Aluminium hybrid metal matrix composites

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ABSTRACT

Silicon carbide-Graphite-Al6061alloy composite having 10 to 20% of silicon carbide and 5 to 10% graphite fibre were fabricated by liquid metallurgy (stir cast) method. The casted composite specimens were machined as per test standards. The specimens were tested to know the characteristics of the Hybrid Metal Matrix Composites (HMMc). Experimental study was carried out to investigate the mechanical properties such as hardness, tensile strength, shear test and impact test. As a result hardness decreases with the increase in the percentage of Gr, tensile strength, and shear test.

Keywords - *Hybrid metal matrix composite (HMMC), stir casting, Al6061, SIC, Graphite, Reinforcement, Hardness, Tensile strength, Compression strength.*

1. INTRODUCTION

In recent decades, composite materials have effectively substituted the customary materials in a few light weight and high quality applications. The reasons why composite are chosen for such applications are for the most part their elevated strength-to-weight proportion, elevated tensile strength at elevated temperature, elevated creep resistance and high toughness.

A composite material is a material system composed of two or more physically distinct phases, the properties of a composite as a whole are enhanced as compared with the properties of its components [1]. The technological and commercial interest in composite materials develop from the fact that their properties not just different than their components but they are superior. Composite material consists of two phases, primary phase and secondary phase. Matrix forms the primary phase within which secondary phase is imbedded. The imbedded is also known as reinforcing agent it improves the overall mechanical properties of the matrix. The reinforcing phase usually in the form of fibers, particles/particulates, flakes and fillers

2. MATERIALS

2.1 Aluminium 6061

The aluminium Al6061 grade was utilized as the matrix material. It was purchased from PMC Corporation, as blanks and was used for casting.

Aluminium is the third richest component after oxygen and silicon. It is extricable in character, reveals reasonable excellence and surpassingly corrosion resistance. They have been contemplated broadly in view of their mechanical significance and due to precipitation hardening it as got their excellent increment in quality.

2.2 Silicon Carbide

Silicon carbide (SiC) can be utilized as reinforcement in the form of particulates, whiskers or fibers to enhance the properties of the composite. SiC certainly improves the overall strength of the composite along with corrosion and wear resistance.

The wear resistance of carbides is very high, therefore the wear resistance of material obtained is high. Also, the hardness of the composites will increase. SiC are very hard as compared with Aluminium metals. If we add SiC in aluminium then they will increases the stiffness of the material.

2.3 Graphite

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Graphite is a crystalline form of carbon having a layered structure with basal parts planes or sheets of close packed carbon atoms. Consequently, graphite is a week when sheared along the layers. This characteristic, in turn gives graphite its low frictional properties as a solid lubricant. However, its frictional properties are low only in an environment of air or moisture, in vacuum graphite is abrasive and a poor lubricant. Unlike in other materials, strength and stiffness of graphite increase with temperature. Also, its small absorption cross section and elevated scattering cross section for thermal neutrons make graphite suitable for nuclear applications.

