MICROSTRUCTURE AND MECHANICAL PROPERTIES OF AL6082-NANO GRAPHITE COMPOSITES FABRICATED BY STIR-CASTING PROCESS

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Abstract : In the present study, the experimental results of the mechanical properties of Al6082-Nano Graphite composites presented. The composites containing 2 to 6 wt% of graphite in steps of 2 wt% were prepared using liquid metallurgy route in particular stir casting technique. For each composite, reinforcement particles were preheated to a temperature of 250˚C and then dispersed in steps of two into the vortex of molten Al6082 alloy to improve the wettability and distribution. Microstructural characterization was investigated by scanning electron microscopy (SEM). Tensile and hardness tests were carried out in order to identify mechanical properties of composites. The results of microstructural study revealed uniform distribution of nano graphite particles and low porosity in micro composite specimens.The results of this study revealed that as nano graphite percentage was increased, there was significant increase in ultimate tensile strength, yield strength and ductility, accompanied by a tremendous drop in the hardness of the material.

***Keywords* :** Al6082, Nano Graphite, Mechanical Properties, Hardness, Stir-Casting.

I. INRODUCTION

Aluminium metal matrix composites (Al MMCs) are being considered as a group of new advanced materials for its light weight, high strength, high specific modulus, low co-efficient of thermal expansion and good wear resistance properties [1]. Combinations of these properties are not available in a conventional material. The commonly used metallic matrices include aluminium, magnesium, titanium, copper, zinc and their alloys. These alloys are preferred matrix materials for the production of metal matrix composites (MMCs). The reinforcements being used are fibers, whiskers and particulates [2]. Aluminium alloys and its composites are widely used in the automotive industry, particularly in automobile engines as cylinder liners as well as other rotating and reciprocating parts [3]. During last decade, because of their improved properties, metal matrix composites (MMCs) are being used extensively for high performance applications such as in aircraft engines [4]. Among several series of Al-alloys, heat treatable Al6082 is a popular choice as a matrix material to prepare MMCs owing to its better formability characteristics, corrosion resistance and which exhibit moderate strength.

In most cases, hard ceramic particulates such as zirconia, alumina, silicon carbide and boron carbide, have been introduced into aluminium based matrix in order to increase the strength, stiffness, wear resistance, corrosion resistance, fatigue resistance and elevated temperature resistance [5]. But, presence of these hard-ceramic particles in the composites makes them extremely difficult to machine by their poor machinabilty, which is a result of their highly abrasive nature [6]. In this study, an attempt has been made to develop Al based MMCs by using graphite particulates as a reinforcement. Due to its potential use as solid lubricant, particulate graphite reinforced MMCs are used for a wide range of applications including engine bearings, pistons, piston rings, and cylinder liners [7].

The purpose of the present work is to process graphite reinforced Al6082 composite at a temperature less than 800˚C by two stage addition using melt stirring method. Two stage additions are being adopted to avoid agglomeration and separation of particles. Further, the work also aims at evaluating the mechanical properties of Al6082- Nano Graphite composite produced by two stage addition.

II. MATERIALS AND EXPERIMENTAL PROCEDURE

In this study, aluminium 6082 alloy with the theoretical density of 2700 kg/m3 was used as the matrix material while graphite with particle size of 125µm and a density of 2200 kg/m3 was used as the reinforcement. The chemical composition of matrix material is as shown in Table1 determined by using Atomic Absorption Spectrometry in Central Manufacturing Technological Institute (CMTI), Bangalore. Graphite particles with size of 125µm and with varying amounts of 2, 4 and 6wt% are being used as reinforcing material in the preparation of composites. The graphite-particle reinforced Al6082alloy metal matrix composites have been produced by using a vortex method. Initially calculated amount of Al6082 alloy was charged into SiC crucible and superheated to a temperature 800˚C in an electrical resistance furnace. The furnace temperature was controlled to an accuracy of ±50˚C using a digital temperature controller. Once the required temperature is achieved, degassing is carried out using solid hexachloroethane (C_2Cl_6) to expel all the absorbed gases. The melt is agitated with the help of a zirconia coated mechanical stirrer to form a fine vortex [8]. A spindle speed of 250 rpm and stirring time 5-8 min. were adopted. The graphite particulates were preheated to a temperature of 250˚C in a pre-heater to increase the wettability. Heating graphite particles to high temperature will lead to dehydroxylation as well as increase of surface energy. The surface energy increase is obtained by the removal of the moisture, gas and other contaminants. The pre-heated graphite particles introduced into melt in steps of two at constant feed rate of 1.2-1.4 g/sec. Two stage additions involve dividing entire weight of reinforcement into two equal weights and then individual weights are added to the melt in two steps rather than adding all at once. At every stage, stirring is carried out before and after introduction of reinforcement to avoid agglomeration and separation of particles and to ensure homogeneous dispersion of graphite particles in the melt. After holding the melt for a period of 5 min., the melt was poured from 750˚C into a preheated cast iron mould having dimensions of 120mm length x 15mm diameter. The composites having 2, 4 and 9wt % graphite particulates were processed in the similar manner.

