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Characterization of Mechanical Properties of Aluminium based Metal Matrix Composite AA6061/ZrO2/SiC using Stir casting method

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ABSTRACT—Composite materials have revolutionized the field of engineering by giving rise to light weighted and high performance materials in modern engineering applicationslike automotive and aerospace, foreseeing its possibilities this work focuses on fabrication and testing the mechanical and metallurgical properties of composite materials with Aluminum of grade 6061 as base matrix and Silicon Carbide and Zirconium dioxide particles as reinforcement in various proportions such as (SiC 2%,ZrO2 2%),(SiC 6%, ZrO2 2%),(SiC 2%, ZrO2 6%) are fabricated by using stir casting which is the most economical. The Aluminum alloys when reinforced with different ceramics show improvement in the hardness, strength, microscopic structure, wear rate and other mechanical properties. The applications of the composites are also presented.

Index Terms—Aluminium MMC, ZrO2, Stir casting

I.INTRODUCTION

Metal matrix composites evolving in industries for its properties like high strength, light weight, inexpensive process, high elastic modules, high stiffness, high electrical and thermal conductivity, etc. Metal Matrix Composites are most preferred among the fastest growing families of new materials and have potential properties like more strength, toughness. There is a continuous development and usage of particulate composites in the making of appliances such as engine parts, cylinder liners, etc., which are regarded as high performance components, due to their superior mechanical and tribological properties. The MMCs are attractive materials for use in structural applications because they combine favorable mechanical behaviours such as better wear resistance and lower thermal expansion Particle-reinforced metal matrix composites(PMMCs) are very promising materials for structural applications due to their isotropic material properties, and metal forming processes to yield the finished products. Particulate-reinforced metal matrix composites have paved a new path to produce high strength and high wear resistant materials by introducing hard ceramic particlesand solid lubricant in the metal matrix. Addition of reinforcements such as SiC, B_4C, Al_2O_3, ZrO2 and TiC, these ceramics improves hardness and thermal shock resistance of the Metal Matrix. AA 6061 is one of most generally used material because of its high mechanical and high corrosion resistance properties.

Many researchers have investigated aluminum alloy based composite material fabrication with stir casting process. The objective of this work is to develop AA6061/Sic/ZrO_2 composites using stir casting technique and to find its mechanical strength and metallurgical properties.

Sachin Malhotra et al. [1] observed that influence of varying weight percentage of zirconia (5% and 10 %) and fixed percentage fly ash (10%) reinforced Al6061 metal matrix composite by stir casting method. It was identified that hardness and ultimate tensile strength increase with increase weight fraction of reinforcement material. A better hardness 94HV and tensile strength 278 MPa for 10% zirconia and 10% fly ash reinforced composite material. Aluminium alloy 6061 had the determinate elongation of 21.66%, which was significantly reduced to a range of 85% to 90% due to the addition of reinforcement material.

K. B. Girisha et al. [2] investigated the effect of different weight fraction of zirconium oxide nanoparticle (0.5%, 1%, 1.5%, and 2%) reinforced Al356.1 metal matrix composite by stir casting method. It was observed that particle agglomeration in composite due to high content of zirconium oxide nanoparticle. Hardness and wear properties increase with increase weight fraction of zirconium dioxide nanoparticle.

J. Jenix Rino et al. [3] investigated the mechanical behaviour of Al6063 alloy composite strengthened by zircon sand and alumina particle with an overall reinforcement in 8 Wt.% by stir casting method. It was observed that homogenous distribution of the reinforcement in Al6063 matrix material. Hardness and tensile strength of the composite having the higher value at the composite sample having the reinforcement mixture of 4wt.%ZrSiO4+4wt.% Al2O3. K. L.

Meena et al. [4] observed that mechanical properties of the developed SiC reinforced Al6063 metal matrix composite material using the melt stirring technique. The experiment was performed by varying the reinforced particle size as 200 mesh, 300 mesh, 400 mesh and different weight percentage, 5%, 10%, 15%, and 20% of SiC particle reinforced composite material. The stirring process was conceded at 200 rpm using a graphite impeller on behalf of 15 min. A homogenous dispersion of SiC particle in the aluminium matrix was observed. Tensile strength, hardness and breaking strength improved with the enlargement in reinforced particulate size and weight percentage of SiC particles. Percentage elongation, percentage reduction area and impact strength decrease with the rise in reinforced particle size and weight percentage of SiC particles. Maximum hardness (HRB) 83, and impact strength 37.01 Nm was achieved at 20% weight percentage of SiC particles.

