(IJAER) 2016, Vol. No. 11, Issue No. I, January **e-ISSN: 2231-5152/ p-ISSN: 2454-1796**

EXPERIMENTAL INVESTIGATION OF MECHANICAL PROPERTIES OF ALUMINIUM ALLOY AL6063 BASED HYBRID METAL MATRIX COMPOSITE

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ABSTRACT

The present study deals with the investigation of mechanical properties of aluminium alloy (Al6063) based hybrid metal matrix composite reinforced with silicon carbide, magnesium and fly ash which were produced by stir casting method. The sample specimens were made by varying the percentage of reinforcement with respect to aluminium alloy. The evaluation of mechanical properties indicates variations in tensile strength, hardness and impact strength with respect to composite combinations. From the experimental results, it is inferred that, to obtain optimum tensile, hardness and impact properties, the percentage of aluminium, silicon carbide, magnesium and fly ash should be 90, 5, 5 and 0 respectively.

Keywords: aluminium; silicon carbide; stir casting; hybrid metal matrix composite; tensile strength

INTRODUCTION

A Composite is a combination of two or more dissimilar materials joined together such that the properties of the resultant material are greater than the individual components. Composite material is composed of two or more constituent phase (i.e): matrix phase and reinforcement phase. A Metal matrix composite is one of the types of composite in which the matrix phase is predominantly a metal or a metal alloy. The metal is the base material which constitutes the major part and the minor constituents are reinforcements that can be in the form of particles, whiskers, continuous and discontinuous fibers. The MMC consists of superior properties such as high strength, high stiffness, high electrical and thermal conductivity, greater resistance to corrosion, oxidation and wear when compared to the base material. A hybrid composite is one which involves more than two constituting materials.

Aluminium is an ideal material to be selected as a matrix as it consists of desirable properties like abundancy, low cost, low density, high strength-to-weight ratio, controlled co-efficient of thermal expansion, increased fatigue resistance and superior dimensional stability at elevated temperatures etc.

SELECTION OF MATERIALS

While selecting a material, one should be very meticulous and take utmost care so that it suits the specified application. It involves both the selection of matrix as well as reinforcement materials.

(a) Matrix

The matrix material to be used was chosen as Al6063 which is a precipitation strengthened aluminium alloy, containing magnesium and silicon as its major alloying elements as indicated in Table I. It has good mechanical properties and exhibits good weldability, good formability and high corrosion resistance.

Table I. Chemical Composition of Aluminium Al6063

Constituents	Percentage
Manganese (Mn)	**0.029%**
Iron (Fe)	**0.102%**
Copper (Cu)	**0.0073%**
Magnesium (Mg)	**0.5%**
Silicon (Si)	**0.431%**
Zinc (Zn)	**0.005%**
Chromium (Cr)	**0.0026%**
Others (Total)	**<0.001%**
Aluminium (Al)	**98.8%**

The properties of Al6063 were discovered by fabricating the alloy and testing under normal room temperature and subtle environmental conditions as stated in Table II .

Table II. Properties of Aluminium Al6063

Properties	Density	Melting point	Tensile strength	Brinell hardness	Izod Impact strength
Al6063	2.68 g/cc	665°C	142 MPa	68 H_B	6.5 Nm

(b) Reinforcement

- Reinforcements into the metallic matrix are hybrid in nature (i.e) more than two constituents. The
  selected materials for reinforcement are Silicon Carbide, Magnesium and Fly ash.
- Silicon carbide is a popular ceramic material which is characterized by high hardness, high compressive strength, high toughness and good insulating properties.

- Magnesium improves oxidation resistance, wettability and miscibility in the composite.
- Fly ash helps in overall weight reduction of the composite. Its composition is shown in Table III.

Table III. Composition of Fly ash

Silica (SiO_2)	**Alumina (Al_2O_3)**	**Calcium oxide (CaO)**	**Iron oxide (Fe_2O_3)**	**Magnesia (MgO)**
67.15%	29.5%	1.5%	0.15%	1.7%

General properties of Silicon Carbide are tabulated in Table IV.