Table.1 shows the chemical composition of the Al6061 alloy used in the present study.

Elements	**Si**	**Fe**	**Cu**	**Mn**	**Ni**	**Pb**	**Zn**	**Ti**	**Sn**	**Mg**	**Cr**	**Al**
Percentage	0.43	0.7	0.24	0.139	0.05	0.24	0.25	0.15	0.001	0.802	0.25	Balance

III. CHARACTERIZATION AND TESTING

For microstructural characterization, metallographic samples sectioned from cylindrical castings were prepared as per metallographic procedure using series of emery papers and diamond grinders. Microstructures were examined using Scanning Electron Microscopy (SEM) equipped with EDS analysis (Hitachi Su-1500 Model) to identify morphology and distribution of graphite particles in Al6082 alloy. The experimental density of the composites was obtained by the Archimedian method of weighing small pieces cut from the composite cylinder first in air and then in water [9], while the theoretical density was calculated using the mixture rule according to the weight fraction of the graphite particles by taking the densities of Al6061 alloy and graphite particles as 2.7 and 2.2 g/cm3 respectively. The hardness of the composites and matrix alloy were measured after polishing to a 1μm finish. The micro-hardness of the samples measured using Brinell Hardness Tester with a Max force of 1 Kg to 1000 Kgs with dwell time of 30 sec. The hardness measurements were carried out at 30 different locations on the specimen and average of 100 readings is being reported. Tensile tests were used to assess the mechanical behavior of the composites and matrix alloy. The composites and matrix alloy rods were machined to tensile specimens with a gauge diameter of 9 mm and gauge length of 54 mm. The surface of the samples was polished on 600 sand grit papers. The tensile test was conducted on a Computerized Universal Testing Machine (INSTRON) as per ASTM E8 M88 standard. Tensile test was conducted on three specimens for each composition and average value was reported.

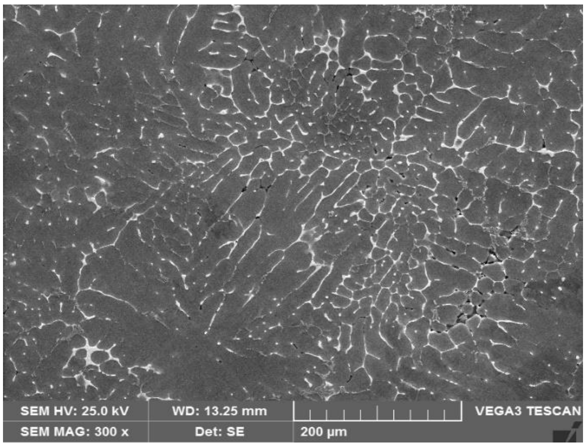
IV. RESULTS AND DISCUSSIONS

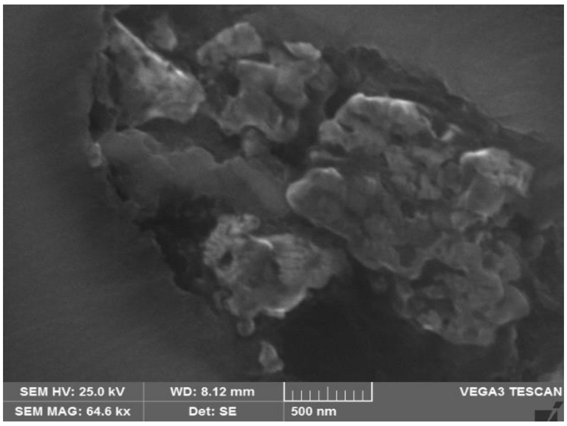
4.1 Microstructural Studies

Fabrication of metal-matrix composites with graphite particles by casting processes is usually difficult because of the very low wettability of nano graphite particles [10] and agglomeration phenomena which results in non-uniform distribution and poor mechanical properties. In the current work, an attempt has been made to prepare Al6082 alloy matrix composites with Nano size graphite particles by stir casting method with a novel two stages mixing combined with preheating of the reinforcing materials. The magnitude of Nano graphite powder used in the composites was 2, 4 and 6wt. %. The SEM microphotographs of the Al6082 alloy with 2, 4 and 6 wt% graphite particulates were shown in fig.1(a-c).