METHODOLOGY FLOW CHART

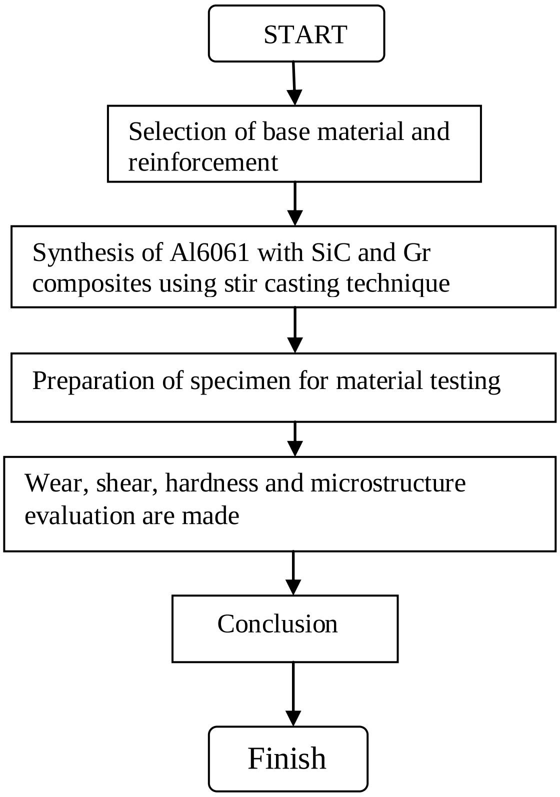

Fig-1: Methodology for production of hybrid

METHODOLOGY FLOW

From earlier work done by the researchers to fabricate the necessary composite to fullfill the needed property for a specific application and process of producing a composite material plays very important role and also method of analyzing the specimen plays a important role. In order to fullfill the objectives selected for the present work, the following methodology has been adopted.

Step1: Casting

In the present work Hybrid aluminium composites are created via stir casting, with varying percentage weight of reinforcement. The required amount of weighed aluminium ingots are melted in a graphite crucible and weighed reinforcement added to the molten metal and vortex is created in the molten metal by the help of the stirrer rotating at the constant speed, then the molten metal is allowed to fill the mould and the solidification takes at room temperature, then cast is taken out from the mould. The tensile, hardness, shear and impact test properties of the cast specimen are evaluated by conducting the experiment.

Step2: Tensile, Hardness, Shear and Impact evaluation

The specimens are subjected to wear, hardness and shear test to assess the wear rate, hardness, and shear strength of the specimens.

Step3: Micro Structural Analysis

The specimens and the fractured surfaces are analysed using scanning electron microscope to study the microstructure and distribution of reinforcements.

4. EXPERIMENTAL APPARATUS

4.1Fabrication of Hybrid aluminium metal matrix composites

Stir casting is utilized to fabricate the Al-SiC-Gr composite specimens with 10 to 20% weight fraction of SiC particles and 5 to 10% weight fraction of Gr particles. Al6061 alloy is selected as matrix material. Silicon carbide and Graphite are utilized as reinforcement. Aluminium alloy is made to a molten state in the furnace and then preheated reinforcement particles are added.

In order to obtain uniform distribution of SiC and Gr particles in aluminium matrix alloy, stirring is continued until the composite slurry obtained. After completing mixing for few minutes, the furnace temperature is slightly raised in order to have better fluidity for the composite slurry. Finally, castings of hybrid composites are produced using a split die. The same procedure is repeated for producing other composite specimens by varying the weight fraction of SiC-Gr.

FIGURE 4.1: STIR CASTING EQUIPMENT

4.2: MEASUREMENT OF TENSILE STRENGTH

The tensile tests were conducted using standard computerized Universal Testing Machine. The machine is of 20 KN capacities with a loading rate of 0.02 mm/sec. The equipment is best suited for tensile, compression, and Shear, Flexural properties of different materials. The tensile test was performed in accordance with ASTM–B557 for standard Aluminium alloy. From the tensile strength tests, the effect of reinforcement on the tensile strength and ductility of composite materials can be studied. Fig4.2 shows the tensile testing machine and fig.4.7 shows the specimen geometry as per ASTM B557 Standard.

Figure 4.2: Computerized tensile Testing Machine

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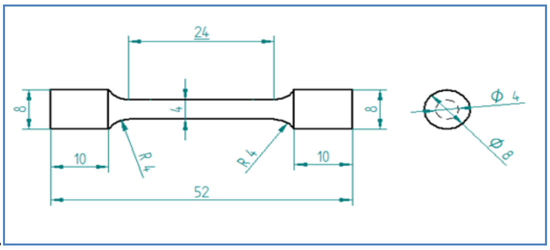

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Fig 4.2.1: Tensile specimen ASTM B557 standard, all dimensions are in mm

4.3: HARDNESS TEST

Hardness can be defined as the resistance to the indentation. Hardness is not a physical property but it is a characteristic of a material. The hardness can be determined by measuring the permanent depth of the indentation

Rockwell is the most common method used for testing. Instead of other hardness testing instrument Rockwell testing equipment can be used since it is easier, accurate to perform. By producing the indentation by load or force on an indenter permanent depth can be measured. Specimen size of 20mm length and 20mm diameter is used for testing.