M.Pandiyarajan [6] investigated effect of addition of zirconium dioxide particulates with AA6061 at various proportions such as 2%,4%,6%,8%,10%. The metal matrix is fabricated using stir casting technique and the tensile strength of 6% zirconia added composite is 169MPa which is 24% higher than that of AA6061. and hardness of same composite is found to be 33% higher than AA6061.

II. MATERIALS AND METHODS

A.Aluminium Alloy

Aluminium alloy, AA6061, was used as a matrix material and its chemical composition is presented in

Table1

ELEMENT	% BY WEIGHT
SILICON	0.714
IRON	0.191
COPPER	0.163
MAGANESE	0.10
MAGENESIUM	0.881
ZINC	0.069
TITANIUM	0.027
PHOSPHOROUS	0.002
ALUMINUM	REMAINDER

Table.1 Chemical composition of AA 66061

B.Zirconium dioxide

Zirconium dioxide (ZrO2), sometimes known as zirconia, is a white crystalline oxide of zirconium. The density is 5.85 g/cm3 and melting point greater than 2600°C. A typical properties exhibited by zirconium dioxide are high strength, high fracture toughness, excellent wear resistance, and high hardness, etc.

C.Silicon Carbide

Silicon carbide (**Sic**), also known as **carborundum**,isa semiconductor containing silicon and carbon with chemical formula Sic. Silicon carbide with high surface area can be produced from SiO_2 contained in plant material. Recent researches have developed it as a excellent reinforcements with metal matrix composites specially with aluminum.

III. EXPERIMENTAL METHODS

Stir casting is best and inexpensive out of the all available method for metal matrix composites production in large quantities and permits very large size components to be manufactured.

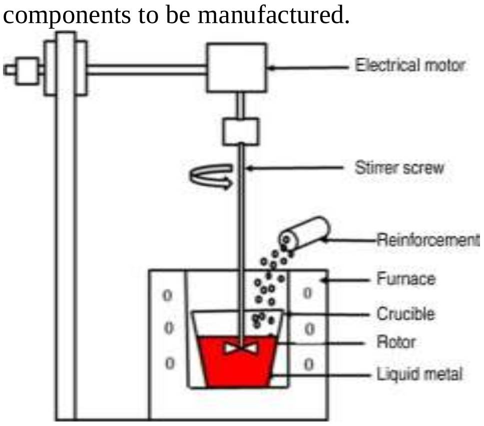

Fig 1 stir casting set up

In this technique, irregular reinforcement is stirred into molten metal. Stirrer was provides greater shearing action in addition to a vortex formation for fast and easy introduction of particle in the molten metal and helps in uniform distribution with minimum breakage. This method is also known as vertex or stirrer method. Here first AA6061 is cut into small pieces and and out into the furnace for melting the AA6061 melts at 650 C now stirrer is switched on and reinforcements are added with stirring the stirrer. The sample prepared are 1st sample AA6061 96%/SiC2% /$ZrO_2$2%,2nd sample AA6061 92%/SiC2% /$ZrO_2$6%,3rd sample AA6061 92%/SiC6% /$ZrO_2$2%. Now the molten material is poured in to the die and allowed to cool. And ready for machining for various tests.

Fig 2 Fabricated MMC

IV.EXPERIMENTAL RESULTS:

A. Tensile Test

The tensile testing was done using a computerized universal testing machine at room temperature. The tensile test specimens were prepared as per ASTM E8 standard. And tensile test is done for three samples and its founded that increase in %weight of Sic increases the tensile strength of the material sample 3 with 6% Sic,2%ZrO_2 has 122MPa tensile strength. The load vs displacement graphs are given below.

