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CHARACTERIZATION OF ALUMINIUM MATRIX COMPOSITE REINFORCED WITH NANO GRAPHENE BY STIR CASTING METHOD

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ABSTRACT
In the present experimental study, aluminium metal matrix composite was studied with reinforcement of nano graphene at different percentages. The effect of graphene quantity (0.5, 1.0, 1.5 & 2.0 wt- %) on mechanical properties and distribution of graphene in the matrix material was studied and reported. The aluminium matrix composite can be produced by stir casting method. The experimental results revealed good hardness and ultimate tensile strength with aluminium graphene sample. The distribution of graphene was also studied and it is found that the uniform distribution of reinforcement in the matrix material plays a major role on the mechanical properties. In the present study it was observed that sample AG2 have the uniform distribution. With this experimental study it is found that the aluminium metal matrix composite reinforced with graphene can be produced by stir casting method. Composite fabricated with graphene has a positive effect on the mechanical properties.

Key words:
Aluminium metal matrix composites, nano graphene, stir casting, hardness, and ultimate tensile strength.

1. INTRODUCTION

Aluminium matrix composites are the class of metal matrix composites. Aluminium based composites are finding increased use in military, automotives and aerospace industries. In general these composites can be fabricated through various methods such as powder metallurgy, melting and squeeze casting [1-2].

Stir Casting is yet another method of producing aluminium matrix composites. It is a liquid state method of composite materials fabrication, in which a dispersed phase (ceramic particles, short fibers) is mixed with a molten matrix metal by means of mechanical stirring [3-5]. Stir casting is the simplest and the most cost effective method of liquid state fabrication.

Pistons are commonly made of cast aluminum alloy for excellent thermal conductivity and lightweight. Engine pistons are mostly made with aluminum alloy or aluminium material composites as they have low density and high thermal conductivity [6]. The continuous development of modern fuels leads to specific objectives for further piston development like reduction of piston weight, increase of mechanical and thermal load capacity and lower friction. These goals are achieved by high performance aluminium piston materials, novel piston designs and the application of innovative coating technologies [6-7]. New compositions of aluminium materials have to be studied so that to meet the development of new kind of fuels.

Graphene nano particles have drawn the attention of researchers due to its superior mechanical, thermal and tribological properties. Graphene has been used as a reinforcement material in the metal matrices such as magnesium, titanium, copper and aluminium for enhancing the properties [8-10]. However limited number of studies related to the mechanical properties of aluminium metal matrix composite reinforced with nano graphene. The present experimental study aims to examine the mechanical properties such as Vickers hardness, tensile strength and nano particle distribution in the aluminium metal matrix composite fabricated by stir casting method.

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2. MATERIALS USED FOR FABRICATION OF ALUMINIUM MATRIX COMPOSITE

2.1. Aluminium alloy A356

A356 alloys are ever more accepted in aircraft and automobiles due to their high strength-to-weight ratio. This has very good casting and machining characteristics. Aluminium alloy can be strengthened by reinforcing with ceramic materials [11]. The chemical composition of A356 aluminium alloy consist silicon (Si) 7.0%, iron (Fe) 0.15%, copper (Cu) 0.03%, manganese (Mn) 0.1%, magnesium (Mg) 0.3%, zinc (Zn) 0.1 %, nickel 0.05 %, Titanium (Ti) 0.1% and balance is aluminium.

2.2. Graphene

It is an abundant mineral which is an allotrope of carbon. Graphene is an allotropic form of carbon consisting single layer of carbon arranged in hexahedral lattice. It has the basic structure of the many other allotropic forms of carbon like diamond, charcoal, carbon nano tubes and graphite. It has very thin atomic thickness (0.345 nm), good strength, electrical properties, thermal conductivity and mechanical properties. Graphene can be used in place of carbon nano tubes as it is also an allotropic form of carbon. Particle size of graphene particle used in fabrication of composite was 3 to 6 nm.

