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Effect of Silicon Carbide and Graphite on Aluminium Metal Matrix Composites

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Abstract - Reinforcement of aluminium metal matrix composites finds a major application due to their upgraded mechanical properties such as high specific strength, wear behavior, corrosion resistant and frictional characteristics. Few investigations have been reported on the mechanical characteristics. The purpose of this study focuses on the significance of adding silicon carbide (SiC) as first reinforcement and graphite particulates as the second reinforcement on aluminium metal matrix composites. Thus the mechanical behavior of the hybrid is tested by fabrication of AMMC by varying weight percentage of SiC (2.5% - 7.5%) and graphite (2.5% - 7.5%). In this case fabrication is done using stir casting method. The static testing like tensile, hardness and impact are conducted. Furthermore microstructure analysis is performed on the sample. Result obtained shows maximum hardness have been accomplished at 90%, 7.5%, 2.5% of aluminium, silicon carbide, graphite respectively.

Key Words: AMMC, Silicon Carbide, Graphite, Stir casting

1.INTRODUCTION

The Composite materials are manufactured by joining two or more materials that have different physical and chemical properties. These materials combine together to form the composite desired properties but within the composition they do not blend together. Generally composites remains in nature. Wood is one of a composite with long fibres of cellulose and lignin. Binding strength of the lignin makes a wood much stronger than fibres. At present composites are manufactured for properties other than increased strength or different mechanical properties. Composites are fabricated to be good conduction or insulation of heat energy or to have particular magnetic properties properties. These composites are widely applied in a huge range of electrical devices like sensors, detectors, diodes and lasers as well as to make anti-corrosive and anti-static surface coatings. Here in this paper Al-SiC-Gr composite is to be fabricated. First the properties of aluminium can be described as physically, chemically and mechanically similar to steel, brass, copper. It can be formed and machined in a similar to above metals and also conducts electric currents. Light weight of aluminum with a specific weight of 2.7 g/cm3, about a third of that of steel. This drastically reduces the costs of fabricating aluminum. Corrosion resistance of aluminum creates a protective thin oxide coat which isolates from contact with the environment. Also a good heat, electricity conductor and increased tensile strength as temperatures drop. Aluminum is non-magnetic, making it useful for electrical shielding and non-toxic. Arvind M. Sankhla et al. [12] concludes that addition of SiC particulates show hardness improvement in the material. Silicon carbide (SiC) has great resistant to wear and also consist of good mechanical characteristics. Technically it is a ceramic material is produced in two major ways. SiC maintains high mechanical strength temperatures upto 1,400 degree Celsius and high chemical corrosion resistance. Graphite is a unique material has the properties of both metal and non-metal. Graphite is flexible but not elastic and has high electrical and thermal conducting ability. Additionally chemically inert and highly refractory characteristics. Shubhranshu Bansal et al. [1] addition of Gr and SiC in aluminium gives the increased wear resistance. Suresh .S et al. [9] concludes in tribological application Al-SiC-Gr should be preferred due to wear properties. This unusual combination of desired properties is because graphite's crystalline structure. Its atoms bonds covalently, at the same time layers are loosely attached by van der Waals forces. Among the matrix materials available today, aluminum and its alloys are commonly used in the manufacturing of MMCs and have reached the production. Al MMCs with different soft and hard reinforcements because of these combinations forming highly desirable composites. Graphite, in the form of fibers or particulates, has long been recognized as a high-strength, low-density material. Aluminum graphite particulate MMCs produced by stir casting process results superior properties such as the low coefficient of friction and low wear. This leds to increased interest on evaluating Al MMC by changing volume fraction of SiC, graphite, Al6061.

2. Fabrication by Stir Casting

Fabrication of metal matrix composites fall under two categories, they are liquid and solid phase. Suryanarayanan K. et al. [11] describes that solid and liquid phase manufacturing used seen from the literature. Prasad Reddy .A et al [6] discusses about the fabricating techniques in which stir casting method has major advantages over other techniques in metal matrix composite fabrication. Solid methods includes such as rolling, extrusion, hot iso static pressing and cold iso static pressing. Liquid phased methods involves molten metals by stir casting and squeeze casting. This study suggests the advantage of using liquid manufacturing method for fabricating Al-SiC-Gr. Casting is highly cost efficient processes of fabricating metallic components. In this present work the metal matrix composites is prepared using the stir casting technique. Schematic diagram of stir casting setup is shown in fig -1.