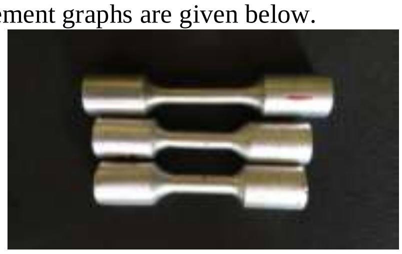

Fig 3 Tensile Test sample

Fig 4 Test samples after test

For sample 1 Al96%Sic2%$ZrO_2$2%

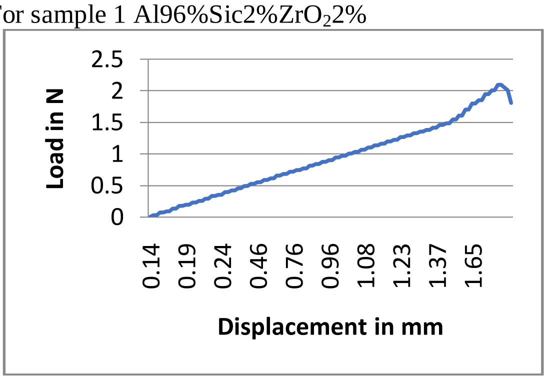

Fig 5 load vs displacement of sample 1

For sample 2 Al92%Sic2%$ZrO_2$6%

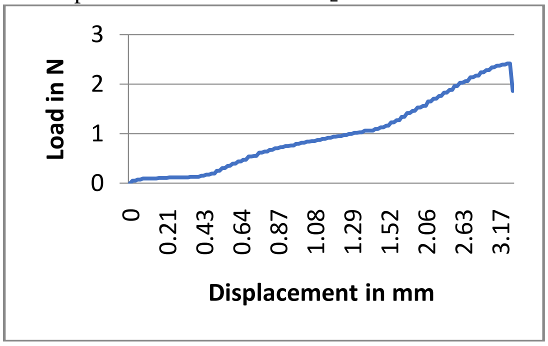

Fig 6 load vs displacement of sample 2

For sample 3 Al92%Sic6%$ZrO_2$2%

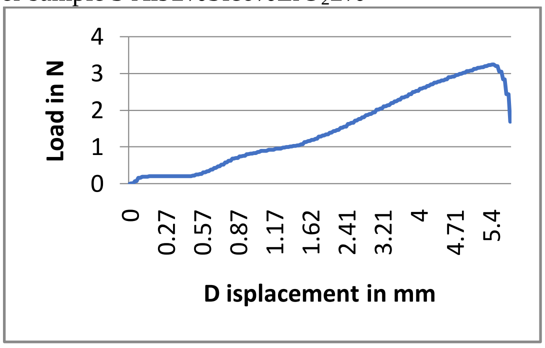

Fig 7 load vs displacement of sample 3

The elongation value of sample 2 is 7.03% is very less compared to the AA6061 elongation value. The ultimate tensile strength of sample 1 is 66.53MPA .sample 2 is 88.40 MPa and sample 3 tensile strength is 122.32MPa.

B. Hardness Test:

Brinell hardness test was performed on the 3 samples on various locations to find out the results of reinforcements in the sample1 the component with 2% zirconium dioxide and 2% silicon carbide has the hardness value of 93.4HRC and sample 2 with 6% zirconium dioxide and 2% silicon carbide has the hardness value of 78.3HRC and sample 3 with 6% silicon carbide and 2% zirconium dioxide has 77.5 HRC as hardness value which are higher than AA6061.

COMPOSITION	HRC
AA606196%SiC2%$ZrO_2$2%	93.4
AA606192%SiC2%$ZrO_2$6%	73.4
AA606192%SiC6%$ZrO_2$2%	77.5

Table 2 Hardness test table

C. Wear Test:

Wear test is to find out the wear rate of material over time. wear characteristic directly shows the micro hardness of the MMC . Pin on disc

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apparatus is used to calculate the wear characters here. The sample is machined to ASTM G99 standards and test is done by taking weight of the component before and after the test, load of 20kN time of 600 sec wear loss are noted to calculate the wear rate. Here the wear rate of sample 1 with 2% silicon carbide and 2% zirconium dioxide is found to be 0.00164 mm^3/m.