Table IV. Properties of silicon carbide

Density	g/cc	3.12
Hardness	Kg/mm^2	2800
Melting point	°C	2200-2700
Fracture toughness	Mpa-√m	4.6

EXPERIMENTAL PROCEDURE

It deals with the fabrication of the metal matrix composite by stir casting method, shown in Fig. 1(a), which is best and inexpensive out of the all the available methods for producing metal matrix composites in large quantities and preferably large sizes. In this technique, the raw material of Al6063 which is in the form of round bar is placed in the graphite crucible inside electrical resistance furnace and melted with high temperature nearing 900°C. Then silicon carbide, magnesium and fly ash are thoroughly mixed together and

preheated at about 450°C and poured into the molten matrix at constant pour rate. Nitrogen is passed inside the crucible to avoid interaction of molten substance with atmosphere. Now the mixture is stirred with an electrical stirrer, maintained at uniform speed as shown in Fig. 1(b), for the even dispersion of reinforcement material inside the metallic matrix. Finally, the solidified composite is quenched with the help of air to reduce the settling time of the particles in the matrix after stirring is over. It is then cut into respective sizes and shapes for the conduction of tests as stated in Table V.

(IJAER) 2016, Vol. No. 11, Issue No. I, January **e-ISSN: 2231-5152/ p-ISSN: 2454-1796**

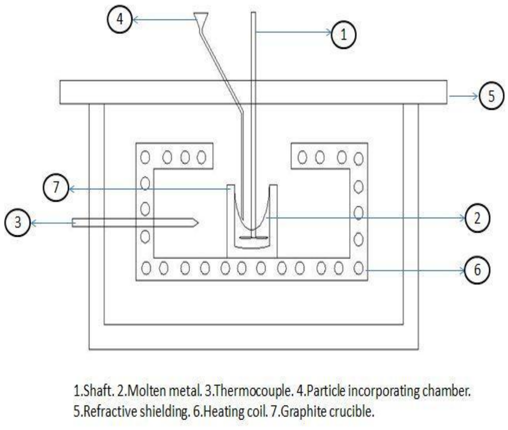

Figure 1. (a) Stir casting (b) Electrical stirre

Table V. Composition of the test specimens

Specimens	Weight of Al6063 in % (in grams)	Weight of SiC in % (in grams)	Weight of Mg in % (in grams)	Weight of FA in % (in grams)
A	100(1000)	0(0)	0(0)	0(0)
B	90(900)	10(100)	0(0)	0(0)
C	90(900)	5(50)	5(50)	0(0)
D	90(900)	5(50)	2.5(25)	2.5(25)

MECHANICAL TESTS AND RESULTS

The cast composite specimens are subjected to a series of mechanical tests such as tensile test, hardness test and impact test to ensure their mechanical properties. The corresponding results are tabulated and indicated in graphs

(1) Tensile test

Tension means “pulling force”. Fig. 2 shows an “Universal Testing Machine” (Model:-UTE-20, Sr. No:-10/2009-4191, Max Capacity:-200KN) to determine the tensile strength of the hybrid AMC composite specimens prepared as per Standard test methods for Tension testing ‘ASTM E8/E8M-13’ as indicated in Fig. 3.

Figure2. Universal Testing Machine

Figure 3. Tensile test specimens

After testing, the test results are tabulated in Table VI and the corresponding graph is drawn taking weight percentage on x-axis and tensile strength on y-axis as shown in Fig. 4.

Table VI. Tensile test results

Specimen	**Composition**	**Tensile strength (MPa)**
A	Al6063(100)	142
B	Al6063(90)+ SiC(10)	138
C	Al6063(90)+SiC(5)+ Mg(5)	145
D	Al6063(90)+SiC(5)+ Mg(2.5)+FA(2.5)	141

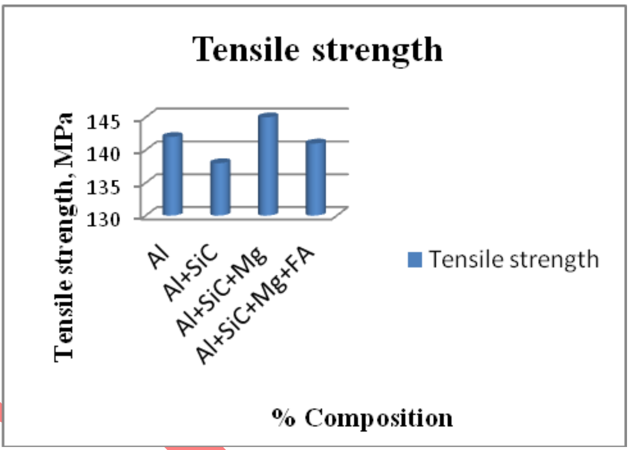

Figure 4. Tensile test results

Figure 4 shows the effect of weight fraction of various combinations of reinforcement materials on the tensile strength. The results show a fluctuation in tensile strength with the addition of reinforcement particles in which Al+SiC+Mg shows best result.

(2) Brinell hardness test

Hardness is the ability of the material to resist wear, scratching, abrasion and indentation. Brinell hardness test is done in the hardness testing machine to determine hardness number in the Al6063 based hybrid MMC specimens prepared as per Standard test methods for Brinell Hardness testing 'ASTM E10-14'.