3. METHODOLOGY

The fabricated stir casting setup is used for making metal matrix composite. The materials used for fabricating the aluminium matrix composite are aluminium A356 and graphene. The aluminium metal matrix composite was fabricated with the base metal as Al (A356) using nano graphene powder particles as reinforcement. The graphene powder was heated up to 200° C in order to avoid the moisture content and have a better mixability of the reinforcement in the matrix material. The matrix material aluminium was heated up to 800° C which is above the melting temperature of aluminium. Preheated reinforcement graphene powder was added to molten aluminium matrix material. The mixture is then stirred for 4 minutes at an impeller speed of 400 revolutions per minute. The melt temperature was maintained at 800° C while adding the reinforcement. The molten mixture is then poured in to a preheated die for casting and made samples for characterization. The samples were made as per the proportions specified in the table-1. The mechanical characteristics of the aluminium metal matrix material were tested using tensile test, and hardness test. Figure 1 shows the methodology flow chart. Scanning electron microscopy was also carried out to know the distribution of reinforcement in the matrix material and to study the microstructure analysis of composite.

Table 1: Proportions for the specimen sample

SL NO	SAMPLE NAME	SAMPLE PROPORTION
1	AG1	99.5% Aluminium,0.5% of Graphene
2	AG2	99.0% Aluminium,1.0% of Graphene
3	AG3	98.5% Aluminium,1.5% of Graphene
4	AG4	98.0% Aluminium,2.0% of Graphene

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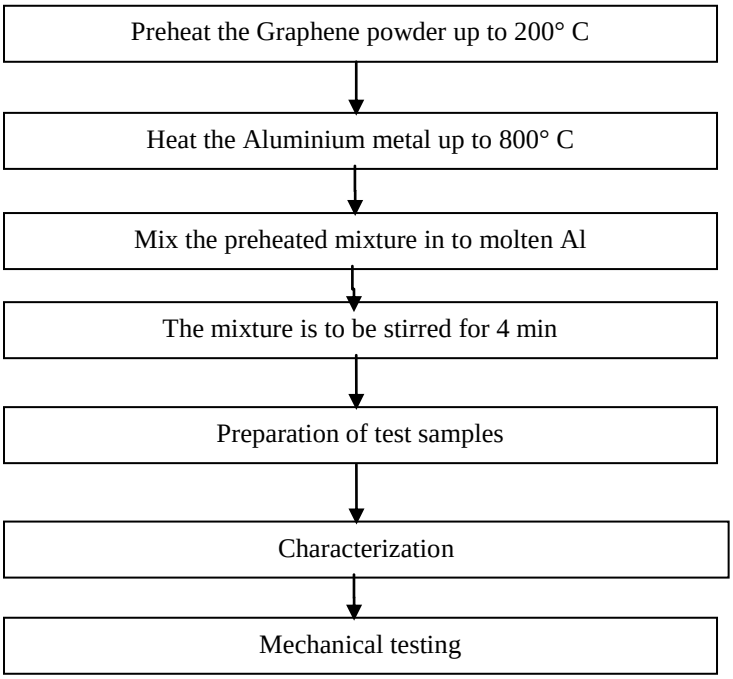

Fig. 1 Methodology flow chart

4. MICROSTRUCTURE OF ALUMINIUM METAL MATRIX COMPOSITE

To study the microstructure of samples, the specimens are grinded with grit papers thoroughly and polished with polishing paste made of alumina. Polished surfaces are cleaned properly with cleaning agents. By using scanning electron microscopy the microscopic structure was carried out on the specimens to estimate the uniformity of the distribution and porosity of the composite material. The following figure 2 shows the microstructures of specimens. The image source AG1 depicts the composite material with 0.5% of graphene. The dark fine particles are graphene. The dispersions are uniform at some locations and scattered at some fields. The distribution is lower in the matrix. The image source AG2 depicts the composite material with 1% of graphene. The dark fine particles are graphene. The dispersions are uniform at all the fields. All the fields show uniform mixing and distribution. The image source AG3 depicts the composite material with 1.5% of graphene. The dispersions are uniform at some fields. The distribution of graphene showed higher in the matrix. The casting showed no porosities. The image source AG4 depicts the composite with 2% of graphene. The dispersions are uniform but the fine nano particles of graphene thickened the grain boundaries.

