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Procedia Engineering 97 (2014) 918 – 924

Procedia Engineering

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12th GLOBAL CONGRESS ON MANUFACTURING AND MANAGEMENT, GCMM 2014

An Investigation on the Mechanical Properties of Hybrid Metal Matrix Composites

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Abstract:

Aluminium alloy materials found to the best alternative with its unique capacity of designing the materials to give required properties. Aluminium alloy Metal Matrix Composites (MMCs) are gaining wide spread acceptance for automobile, industrial, and aerospace applications because of their low density, high strength and good structural rigidity. In the present work, an attempt is made to prepare and compare the mechanical properties of Al6061-SiC & Al6061-SiC/Graphite hybrid composites. The composites were prepared using stir casting method in which amount of reinforcement is varied from 5-15% in steps of 5wt%. The prepared composites are characterized by microstructural studies and density, and mechanical properties were evaluated as per the standards. The microphotographs of the composites revealed fairly uniform distribution of the particles in composites with clustering at few places. The experimental densities were found to be lower than theoretical densities in all the composites. The dispersed Graphite and SiC in Al6061 alloy contributed in enhancing the tensile strength of the composites. The scanning electron micrographs of the samples indicated uniform distribution of the reinforcement particles in the matrix without any voids.

Selection and peer-review under responsibility of the Organizing Committee of GCMM 2014

*Keywords:*Metal matrix composites, Aluminium alloy 6061, hybrid composites.

1. Introduction:

Metal matrix composites (MMCs) are increasingly becoming attractive materials for advanced aerospace applications because their properties can be tailored through the addition of selected reinforcements [1]. Metal matrix composites have a market potential for various applications, particularly in the automotive industry where the pressure to use lightweight materials has increased because of environmental issues. Examples of components that have been manufactured using metal matrix composites include pistons for diesel engines and connecting rods [2].

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Selection and peer-review under responsibility of the Organizing Committee of GCMM 2014
doi:10.1016/j.proeng.2014.12.367

These materials have also been shown to possess great potential for applications in the brake disks for railway brake equipment [3]. Aluminium-based Metal Matrix Composites (MMCs) have received increasing attention in recent decades as engineering materials. The introduction of a ceramic material into a metal matrix produces a composite material that results in an attractive combination of physical and mechanical properties which cannot be obtained with monolithic alloys [4]. The various reinforcements that have been tried out to develop aluminium matrix composites(AMCs) are graphite, silicon carbide, titanium carbide, tungsten, boron, Al203, fly-ash, Zr, TiB2. Addition of hard reinforcements such as silicon carbide, alumina, and titanium carbide improves hardness, strength and wear resistance of the composites [1, 2-4]. Aluminium alloys are still the subjects of intense studies, as their low density gives additional advantages in several applications. These alloys have started to replace cast iron and bronze, to manufacture wear resistant parts. Previous studies have shown that mechanical properties of Al-matrix composites would be enhanced with particulate reinforcement [5]. The particulate reinforced MMCs is mainly used due to easy availability of particles and economic processing technique adopted for producing the particulate reinforced MMCs. Al alloy has been commonly used as a base metal for MMCs reinforced with a variety of fibres, particles and whiskers [6-7]. Amongst different kinds of the recently developed composites, particle-reinforced metal matrix composites and, in particular, aluminium base materials have already emerged as candidates for industrial applications [8-9]. Investigation of mechanical behaviour of aluminium alloys reinforced by micro hard particles such as Graphite is an interesting area of research.

Therefore, the aim of this study is to investigate the effects of different factors such as: (i) particle size (ii) weight percentage of the particles (iii) Fabrication process on the microstructure, mechanical and wear properties of the composites. Mechanical properties were evaluated as per ASTM standards using computerized universal testing machine

2. Experimental details

2.1 Materials Used

The matrix material for present study is 6061Al. The reinforcing material selected was silicon carbide particle of 37 μm Graphite of particle size 1μm.