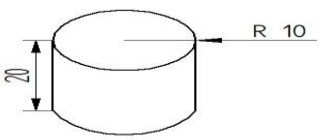


Figure 4.31: Hardness specimen

4.4 SHEAR TEST

A force acting parallel to the plane gives rise to a shearing stress. Shear testing is performed to determine the shear strength of a material. It measures the maximum shear stress that may be sustained before a material will rapture. The stress necessary to create rupture in the plane of cross section, acted on by the shear force is called shear strength

Specimen size of 85mm length and 10mm diameter is used for shear testing.

$$\text{Ultimate shear strength} = \frac{P}{2A} \text{ N/mm}^2$$

Figure 4.4.1: Universal Testing Machine

Figure 4.4.2: Shear Box

Figure 3.14: Hardness Testing Equipment

4.6 SCANNING ELECTRON MICROSCOPE (SEM)

Scanning electron microscope is a magnifying instrument that utilizes electrons rather than light to develop an image.

The SEM has a abundant points of attention over conventional microscopes. A greater amount of specimen can be focused at one time with the help of extensive depth of field in SEM. Firmly dispersed specimens can be magnifies at much more superior levels due to much advanced resolution of SEM. Instead of using lenses, SEM uses electromagnets therefore the explore has much further control in the level of intensification. All of these compensation and moreover real noticeably apparent images, build the scanning electron microscope device a show tester was 15 kg at dwell time of 10seconds for each sample up amongst the finest research instrument at present. tester was 15 kg at dwell time of 10seconds for each sample.

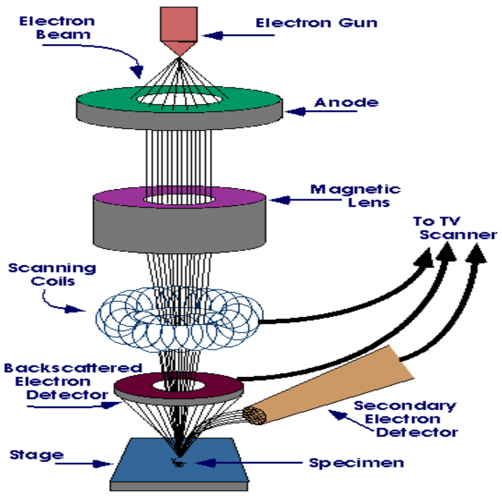
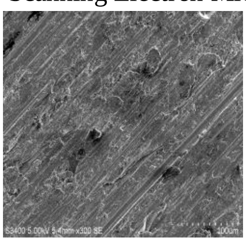


Figure 3.14: Scanning Electron Microscope

5 RESULTS AND DISCUSSIONS

5.1Microstructure Analysis

5.1.1 Scanning Electron Microscope



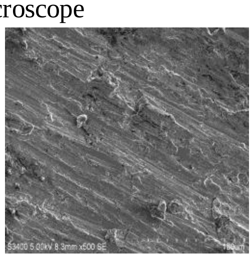


Fig5.2: Al6061 **Fig 5.1: Al6061+Sic10%+Gr5%**

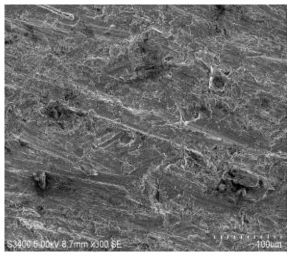


Fig 5.3: Al6061+Sic20%+Gr10%

Hardness Test

Hardness measurement is made by using Rockwell hardness tester machine. The surface being tested generally requires a metallographic finish and it was done by using 600 and 100 grit size emery paper. Load used on Rockwell's hardness tester was 15 kg at dwell time of 10seconds for each sample.

