MECHANICAL PROPERTIES OF ALUMINIUM METAL MATRIX COMPOSITES REINFORCED WITH SiC AND ZIRCON SAND

Shibabrata Mohapatra*, Sudhakar Majhi

***Corresponding author: shibabratamohapatra@gmail.com**

Abstract: Aluminium alloys are widely used due to their good mechanical properties, better corrosion and wear resistance, low melting point as compare to others. The most important property of these materials are relatively light in weight and having low production cost which make them attractive for different applications from technological point of view. The purpose of designing metal matrix composite is to add the desired attributes of metals and ceramics.The nature and distribution of hard ceramic particles in composite materials influences the properties to greater extent. In the present work, the role of hard ceramic reinforced particles on the mechanical and tribological behaviour of aluminium metal matrix composites consisting of dual reinforced particles (DRP) is studied. Zircon sand and Silicon Carbide particles of size 30-45 micron are used as reinforcement in commercial grade LM13 piston alloy. Composites of dual reinforced particles in aluminium matrix (DRP-AMCs) are developed by mixing 15wt% reinforced particles by stir casting technique with a step of 5wt%. From the cast sample ASTM. Standard specimens are prepared for mechanical characterization. The tensile strength, hardness value, impact strength of the composite are examined.

Keywords: Aluminium metal matrix; Dual reinforced particles; Impact strength.

1. Introduction:

Aluminium is the most abundant metal in the earth's crust, and the third most abundant element after oxygen and silicon. It makes up about 8% by weight of earth's solid surface. The chief source of aluminium is bauxite ore. Its atomic no. is 13. Aluminium is a soft, durable, light weight, ductile and malleable metal with appearance ranging from silvery to dull gray, depending on the surface roughness. It is nonmagnetic and non-sparkling and about one-third the density and stiffness of steel. It is easily machined, cast, drawn and extruded. Corrosion resistance can be excellent due to thin surface layer of aluminium oxide that forms when the metal is exposed to air, effectively preventing further oxidation.Aluminium alloys are alloys in which aluminium is predominant material.It situate in two forms like wrought alloy and cast alloys. The international Aluminium designation system mostly widely designated system with different properties as different name series.Here Al is used as matrix element.

1.1Role of reinforcement in the composites:

The role of reinforcement in a composite material is fundamentally one of increasing the mechanical properties of the neat resin system. The desirable properties of the reinforcement include: High strength, Ease of fabrication and low cost, Density and distribution, Suitable particle size and shape, chemically inert with molten metals, Consistent in cleanliness and pH. The performance of the composite materials is mostly dependent on selecting the right combination of reinforcing materials since some of the processing parameters are associated with the reinforcing particulates. A numerous combinations of reinforcing particulates have been conceptualized in the design of aluminium composites. Like (SiC ,B_4C ,WC, TiC, TiB_2, MOS_2, TiO_2,Si_3N_4,Al_2O_3,Redmud,Gr,SiO_2,$ZrSiO_4$).[1] There are several work already carried on and continuous research is going on single and hybrid AMCs. The double synthetic ceramics reinforced hybrid AMCs despite showing good mechanical and tribological properties over the unreinforced alloys.

1.2 SiC as reinforcement:

Silicon carbide is the only chemical compound of carbon and silicon. It was originally produced by a high temperature electro-chemical reaction of sand and carbon. Silicon carbide is an excellent abrasive and has been produced and made into grinding wheels and other abrasive products for over one hundred years. Today the material has been developed into a high quality technical grade ceramic with very good mechanical properties.
It is used in abrasives, refractoriness, ceramics and numerous high performance applications. [2]The material can also be made an electrical conductor and has applications in resistance heating, flame igniters and electronic components. SiC is composed of tetrahedral of carbon and silicon atoms with strong bonds in crystal lattice. It

is having the properties like Low density, High strength, Low thermal expansion, High thermal conductivity, High hardness, Excellent thermal shock resistance, Superior chemical inertness etc.