2.2 Preparation of composites:

In this process, first the aluminium alloy was preheated at 450^0 – 800^0c for 2 hours in an electrical resistance furnace before melting. Reinforcing particulates (SiC) are preheated at 600^0 c for a soaking period of 2 hours s and graphite particles were preheated at 1100^0 c for a soaking period of 2 hrs to improve the wetness properties to remove the adsorbed hydroxide and other gases from the surface. Then the matrix is heated to above its liquidus temperature i.e. 750^0 c, so that the metal is totally melted. This melt is then cooled down to a temperature between the liquidus and solidus points and kept in a semi solid state. Prior to particle addition, Magnesium powder was added to melt to maintain the wettability. The melt was degasified by using solid hexachloroethane (C_2Cl_6).At this stage, the preheated particles are added in three steps i.e. Total amount of reinforcement was calculated and is being introduced into the melt 3 times rather than introducing all at once, and mixed manually for 10 min, because it was very difficult to mix using automatic device when the alloy was in a semi solid state. The slurry is again heated to a fully liquid state and then automatic mechanical mixing was carried out for 10 - 20 min at 200 – 400 rpm. In the final stage the temperature of the furnace was controlled at $760^0 \pm 100^0$c.Molds are to be preheated at 250^0 - 350^0 c for 2 hours before pouring the melt. The stirrer was preheated before immersing into the melt, located approximately to a depth of 2/3 height of the molten metal from the bottom and run at a speed of 200 rpm.Then the melt was poured into the mold at 730^0 - 800^0c.This novel mixing process results in uniform microstructure compared to conventional stirring, and also it breaks the thin gas layer around the particle surface, which impedes wetting between the particles and matrix. The gas layer around the particle surface breaks effectively, because of great abrasive action by the high melt viscosity.

After solidification the casting were taken out from the mould and were cut to required shape and sizes for mechanical and buckling testing as per ASTM standards. To ascertain the distribution of reinforcement particulates cut pieces of the samples were polished and were inspected under optical microscope.

3. Testing of composites:

3.1 Tensile strength:

The tensile behaviour of all the prepared samples was determined as per **ASTM B-557 M "Standard Test Methods of Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products"**.

3.2 Density:

The densities of the prepared specimens were investigated experimentally by the Archimedean's principle using sensitive electronic weighing machine having L.C of 0.1 mg, with a beaker of 100 ml distilled water.

3.3 Microstructure:

To ensure the distribution of the reinforcement in the matrix, microstructure characterization was investigated experimentally by using inverted metallurgical microscope.

the specimens were cut from the central portion of the composites, and then polished on the belt grinding machine for 2 mins, and next polished on a disc polishing machine with different grades of emery papers for 2 min each rotating the specimen 900 for every time, and then finally on a velvet disc polishing machine with Alumina paste for 5 min, and then etched with Keller's reagent to remove the burrs and foreign particles.

And then, the specimen was placed on the viewing stage of the inverted metallurgical microscope and then examined the microstructure with the monochromatic light source and photographs of microstructure was captured at magnification of 50X, 100 X and 500 X.

3.4 SEM analysis:

SEM analysis was carried out on the composites for morphology of the composite, to ensure distribution of particles in the matrix, as per the standards

4. Results and discussions:

4.1 Tensile test:

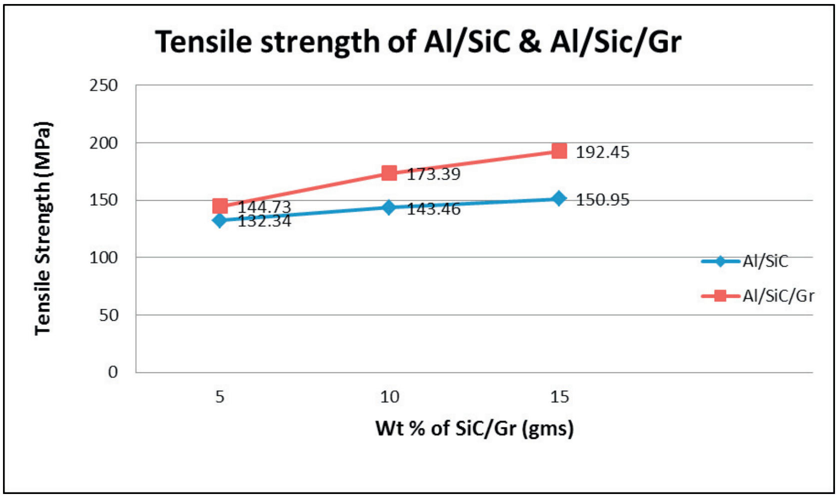


Fig 1. Tensile strength of Composites

From the fig 1, its shows that the tensile strength of the composites increased with increase in weight fraction of reinforcement, and the tensile strength is more in hybrod composites than single reinforcement.