The result of Rockwell hardness test for the specimen HAMMCs and base metal are given below in Table 4.1

Table4.1-Hardness measurement of sample

Sample No.	Sample Name	Hardness value
1	Al6061	28
2	Al6061+Sic10%+Gr5%	78
3	Al6061+Sic20%+Gr10%	115

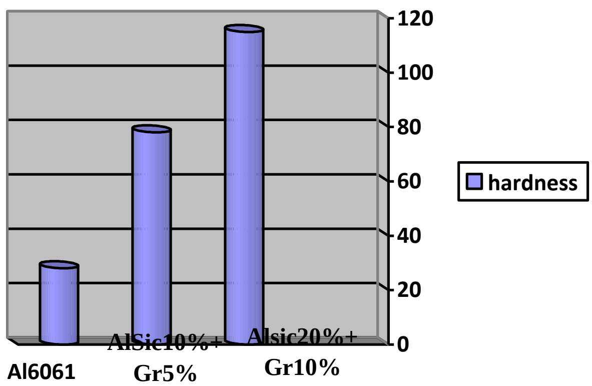


Figure 4.1: Hardness measurement of samples

Figure 4.1 shows the hardness of Al alloy and Al based MMCs reinforced with Sic and Gr. It is observed from fig4.1 that the hardness of aluminium alloy is less than that of SiC and Gr reinforced composite. As the percentage of reinforcement increases the hardness also increases.

Shear Test

Shear test has been carried out using universal testing machine (UTM) with the specimen of dimension 85mm length and 10mm diameter.

Serial No.	Specimen	C/s area in mm^2	Ultimate shear load in KN	Ultimate shear strength in N/mm^2
1	Al6061	78.53	18.9	240.67
2	SiC10%+Gr5%	78.53	20.7	263.59
3	SiC20%+Gr10%	78.53	22.6	287.78

Table4.3: Shear measurement of samples

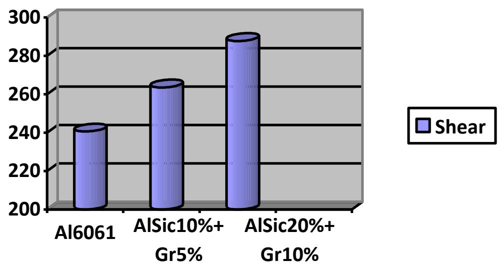
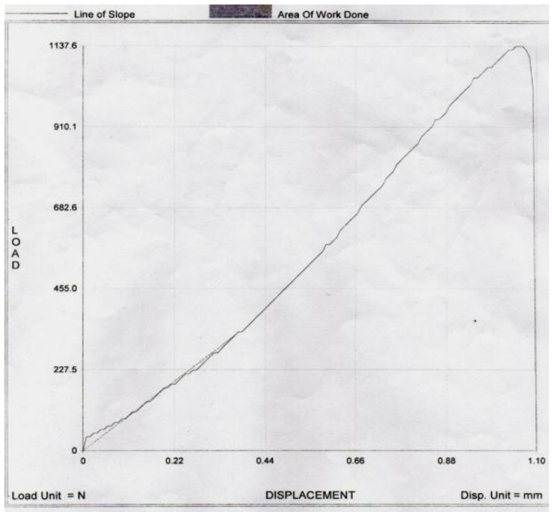


