Strength on SiC metal powder-filled ZA-27 alloy composites

The Sample for compression test prepared as per ASTME9-09 the specimen size is 10 ×10 ×30 mm are shown in 4 (b).The compressive Strength SiC mixed ZA-27 metal alloy composite varies 420 M Pa to 480M Pa is shown In figure 4(a) the confirmed that the weight percentage of SiC increases compressive Strength is increases. The unfilled particulate alloy composite indicates compressive Strength 420 M Pa and the addition Of 2 wt. -% filler content (SiC) leads to an increase in compressive Strength by 4.76 % to 440 M Pa. Furthermore, increment of 4 wt.-% over unfilled reinforced alloy composite leads to an increase in compressive Strength by 9.52 % to 460 M Pa. Furthermore, addition of 6 wt.-% particulate content an increase in compressive Strength by 14.28% to 480 M Pa purpose is ceramic Particles is mixed with base metal they increase the compressive Strength. The maximum compressive Strength is 6 wt. % SiC mixed ZA-27 metal alloy composite i.e. 480 M Pa. The compressive Strength increased by 14.28 % over neat alloy at 6 wt.-% Silicon Carbide metal powder particulate composite and the Growing rate continues with Gradually enhancing compressive Strength of SiC metal powder mixed ZA-27 metal alloy composite with unfilled particulate composite. The compressive Strength of composite metal increase with the addition of SiC because SiC hard ceramics metal powder so it is control of the plastic flow , the hard ceramic particles are distribute in the matrix, thereby compression Strength of SiC mixed ZA-27 metal alloy composite increases with SiC filler content [9].



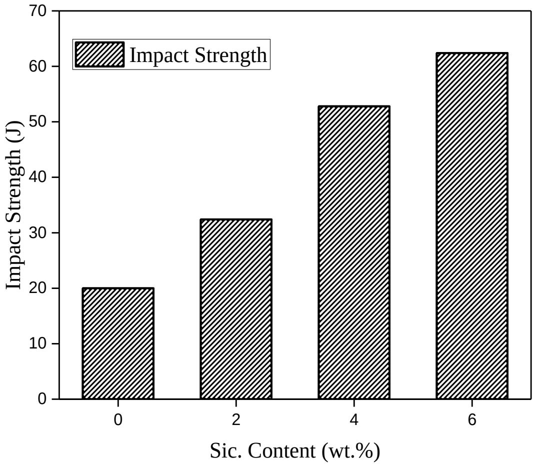
(a)

(b)

Figure 4 (a) Variation of composite compressive Strength with SiC content (b) Compression test specimens

3.4. Influence of Impact Strength on SiC metal powder-filled ZA-27 alloy composites

Impact Strength determine by performing Charpy impact test is carried out in this work. The specimen cut as per ASTM D 256 standard size 10×10 mm^2 cross section and 55 mm length at the middle length of the specimen V notch create at 45^o angle with 2 mm depth The specimen are Shown in figure 5 (b).Figure 5 (a) shows the Influence of Silicon Carbide Metal powder content on the Impact Strength of ZA-27 alloy SiC particulate composites. The Graph suggests that Impact Strength increases with filler content from 20 J at 0 wt.-% of SiC metal powder to 32.4 J at 2 wt.-% SiC powder in the unfilled matrix. On extra addition of SiC metallic powder, the have an Influence on Strength is 55.8 J at 4 wt.-% SiC metal powder to 62.4 J at 6 wt. % SiC metal powder. The similar result is also said by Bhaskar et al [9] for SiC particulate mixed ZA-27 metal alloy composite.



(a)

(b)

Figure 5 (a) Variation of Impact Strength with SiC filled content (b) Specimens of Impact test

4. CONCLUSIONS

In this research paper fabricate different type of composite by stir casting method i.e. Al-alloy (ZA-27) Hybrid composite with reinforced SiC ,Gr and Marble Dust .The experimentally proved that the Hybrid reinforced physical and mechanical properties of the composite when compared with the monolithic material. This research work describes the density, void contents, Hardness, compressive Strength, Impact strength.

- Stir casting Method has been used for fabricate Al – alloy hybrid composite .The stir casting technique is most economical and conventional method of casting component.
- The wt.% of reinforced increase in the composite leads to increase the experimental density of the composite and void content also increase with increase the wt.% of reinforced in fabricated Hybrid Composite.
- The wt. % of filler content increase in the Hybrid Composite leads to increase the hardness of the composite. The hardness of the composite increases up to 35 % (i.e.54 HV) at ZA-27-SiC 6 %.
- The wt. % of filler content increase in the Hybrid Composite leads to increase the compressive strength of the composite. The compressive strength of the composite increase up to14.28 % (i.e. 480 M Pa) at ZA-27-SiC 6 %.
- The wt. % of filler content increase in the Hybrid Composite leads to increase the impact strength of the composite. The impact strength of the composite increase up to 62.4 J at ZA-27-SiC 6 %.

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