4.2 Density:

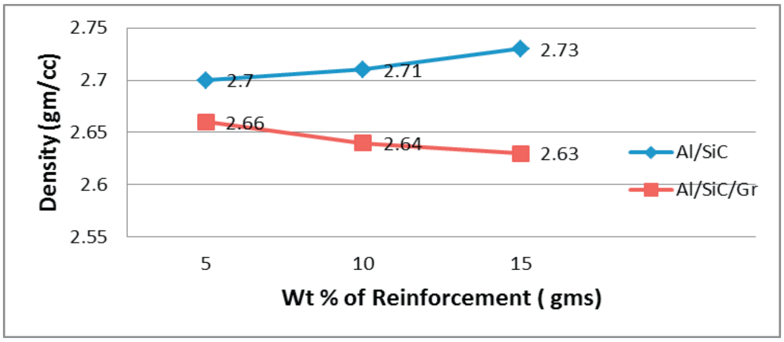
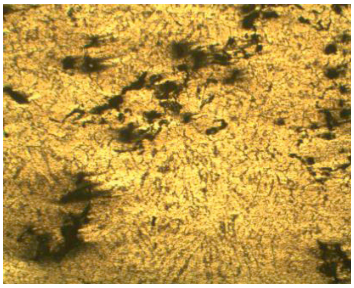


Fig 2. Tensile strength of Composites

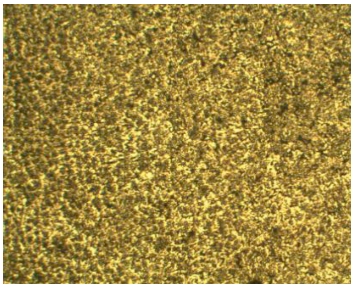
From the fig 2, it shows that, on increase in wt% of SiC, the density increases and on increase in wt % of combined SiC and Gr , the density of the composite decreases because of presence of graphite.