Fig4.2: Ultimate shear strength for samples

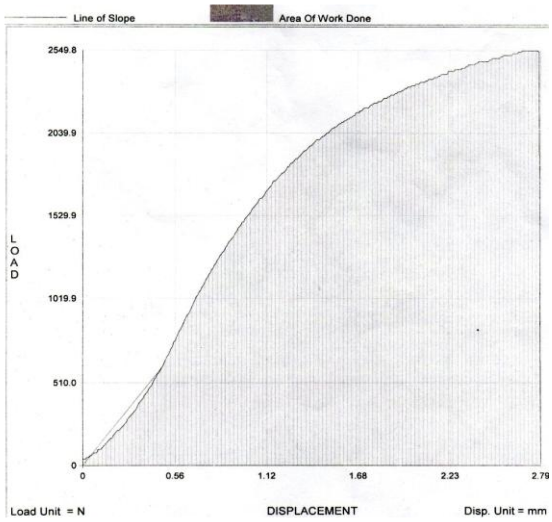
Fig4.2 shows the ultimate shear strength of Al alloy and Al reinforced with SiC and Gr for samples. As the percentage of reinforcement increases shear strength is also increases in the samples.

TENSILE STRENGTH

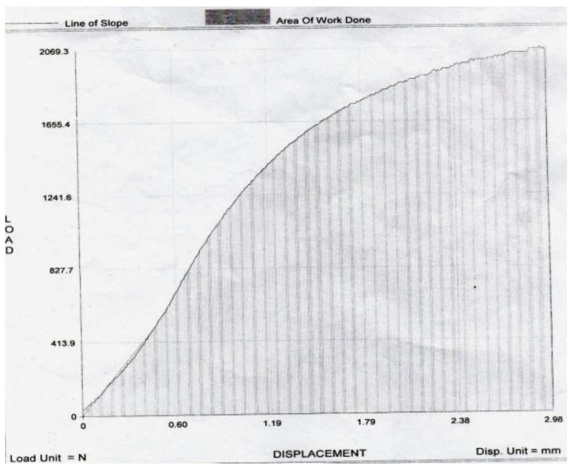
The cast hybrid composite are subjected to tensile test as per ASTM B547 standard. Fig 5.3 (a), (b) & (c) show the load-displacement curves and fig 5.4 (a), (b) & (c)shows the stress-strain diagram of as cast specimens with 0%, 10% & 20% SiC& 0%, 5%& 10%of Gr respectively. From the load-displacement curves and stress-strain diagram Tensile strength and strain to failure of the cast composites have been calculated and are shown in Fig5.5, 5.6 & 5.7 respectively.



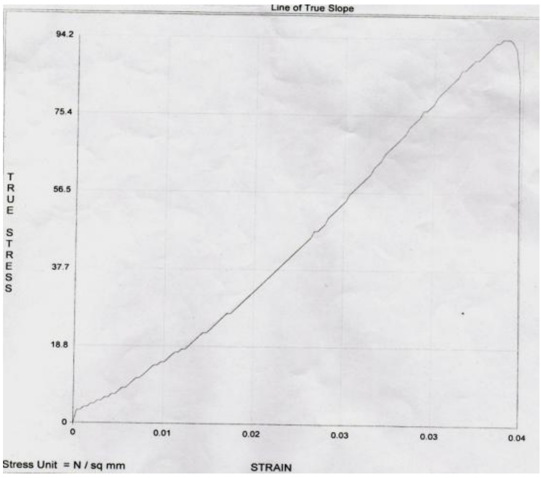
(a): Load v/s Displacement (elongation) of 0% SiC & 0% Gr



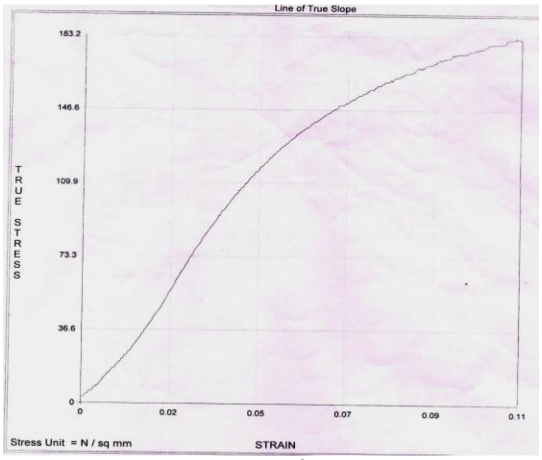
(b): Load v/s Displacement (elongation) of 10%SiC & 5% Gr