In the brinell test, a steel indenter, having diameter of 5 mm is forced in the surface of the composite. Standard load of 250 kgf is supplied and maintained constant for 10 seconds and then removed. Brinell hardness number is calculated from the impression of the indentation.

After testing, the test results are tabulated in Table VII and the corresponding graph is drawn taking weight percentage on x-axis and brinell hardness on y-axis as shown in Fig. 5.

Table VII. Hardness test results

Specimen	**Composition**	**Brinell Hardness (H_B)**
A	Al6063(100)	68
B	Al6063(90)+ SiC(10)	72
C	Al6063(90)+SiC(5)+ Mg(5)	72
D	Al6063(90)+SiC(5)+ Mg(2.5)+FA(2.5)	71

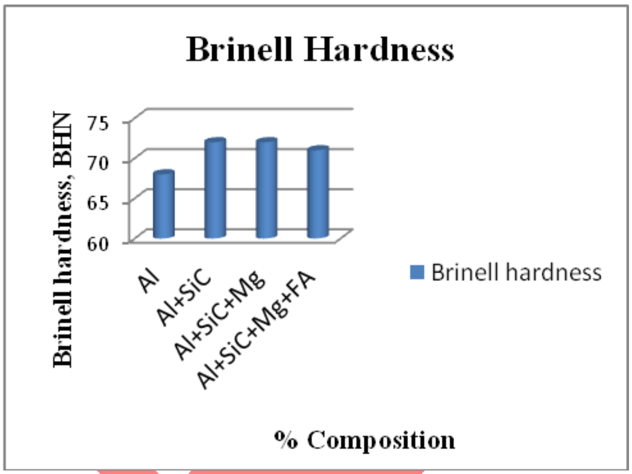

Figure 5. Hardness test results

Figure 5 shows the effect of weight fraction of various combinations of reinforcement materials on the hardness. The results show a fluctuation in hardness with the addition of reinforcement particles in which Al+SiC+Mg shows best result.

(3) Izod impact test

Impact strength is the capacity of a material to withstand blows without fracture [7]. The Izod impact test is done on the Al6063 based hybrid MMC specimens as in Fig. 6 as per Standard test methods for notched bar tensile strain Impact test method 'ASTM E23-12C' in Impact testing machine and the results are tabulated in Table VIII .

Figure 7 shows the effect of weight fraction of various combinations of reinforcement materials on the impact strength. The results show a fluctuation in impact strength with the addition of reinforcement particles in which Al+SiC+Mg shows best result.

Figure 6. An impact test specimen

Table VIII. Impact test results

Specimen	Composition	Impact Strength (Nm)
A	Al6063(100)	6.5
B	Al6063(90)+ SiC(10)	5.8
C	Al6063(90)+SiC(5)+ Mg(5)	6.7
D	Al6063(90)+SiC(5)+ Mg(2.5)+FA(2.5)	6.0

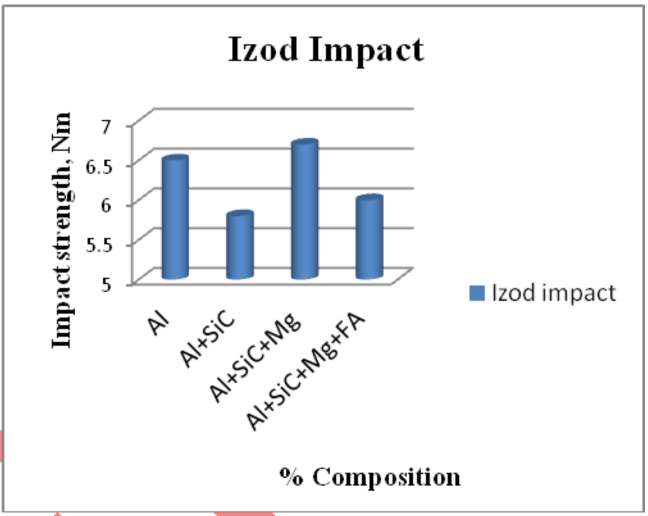

Figure 7. Impact test results

CONCLUSION

From the results it is clear that the best percentage of Aluminium, Silicon carbide and Magnesium is 90, 5 and 5 respectively that gives more desirable properties.

ACKNOWLEDGMENT

Our sincere thanks to Dr. Lakshmi Narayanan, Professor, Department of Mechanical Engineering, Annamalai University for providing fused zirconia alumina and the Department of Mechanical Engineering of Coimbatore Institute of Technology for permitting us to do Stir casting in their Production laboratory.

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