4.3 Microstructure:

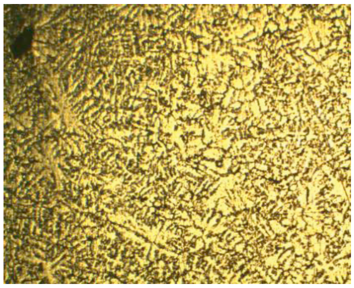
A) Microstructure of Al/SiC MMC



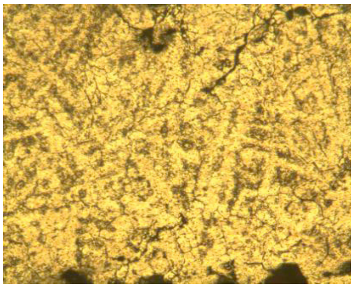
a) 5 % SiC at 50X



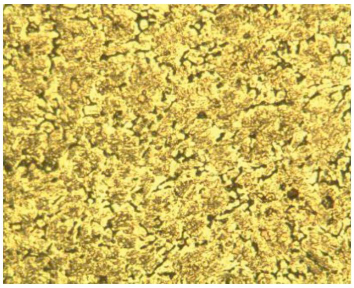
e) 10 % of SiC at 50 X



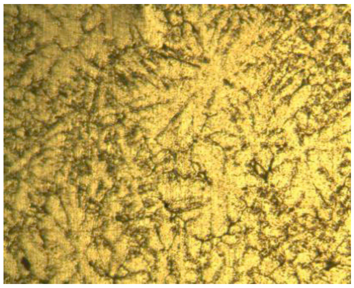
i)15 % of SiC at 50 X



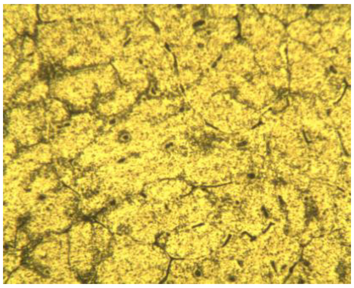
b) 5 % of SiC at 100X



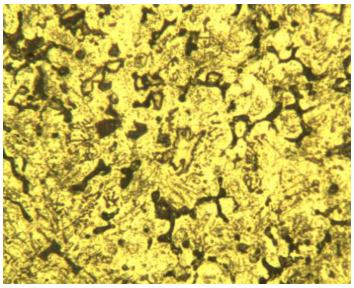
f) 10 % of SiC at 100X



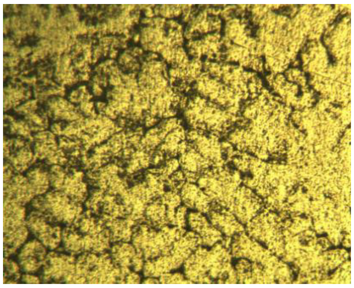
j) 15 % of SiC at 100X



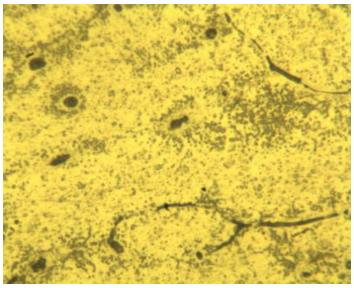
c) 5 % of SiC at 200 X



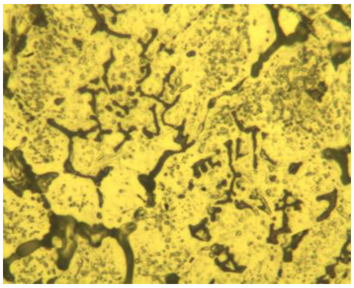
g) 10 % of SiC at 200 X



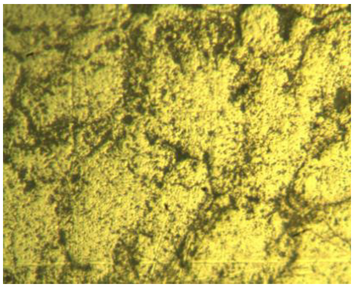
k) 15 % of SiC at 200 X



d) 5 % of SiC at 500X



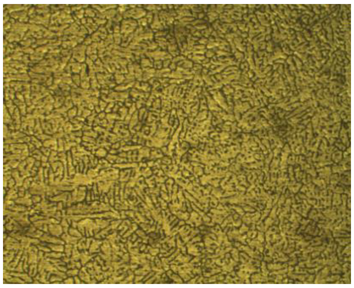
h) 10 % of SiC at 500X



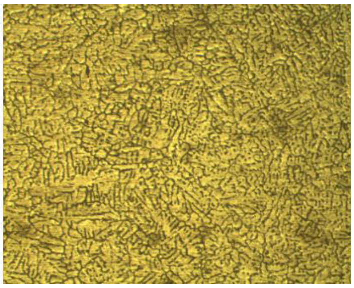
l)15 % of SiC at 500X

Fig 3 Optical microphotographs of Al/SiC MMCs

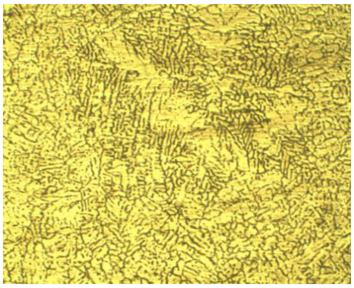
B) Microstructure of Al/SiC MMC



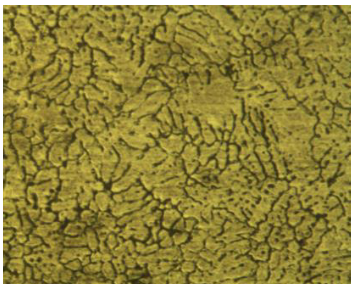
a) 5 % SiC/Gr at 50X



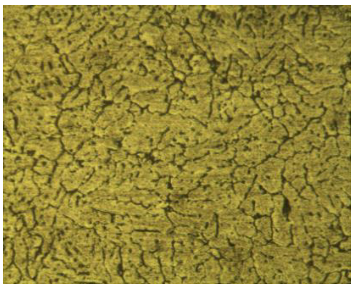
e) 10 % of SiC/Gr at 50 X



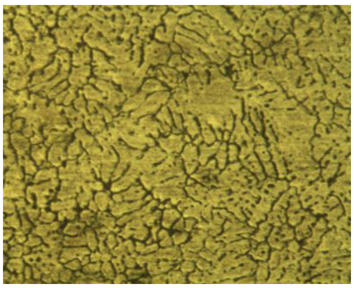
i)15 % of SiC/Gr at 50 X



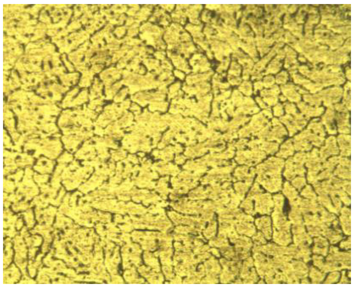
b) 5 % of SiC/Gr at 100X



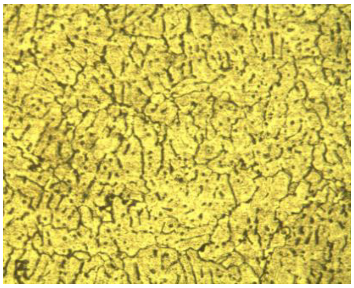
f) 10 % of SiC/Gr at 100X



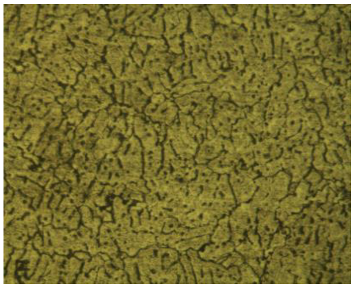
j) 15 % of SiC/Gr at 100X



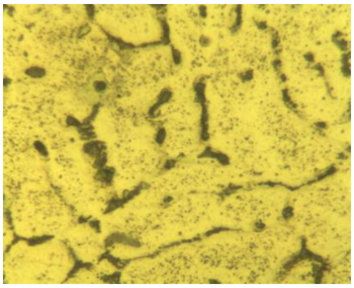
c)5 % of SiC/Gr at 200 X



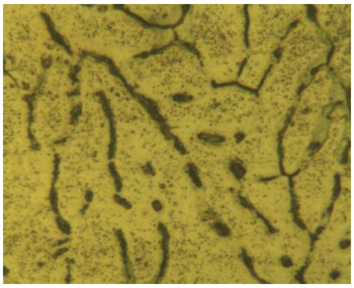
g) 10 % of SiC/Gr at 200 X



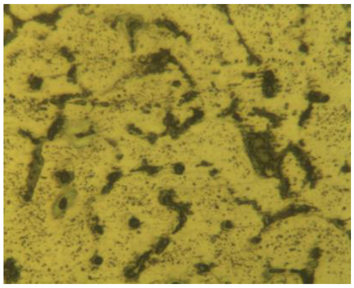
k) 15 % of SiC/Gr at 200 X



d)5 % of SiC/Gr at 500X



h) 10 % of SiC/Gr at 500X



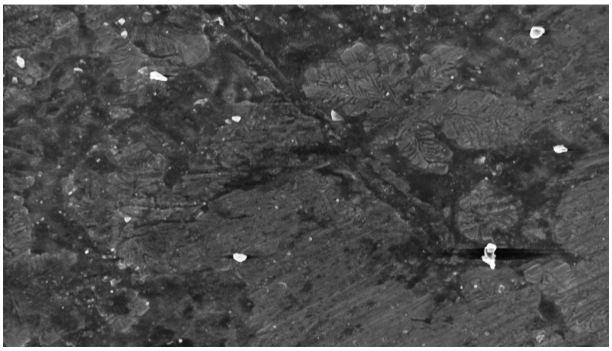
l)15 % of SiC/Gr at 500X