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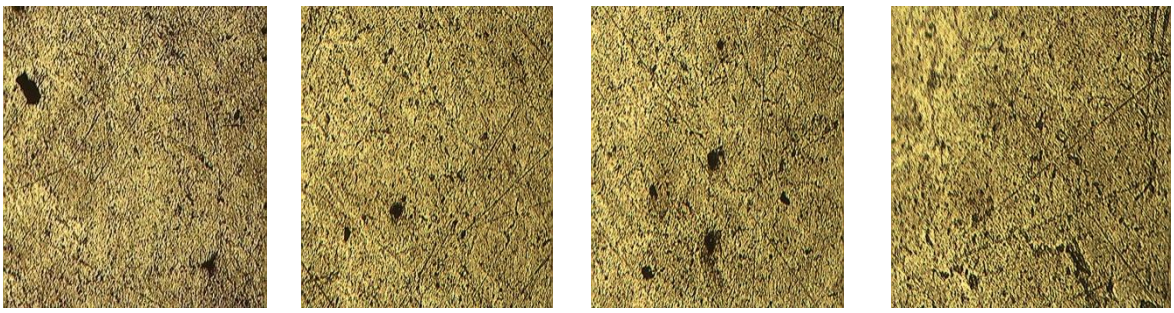

AG1 AG2 AG3 AG4

Fig. 2 Microstructures of Metal matrix composite of A356 & Graphene samples AG1, AG2, AG3 & AG4 (Magnification: 100X)

The sample AG2 have the uniform distribution and dispersion of graphene particles in the matrix material when compared to other samples. The casting with AG2 sample proportions showed no porosities.

5. MECHANICAL PROPERTIES

5.1. Hardness test

The hardness test carried out on Vickers hardness testing machine according to ASTM E92 standard. A diamond indenter was equipped in the testing machine. The indenter was in the shape of pyramid with a square base and produces an indentation on the specimen surface. The specimen was placed on the test platform and a load of 100 Kgf was applied on the specimen surface for 15 seconds. The load was then released and the indentation on the specimen was viewed using microscopic screw gauge. The two diagonals of indentation on the specimen surface were measured by using the microscope and their average was calculated. The procedure was repeated for four different locations on the surface of each sample. The Vickers hardness number was then calculated and the average value was taken as the hardness value of the specimen. Table 2 shows the hardness values of composite samples. The hardness values of composite were increased when the graphene percentage increases up to 1% after that a considerable reduction in hardness is observed. So out of the four samples the sample with 1% graphene shown the best result. The reduction in the value of hardness is may be due to agglomeration property of the graphene. Figure 3 depicts the bar chart representation of hardness values of aluminium metal matrix composite.

Table 2. Hardness values of aluminium metal matrix composite

Composite Name	**AG1**	**AG2**	**AG3**	**AG4**
Hardness (VH)	**68.66**	**70.66**	**67.66**	**65.33**

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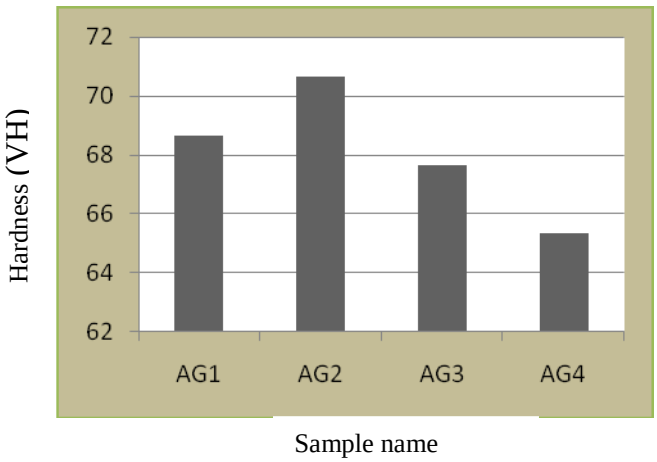

Fig.3. Hardness values of aluminium composite with graphene

5.2. Tensile test

Tensile test was performed on the sample specimens using universal testing machine. The specimens were machined as per ASTM –E8 standard. To carry out the experiment, the specimen was fitted in between the jaws of the universal testing machine. The tensile load was applied gradually on both ends of the specimen by pulling action at the speed of 0.5mm/min. the specimen broke after the formation of neck. The broken specimen was then removed from the machine.