1.3 Zircon Sand as reinforcement:

Zircon is a mineral that does contain all of the properties listed above, and thus, it is an excellent reinforcement material. It resists abrasion, impact, thermal shock and chemical attack, and it has a high melting point. Elemental zirconium is not found in nature. Instead, zirconium bonds with sodium, calcium, iron, silicon, titanium, thorium and oxygen to form a number of different zirconium bearing minerals. Of the zirconium minerals, baddeleyite (ZrO_2) and zircon ($ZrSiO_4$) are mined on a commercial scale. Other zirconium-bearing minerals are rare and have not been found in deposits suitable for mining. Although baddeleyite is mined and marketed for refractory purposes, this paper will focus only on zircon. The general chemical composition of zircon is 67% zirconia and 32.8% silica.[3,4,5,6] Zircon usually contains some hafnium, typically about 1%. The effect of dual reinforced ceramic particles on high temperature tribological properties of aluminium composites. Zircon sand and silicon carbide particles of size 20–32 micron were used as reinforcement in composites developed by mixing 15 wt% reinforced particles by two step stir casting technique in commercial grade LM13 piston alloy A combination of 3% zircon sand and 12% silicon carbide particle reinforced composite exhibits better wear resistance as compared to other combinations[6].On Synthesis, microstructural and mechanical properties of ex situ zircon particles (ZrSiO4) reinforced Metal Matrix Composites (MMCs).It was observed that Composites produced by squeeze casting, compo casting and powder metallurgy exhibit lesser porosity compared to the composites produced by stir casting technique[5]. The micro structural characteristics of spray formed zircon sand reinforced LM13 composite. The microstructural features and hardness of spray formed LM13/zircon sand composite revealed equiaxed morphology with nearly uniform distribution of zircon sand particles in the middle of preform as well as good particle/matrix interfacial bonding. The linear expansion coefficient of base alloy is found to be 8.67×10^{-6} K^{-1} and for spray formed composite is 8.38×10^{-6} K^{-1} (5% Vf of zircon sand) and 9.11×10^{-6} K^{-1} (15% Vf of zircon sand) in 25–465 ◦C temperature limit, which is quite comparable indicating good interfacial bonding. The bulk hardness is found to increase with addition of zircon sand particles in LM13 alloy [6]. Role of fine size zircon sand ceramic particle on controlling the cell morphology of aluminium composite foams. For this purpose LM13 piston alloy of near eutectic composition was used as foaming matrix material and zircon sand ceramic particles as reinforcement. Composite foam was developed by stir casting route at different temperatures. Variation in microstructures of the composite foam is observed with the addition of zircon sand ceramic particles and also with varying foaming temperatures.. The density of LM13 alloy foam with addition of fine grade blowing agent increases from 0.62 g/cm^3 to 0.90 g/cm^3 and cell size decreases with increase foaming temperature from 850°C to 900°C.The cell size of LM13 alloy composite foam with addition of fine grade blowing agent increases but the effect of coarse grade blowing agent is vice versa when the foaming temperature increases from 850°C to 900°C.The optimized condition of foaming temperature for composite foam containing 5 wt.% zircon sand and alloy foams are 875°C and850°C, respectively, when 2 wt.% $CaCO_3$ as foaming agent having narrow particle size (1–25micron) has been used. Cell size of the sample foamed increases with increasing particle size of blowing agent [7].

2. Specimen Preparation:

Stir Casting: A recent development in stir casting process is a double stir casting or two-step mixing process. In this process, first the matrix material is heated to above its liquidus temperature. The melt is then cooled down to a temperature between the liquidus and solidus points to a semi-solid state. At this point the preheated reinforcement particles are added and mixed. Again the slurry is heated to a fully liquid state and mixed thoroughly. In double stir casting the resulting microstructure has been found to be more uniform as compared with conventional stirring. The potency of this two-step mixing method is mainly due to its ability to break the gas layer around the particle surface which otherwise impedes wetting between the particles and molten metal. Thus the mixing of the particles in the semi-solid state helps to break the gas layer because of the abrasive action due to the high melt viscosity. The major advantage of stir casting process is its applicability to mass production. Compared to other fabrication methods, stir casting process costs as low as 1/3rd to 1/10th for mass production of metal matrix composites. Because of the above reasons, stir casting is the most widely used commercial method of producing aluminium based composites.

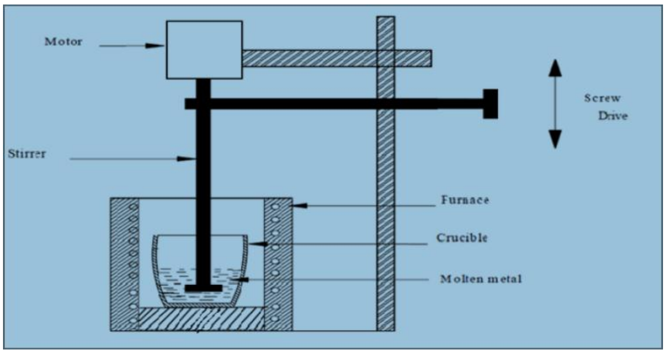

Fig: 1 Stir casting

2.1Reinforcement Combination of Composition:

Table-1

Composites	Total 15wt% Reinforcement	
	SiC (wt% in Total reinforcement)	$ZrSiO_4$ (wt% in Total reinforcement)
A (Al LM13)	0	0
B	15	0
C	10	5
D	5	10
E	0	15