Wear test graph for sample 1

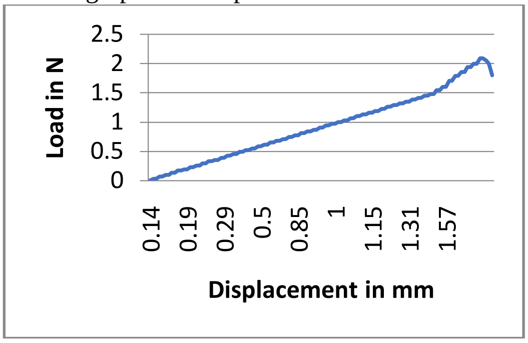

Fig 7 Wear test graph for sample 1

Co efficient of friction graph for sample 1

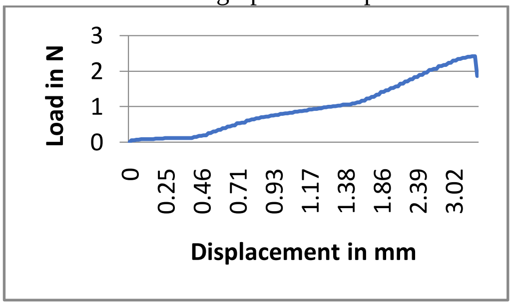

Fig 8 Co efficient of friction graph for sample 1

Friction factor graph for sample 1

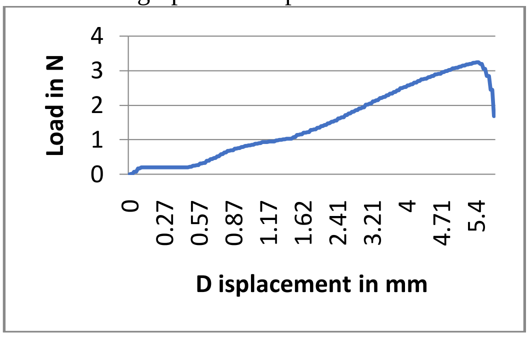

Fig 9 Friction factor graph for sample 1

D. Microstructural Study

A micro structure analysis is done to determine the proper mixing of the reinforcements. It is analyzed with optical microscope with 100x, 200x, and 500x.

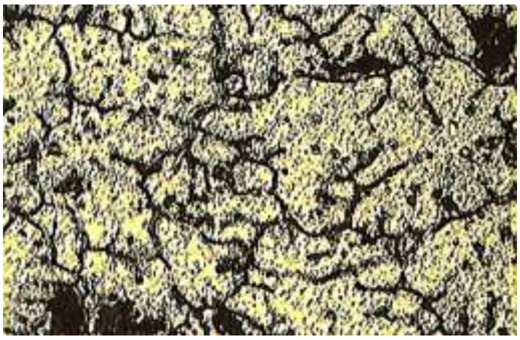

Fig. 10 Micro structural Image of SiC 6 % and ZrO2-2% 100x

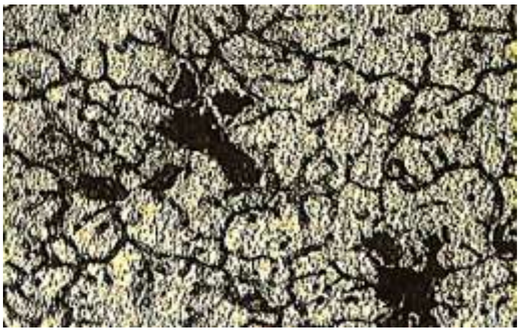

Fig. 11 Micro structural Image of SiC 6 % and ZrO2-2% 100x

Fig. 12 Micro structural Image of SiC 6 % and ZrO2-2% 100x

Magnification: 100X, 200X and 500, Enchant: Keller reagent solution.

Fig. 10 Shows the etched metal matrix composite with grains of primary aluminum matrix and its eutectic s Mg2Si. Along with the eutectic it is observed that the composite particles which are finer occupied the grain boundary sites.

Fig. 11 Same field which is further magnified to 200X and the composite particles are resolved.

Fig. 12 These photo micrographs are taken at 500X to resolve the composite particles trapped in the grains boundaries of primary aluminum grains. The grain boundaries show the composite particles at the grain boundaries and the grain boundary junction.

Photo-6 shows the particles trapped inside the grain boundary.

V.CONCLUSION

(1) Micro-structural Examination shows the presence Reinforcements. Also it is observed that uniform distribution of elements having weight % more than 10.

(2) The hardness of the developed composite is better than that of base alloy by 5-10 %

(3) Nearly 7 % increase in tensile strength is observed.

(4) The wear behavior shown reduction in mass loss and wear rate at higher loads. The influence of ZrO2 presence is clearly felt when the applied load is 20N.

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