Fig 4. Optical microphotographs of Al/SiC/Gr Hybrid MMCs

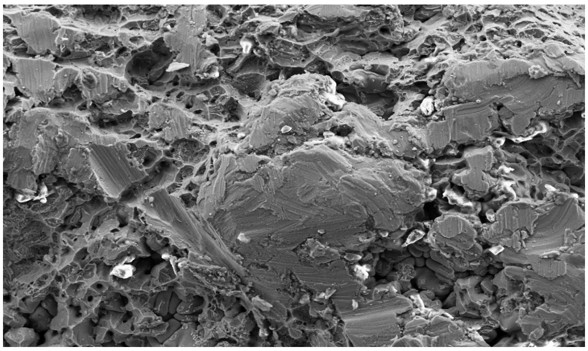
From the fig 3 & 4, it is observed that uniform distribution of reinforcement takes place in the matrix.

4.4 SEM analysis:

Electron microscopy of the composite surface was carried out to know the morphology of the composite. The below Figure 5 shows the surface of the composite samples which indicates that the mixture was uniform because there was no segregation of SiC particles.



5% of Sic composite



Fractured surface of the composite

Fig 5.SEM Images of Composites

From the above fig 5, it shows that the uniform distribution of particles in the matrix takes place.

Conclusion:

- It has been noticed that the mechanical properties of the composites such as tensile strength, of the composites are also greatly influenced by the weight fractions.
- The tensile strength of SiC & SiC/Gr reinforced hybrid particulate Aluminum composites with different weight fractions, was studied and the maximum tensile strength observed is 192.45 MPa at 15wt.% of SiC/Gr.
- The mechanical behaviour of SiC/Gr reinforced hybrid composites showed improved results when compared with single reinforcement.
- The density of the SiC & SiC/Gr reinforced hybrid particulate Aluminum composites with different weight fractions, was studied and the density increases with SiC and decreases with SiC/Gr hybrid particulates, so these SiC/Gr hybrid composites can be regarded as a useful light weight Engineering Material.
- From the studies of microstructure, it reveals that the uniform distribution of reinforcing particulates takes place in the matrix.

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