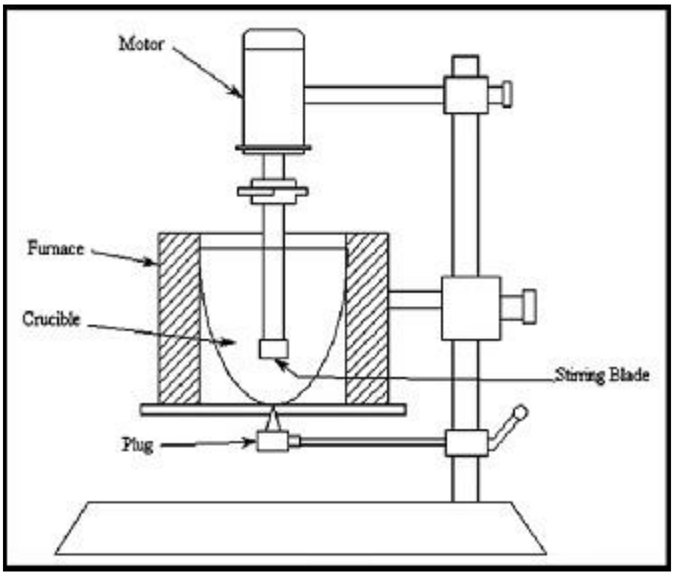

Fig -1: Schematic Diagram of Stir Casting

Preparation of Aluminium silicon carbide composite by stir casting on the basis of three volume fraction ratio. In this study we take three samples with different composition. Composition is altered for Al6061 (90%), SiC (2.5-7.5%) and Graphite (2.5-7.5%).The raw materials and samples of Aluminium are in ignots, Silicon Carbide and Graphite in the form of particulates is used. Gubbala Eshwar Kumar et al. [14] concluded that temperature at which material plays a crucial role in the physical strength of the cast and occurance of blow holes reduces the strength as well. Before casting process preheat of aluminium and SiC set up to a temperature of 450 °C and 1100 °C in oven respectively. Crucible is heated to 760 °C which is used for composite slurry pouring in the mold. Here stir caster was created to manufacture MMC. To obtain 600 rpm output. whole melting process was done in a graphite crucible in a gas furnace. Aluminium were pre heated at 450 °C upto 3 - 4 hours before melting additionally SiC particles also pre heated at 1100 °C upto 1 - 3 hours to make oxidized surfaces. At first temperature of furnace was increased above the liquidus to completely melt the alloy then cooled just below liquidus to maintain as semi-solid. Here the preheated SiC were added then manually mixed. Manual mixing due to difficulty in mixing via automated machine because of semi-solid state of alloy. After the above process composite slurry were reheated to a full liquefied state automated mixing was conducted for good 10 minutes at rate of stirring as 600 rpm. At final mixing temperature of furnace was controlled within 770 °C. The composite slurry pouring has been done in the sand mould prepared as per the dimensions needed for hardness, tensile and impact test. Three casted samples with compostion are sample 1 with (90% Al-2.5% Sic-7.5%Gr), sample 2 with (90% Al-5% Sic-5%Gr) and sample 3 with (90% Al-7.5% Sic-2.5%Gr) obtained from stir casting in fig -2.

Fig -2: Cast of Three Samples

3. Mechanical Testing

Failure of machines and its components occurs because of excessive deformation or fracture. In order to avoid such kind of failures engineers calculates the amount of stress can be expected and recommends the materials that can sustain anticipated stress. Mechanical properties like hardness, impact and tensile can be accomplished experimentally.

3.1 Hardness Testing

Hardness of material is not a physical property but a characteristic of a testing material. It is based on indentation resistance and identified by measuring fixed indentation depth. Simply, while applying a fixed force and by given indenter, smaller the indentation shows hardness of the material. Indentation hardness value is obtained by Measuring by the depth or else indentation area. Here fabricated three samples are tested individually and their brinell hardness value is noted. Sample to be tested for hardness is shown in fig -3.

Fig -3: Samples for Brinell Test

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Sample	Hardness (BHN)
1	28
2	35
3	39

Table -1: Hardness Test

Hardness test result shows sample 3 (90% Al-7.5% SiC-2.5% Gr) exhibit higher hardness number than other 2 samples.

3.2 Tensile Testing

Tensile strength of a material is ability to with stand tensile forces and also refers to the breaking strength of a material when enough force is applied at a steady load. It is typically measured in terms of units of force per cross-sectional area. As the name suggests, tensile strength of a material is resistance to tension that is resulted by mechanical loads.Tensile dimension is shown in fig -4 and samples to be tensile tested is shown in fig -5.