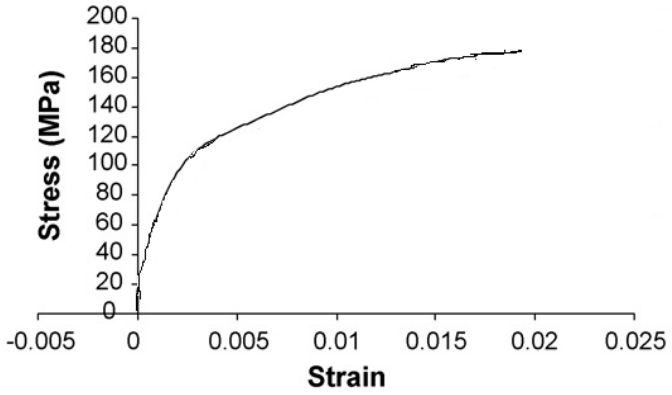

Fig. 4 Stress strain curve of Aluminium matrix composite with 1% Graphene

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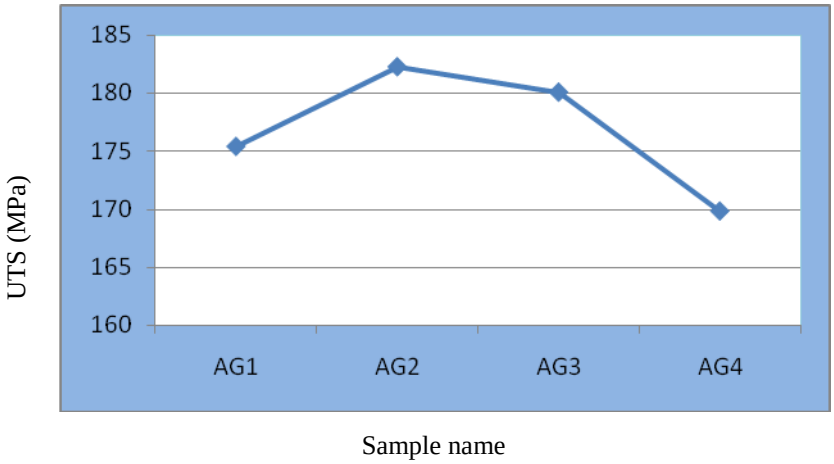

Fig. 5 The effect of graphene on Ultimate Tensile Strength (UTS)

The tensile strength values of composite were increased when the graphene percentage increases up to 1% after that a noticeable reduction in tensile strength was observed. So out of the four samples the sample with 1% graphene shown the best result. The reduction in the value of tensile strength is may be due to agglomeration property of the graphene. The figure -4 shows the stress strain diagram of AG2 sample. The figure 5 shows the effect of graphene percentage on the ultimate tensile strength of the aluminium matrix material composite. The maximum tensile strength observed is 182.3 MPa shown figure 5. Table 3 shows the ultimate tensile strength values of all samples of composite.

Table 3.UTS values of aluminium metal matrix composite

Composite Name	AG1	AG2	AG3	AG4
UTS (MPa)	175.4	182.3	180.1	169.8

CONCLUSION

The A356/graphene composite was fabricated with stir casting method with different percentage of graphene and the microstructure, mechanical properties were studied and evaluated the following conclusions.

The microscopic study revealed the presence of graphene in all the four samples with distribution. In the sample AG1 the distribution was not uniform due to less quantity of graphene. In the sample AG2, graphene was distributed uniformly and scattered with no porosity. The samples AG3 and AG4 the graphene was not distributed uniformly and found some porosity due to excess amount of graphene. Addition of graphene to the aluminium matrix improved the hardness and ultimate tensile strength when the graphene as added up to 1% after that a negative result was observed when the graphene percentage crosses 1%, this may be due to agglomeration property of the graphene. Aluminium matrix composite with 1% graphene has given the best results, due to uniform distribution of graphene with no agglomeration.

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