2.2 Composite Preparation

After the Collection of the reinforcing materials i.e Boron Carbide Powder and Zircon Sand then the composite preparation was carried out. For this Al LM13 alloy heated to 700-750˚C till the entire alloy melted in a Muffle Furnace, which is carried out in a Crucible made up of graphite. Silicon Carbide Powder and Zircon Sand prepared for reinforcement is preheated to 400-450˚C for 1 hour before mixing in melt. Then the molten metal (Al alloy, LM13) is stirred to create a VORTEX and the particulate are added and Stirring is done at 600-650rpm. Then the preheated Silicon Carbide Powder and Zircon Sand particle is added slowly in small packets of aluminium foil constantly for better mixing and uniform composition and Stirring is continued for another 5 minutes. Mixture is then poured to the mould (cylindrical with diameter of 35cm and length of 22cm) which is also preheated to 350-500˚C for 20 minute for uniform solidification.

3. Various tests carried out:

3.1Tensile Test

The tensile test is a common test performed on metals, wood, plastics, and most other materials. The specimen required for tensile test is prepared in the workshop with different operations carried out.

Test Samples

The samples are cut from the composite according to the ASTM E8 standards as shown in the fig.1 for tensile tests respectively.

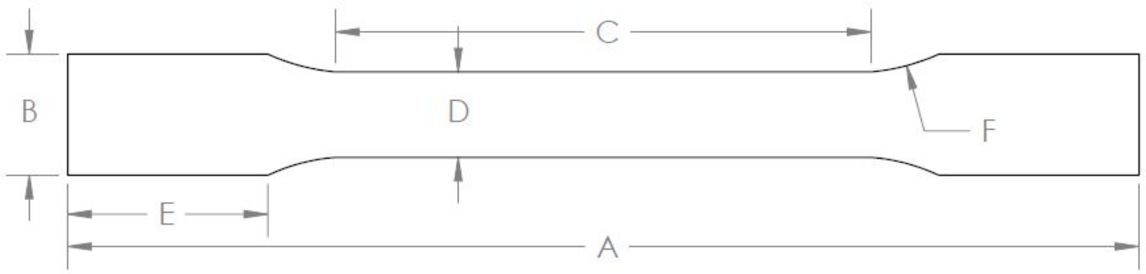

Figure: 2 Tensile specimen Dimensions

Table-2

Specimen	A	B	C	D	E	F
Standard	136	14	50	8	40	R3

3.2 Hardness Test Procedure (Rock Well Hardness Number, RHN)

In this work, the Rockwell hardness number of the samples are measured. At first the samples are prepared to the dimension of 30mm diameter .Then the sample is placed on the base of the plate and the indenter is having a diameter of 10mm. Then the indenter is pressed on the surface of the sample. The pressing of the indenter is done with the help of a constant load. The applied load is 150 kgf. Then the indicator which is fixed above the Rock Well hardness Machine will show deflection and Note down the Rockwell hardness number.

3.3 Impact Test Procedure (CHARPY Test):

In manufacturing locomotive wheels, coins, connecting rods etc. the components are subjected to impact (shock) loads. These loads are applied suddenly. The stress induced in these components are many times more than the stress produced by gradual loading. Therefore, impact tests are performed to asses shock absorbing capacity of materials subjected to suddenly applied loads. These capabilities are expressed as (i) Rupture energy (ii) Modulus of rupture and (iii) Notch impact strength**.** In charpy test, the specimen is placed as 'cantilever beam'. The specimens have V-shaped notch of 45°. U- Shaped notch is also common. The notch is located on tension side of specimen during impact loading. Depth of notch generally taken as t/5 to t/3.

4. Results

4.1Tensile test:

Specimen	Wt% of SiC	Wt% of Zircon Sand	Tensile stress result in MPa
A(pure Al LM13)	0	0	77.03
B	15	0	92.29
C	10	5	88.54
D	5	10	96.96
E	0	15	86.29

4.2Hardness Test

Specimen	Trial1	Trial2	Trial3	Mean hardness value
A	33	35	36	35
B	43	40	41	41
C	43	40	42	42
D	47	45	41	45
E	41	47	44	44

4.3 Impact strength:

Specimen	Maximum energy stored in Joule
A	2
B	3.5
C	2.5
D	4
E	3

5. Conclusion

From the experimental procedure it is clearly observed that the specimen-D that is having reinforcement of (5%SiCand10%Zircon Sand) is maximum tensile strength, hardness value and impact strength .So the above composition can be used as a better material over the existing material.

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Biographical Notes

Mr. Shibabrata Mohapatra is an Assistant Professor in Dept. of Mechanical Engineering, DRIEMS, Tangi, Cuttack. He has 5 years of teaching experience. His area of interest is in system design and composite materials

Mr. Sudhakar Majhi is an Asst. Professor in Mechanical Engineering, at I.G.I.T Sarang. He has 10 years of teaching experience. His area of interest is composite materials. He has published 05 no. of national and international journals.