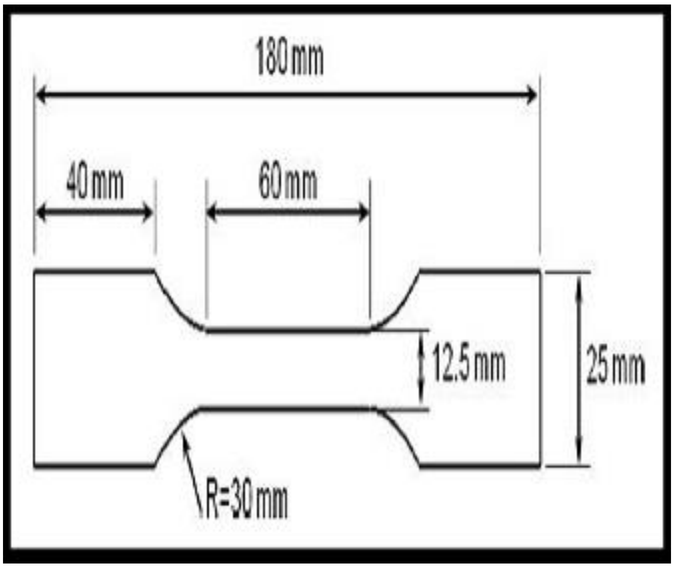

Fig -4: Dimension for Tensile Specimen

Fig -5: Samples for Tensile Test

Sample	Ultimate tensile strength (N/mm^2)
1	103.2
2	111.4
3	114.33

Table -2: Tensile Test

Tensile test result shows sample 3 (90% Al-7.5% SiC-2.5% Gr) exhibit higher tensile strength than other 2 samples.

3.3 Impact Testing

Observation of an impact test gives us an understanding of mechanics of that material will exhibit while it undergoes a shock load that makes the specimen to sudden deformation, fracture completely. In order to perform this test the secimen is fixed into a holding fixture with the dimension determined by type of the test that is tested and then a measured weight usually but not always in the shape of pendulum from known height is released so as to collide with the sample with a impact force. The collision between the sample and load generally results in destruction of sample but energy transfer in between these two determines the fracture mechanics. This energy can be used to measure the impact strength, toughness and fracture resistance. Specimen for impact testing is shown in fig -6.

Fig -6: Samples for Charpy Test

Sample	Impact strength (J)
1	6
2	8
3	11

Table -3: Impact Test

Impact test result shows sample 3 (90% Al-7.5% SiC-2.5% Gr) exhibit higher impact strength than other 2 samples.

SAMPLES	ULTIMATE TENSILE STRENGHT (N/mm2)	IMPACT STRENGHT (J)	HARDNESS (BHN)
SAMPLE 1 (90% AL-2.5% SiC-7.5% Gr)	103.2	6	28
SAMPLE 2 (90% AL-5%SiC-5%Gr)	111.4	8	35
SAMPLE 3 (90%AL-7.5%SiC-2.5%Gr)	114.33	11	39

Table -4: Experimental Values from Mechanical Testing

From the above experimental values for mechanical testing result shows sample 3 (90% Al-7.5% SiC-2.5% Gr) performs better than other 2 samples.

4. Microstructure Examination

Samples are cut from the stir casted rod. A HF solution was applied to etch the samples wherever needed. In order to observe the distribution difference of SiC and Gr particles in the aluminium matrix, Images of samples were taken on Optical type Metallurgical Microscope. All samples were developed using stir casting technique by taking varying weight fractions of SiC particles. Images shows the resulting homogeneous distribution of SiC and Gr particles.

Microstructures of stir casted Al-SiC-graphite particle composites are shown in Fig. 7, 8 and 9 with the composition of sample 1, 2 and 3 respectively.Below figures gives the clear idea of distribution of silicon carbide and graphite particulates and the micro structure of the matrix and homogeneous mixture of particles.