Figure 1. a-b shows optical microphotographs of as cast Al6082 and Al6082 with 6 wt% (fig. 1-b) Nano graphite particulates. The microstructure of the prepared composites contains primary α-Al dendrites and eutectic silicon. The stirring of melt before and after introducing particles has resulted in breaking of dendrite shaped structure into equiaxed form, it improves the wettability and incorporation of particles within the melt and also it causes to disperse the particles more uniformly in the matrix [11].

Figure 2 indicates the Energy dispersive spectrum of Al6082 and 6 wt.% of Nano graphite reinforced composites. The spectrum shows the presence of Nano graphite particles in the form of element 'C', since graphite is one form of carbon.





(a) **(b)**

Figure 1: Showing the SEM microphotographs of (a) as cast Al6082 alloy (b) Al6082-6wt. % nano Graphite particulates composite

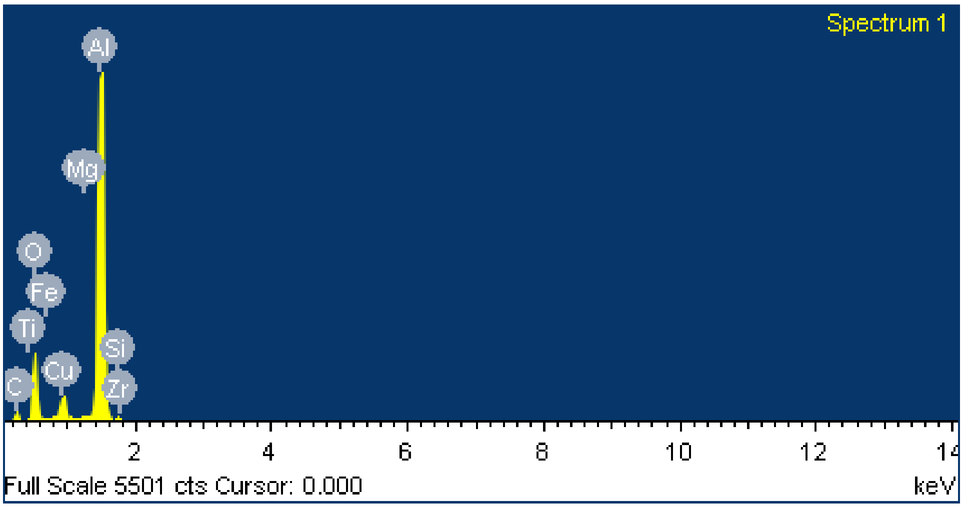


Figure 2: Energy dispersive spectrum of Al6082-6 wt.% of nano Graphite composites.

4.2 Hardness Measurements

Fig. 3 is a graph showing the effect of graphite content on the hardness of Al6061-graphite particulate composites. It can be seen that as the graphite content increases, the hardness of the composite material decreases monotonically by significant amounts. This decrease in hardness is to be expected since graphite, being a soft dispersoid, does not contribute positively to the hardness of the composite [13]. The graphite being an effective solid lubricant [14], renders the material more easily deformable with respect to the indenter of the hardness tester. Hardness is directly related to wear resistance. Therefore, a compromise is necessary when deciding how much graphite should be added to enhance ultimate tensile strength of the composite, so as not to sacrifice too much of its hardness, especially in components such as engine bearings, pistons, piston rings and cylinder liners, in which wear resistance is of paramount importance.