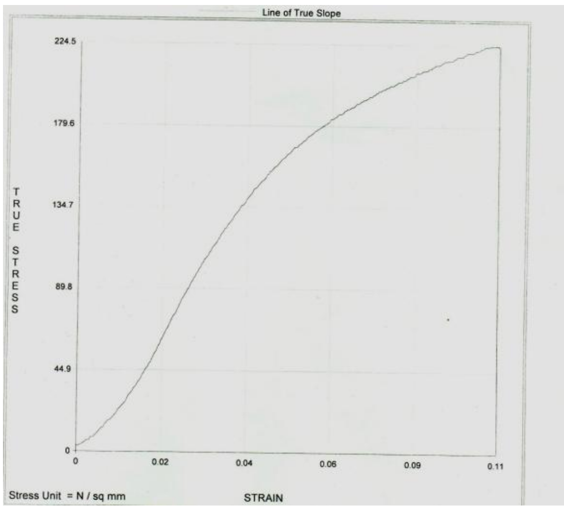
(c): Load v/s Displacement (elongation) of 20% SiC& 10% Gr



(a): Stress-Strain diagram of 0% SiC& 0% Gr



(b): Stress-Strain diagram of 10%SiC & 5% Gr



c): Stress-Strain diagram of 20% SiC &10% Gr

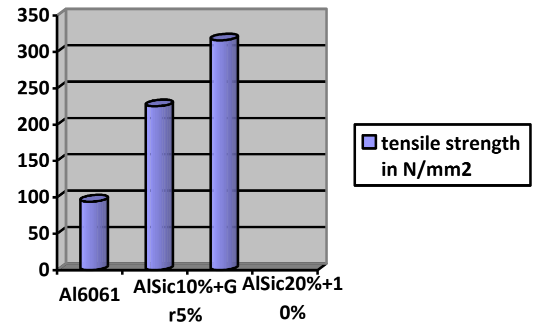


Figure 5.5: Tensile strength of base alloy Hybrid Composite

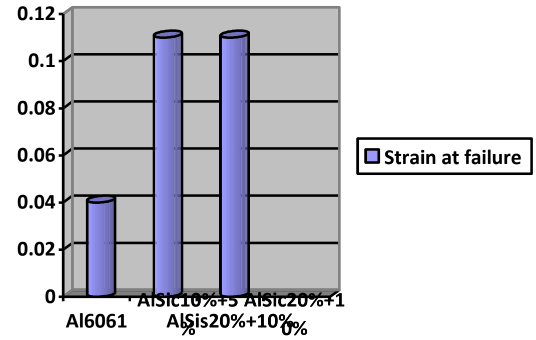


Figure 5.6: Strain at failure of base alloy Hybrid Composite

The tensile strength of the composite increased with increase in SiC particles shown in Fig. 5. The tensile strength of the composite material improved by 5%, with an addition of 3 wt% of SiC and graphite particles. The reinforcement of the particle in alloy plays a significant role in overall strength of the composite. The increase in strength of the matrix enhances the mechanical properties of the composites.

CONCLUSIONS

From the experimental investigation, the following conclusions were drawn to study the influence of percentage composition of SiC and graphite particulates in Al6061 Aluminium matrix and from the microstructure and mechanical characteristics of hybrid aluminium composite.

1. Al6061 hybrid composites have been successfully fabricated by stir casting method with uniform dispersion of SiC and Gr particles.

2. The hardness of hybrid composites increased upto 10 to 15% with addition of SiC and Gr.
3. The addition of weight percentage of SiC and Gr to Al6061 leads to increase in tensile strength about 30-50%.
4. The shear strength of the hybrid composite increased about 10 to 20 %.

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