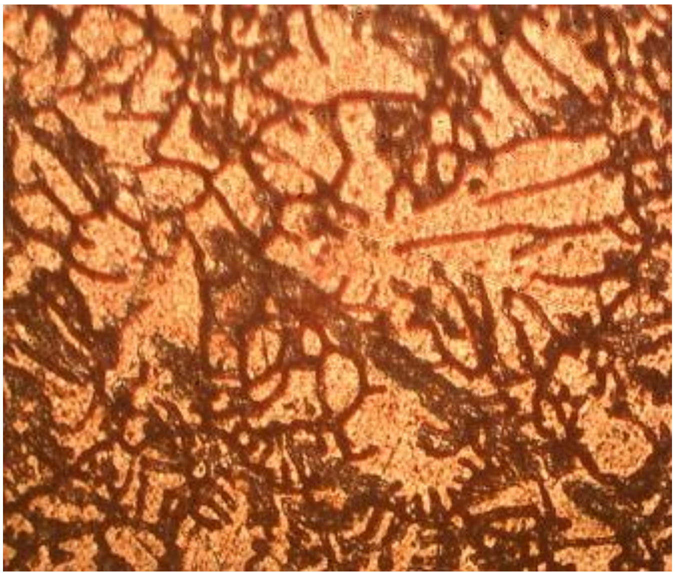

Fig -7: Microstructure Image of Sample 1

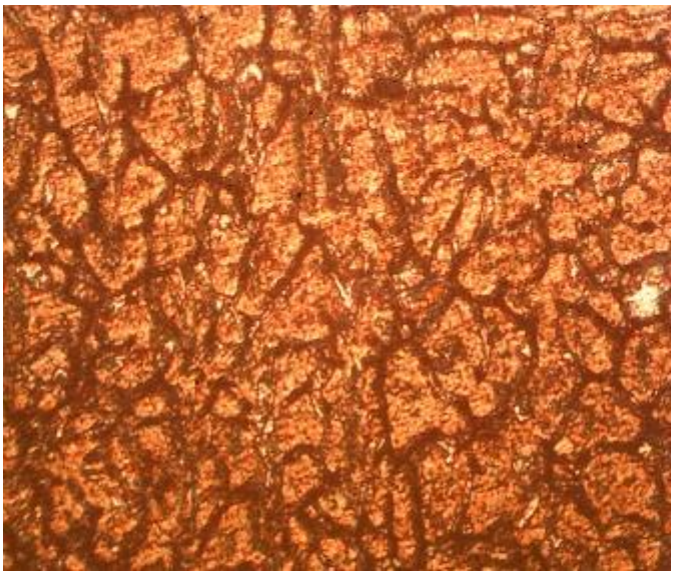

Fig -8: Microstructure Image of Sample 2

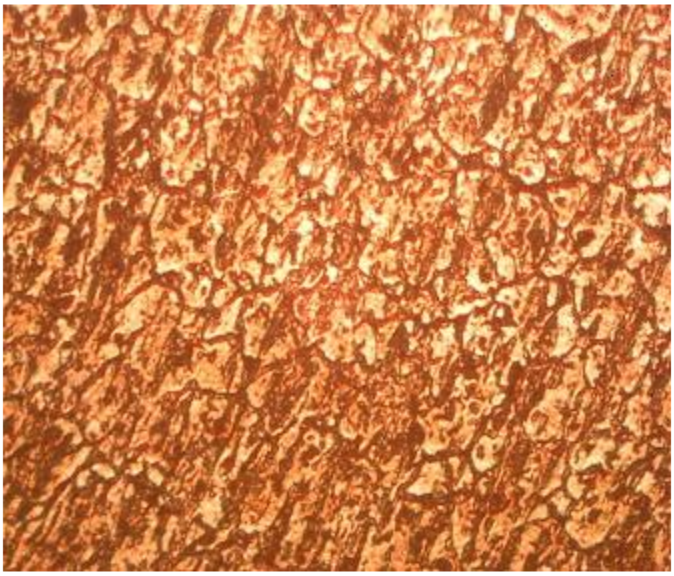

Fig -9: Microstructure Image of Sample 3

5. CONCLUSIONS

Reinforcement effect of SiC and Gr on the mechanical properties of Al6061 alloy were investigated here

- The hardness of Al MMC was increased by adding SiC and Gr particles in Al6061 alloy. The hardness is better in sample with 7.5% SiC - 2.5% Gr particles.
- Tensile strength of the composite increases with increase in SiC addition compared to base Al6061. SiC and Gr addition bonds very tight which results to withstand high load and decrease in percentage elongation. Sample with 7.5% SiC - 2.5% Gr exhibits better ultimate tensile strength.
- Impact strength is measured via Izod method. Here sample with 7.5% SiC - 2.5% Gr exhibits high toughness.
- Microstructure analysis of sample with 7.5% SiC – 2.5% Gr shows very fine cavities, grooves and micro cracks compared to other samples.

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