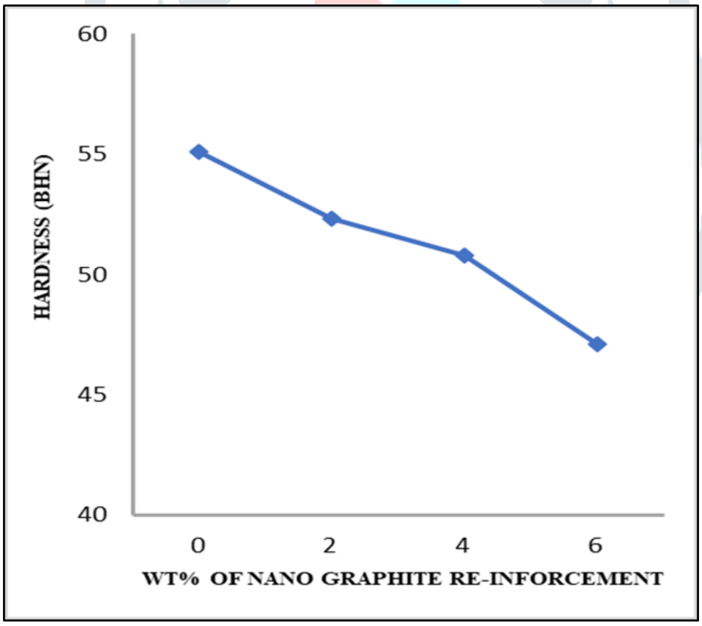
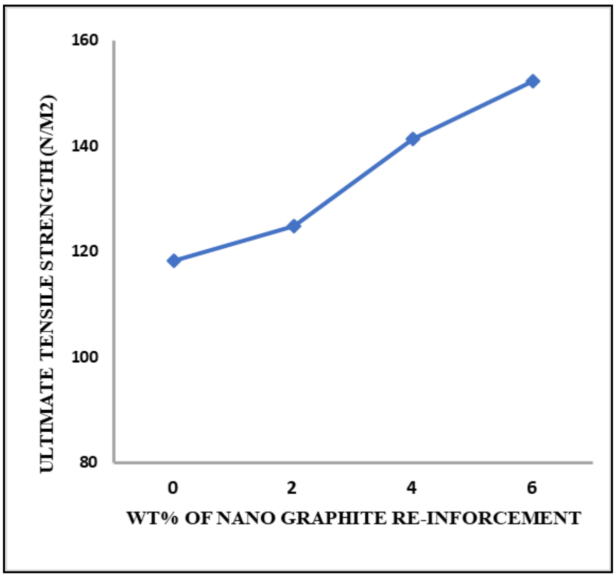


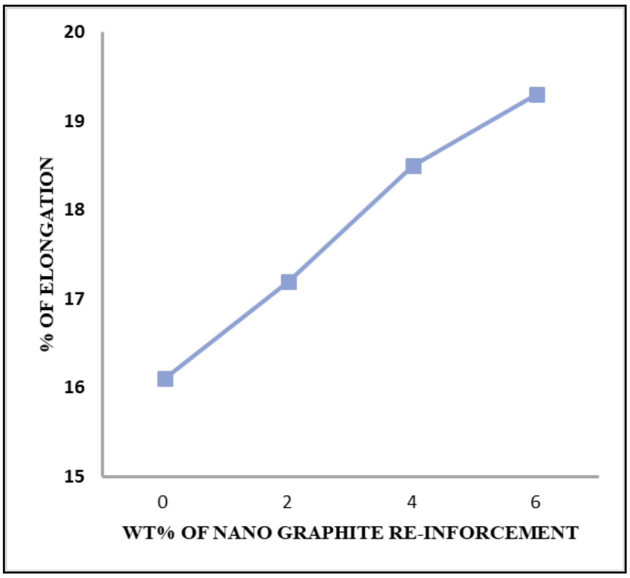
Fig.3. Graph showing the variations in hardness of Al6082 before and after addition of different wt% of graphite particulates

4.3 Tensile Properties

The results of the tensile tests carried out on the composites prepared by melt stirring involving with two step additions are presented in fig. 4-a. shows the extent of improvements obtained in the ultimate tensile strength of the Al6061 alloy matrix after addition graphite particulates. It is clear that from fig. 4-a ultimate tensile strength (UTS) properties of Al6061 matrix are improved with the addition of graphite particulates. Further, improvements in tensile properties were obtained with increasing amount of Nano graphite particulates which clearly suggests that Nano graphite particles are effective in improving the properties. The extent of improvement obtained in the ultimate tensile strength of Al6082 alloy after addition of 2, 4 & 6 wt% of Nano graphite particulate were 29.94% and 36.18% respectively. The results obtained are consistent with trends reported by the earlier investigators [15]. This increase in UTS may be due to the graphite particles acting as barriers to dislocations in the microstructure.



(a)



(b)

Fig.4. (a-b) showing variation in ultimate tensile strength and percentage elongation of the Al6082-Graphite composites as a function of amount of Nano graphite particulates

V. CONCLUSIONS

The present work on graphite particulate reinforced Al6082 composite by two stage addition using melt stirring method has led to the following conclusions.

1. Graphite particulate reinforced Al6082 composites with 2, 4 and 6 wt% of graphite were successfully fabricated by melt stirring method involving two stage additions.
2. Two stage addition method adopted for introducing Nano graphite particulates during melt stirring has resulted in homogeneous distribution of graphite with no clustering or agglomeration as evident from SEM microphotographs.
3. The hardness of the composites decreases with increasing wt% of Nano graphite particulates.
4. Improvements in ultimate tensile strength of the Al6082 matrix were obtained with the addition of graphite particulates. The extent of improvement obtained in Al6061 alloy after addition 2, 4 and 6 wt% of graphite particulates were 29.94% and 36.18% respectively.

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