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Microstructure & Mechanical Behavior of Graphite Particulates Reinforced Al6082 Alloy Composites

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Abstract

In the current study and investigation made on fabrication of graphite reinforced Al6082 alloy composites and evaluation of mechanical properties, Al6082-graphite composites were synthesized by two step reinforcement mixing melt stirring process. The weight percentage of graphite particulates was varied in steps of 3, 6 and 9 %. Microstructure characterization was carried out by using scanning electron microscope, energy dispersive spectroscope and X-ray diffractometer. Prepared composites were evaluated for hardness, tensile and compression strength as per ASTM standards. Scanning electron micro photographs revealed the distribution of graphite particulate in the Al matrix and were confirmed by EDS analysis and XRD pattern. Graphite particulates reinforced composites were shown more enhanced tensile properties as compared to Al6082 alloy. Further hardness and compression strength of Al6082-graphite composites decreased with the addition of soft graphite particles.

Keywords: Al6082 Alloy; Graphite particulates(100 microns); Hardness; Ultimate tensile strength; Yield strength; Compression; Microstructure; Stir casting

INTRODUCTION

Aluminum based MMC have received increasing attention in recent decades as engineering materials for many engineering applications specifically aircraft sector. This aluminum alloy has been commonly used as base metal for MMC's reinforced with varieties of fibers, particles and whiskers [2]. There aluminum alloy has eight series and research is going on nine series. Each series has different main constituents and sixth series (Al6XXX) has Magnesium and Silicon as major constituents.

Metal matrix composites (MMC's) offered designers requirements, they are particularly suited for applications requiring high strength to weight ratio at high temperature, good structural rigidity, dimensional stability and light weight. The inadequacy of metals and alloys in providing both strength and stiffness to a structure has led to the development of various composites particularly metal matrix composites (MMC's) [3-5]. Composite materials are used extensively as their higher specific properties (properties per unit weight) of the strength and stiffness, when compared to metals, offer interesting opportunities for a new product design. MMC's are metals reinforced with other metal, ceramic or organic compounds. They are made by dispersing the reinforcements in the metal matrix [6]. Reinforcement are usually done to improve the properties of the base metal like strength, stiffness, conductivity, etc. The particle distribution plays a very vital role in the properties of Al MMC and is improved by intensive shearing [7]. Addition of Graphite particle enhances the wear and formability properties. Graphite particles has an attractive property like wear, low density (2.2g/cc). Good wear resistance and good chemical stability. Hence reinforcing the aluminum with Graphite particles confers high specific strength, elastic modulus, good wear resistance [8]. From the literature survey it can be concluded that most of the studies on aluminum based MMC's are devoted to Graphite particulate reinforcement; however use of Graphite particulates as reinforcement in aluminum matrix is relatively limited.

Al6082 is a medium strength alloy with excellent corrosion properties and wear resistance and having application in the field of high stresses such as bridges, trusses, cranes, transport applications etc [9]. There are number of manufacturing methods available to fabricate MMC's like powder metallurgy, ball milling, friction stir processing, pressure less infiltration method etc., but conventional stir casting is very effective and low cost process and can produce complex shape products and offer a wide range of material and processing condition [10-11]. Graphite provides self lubrication property. Some researchers have reported an improvement in wear resistance of aluminum alloys with reinforcing levels (2% weight) of Graphite particles. Moreover, higher addition of graphite (8% weight) weakens the alloy thereby significant reduction in yielding and increased wear rate. The graphite particle may also increase the rate of damage accumulation by formation of crack and propagation and hence deteriorate the wear resistance of aluminum alloy matrix [12]

EXPERIMENTAL DETAILS

Matrix Material

Cast Al6082 was used as matrix material. Chemical composition is listed in table 1. Al6082 is one type of wrought(Heat Treatable) aluminum alloy containing magnesium and silicon as major alloying element. The theoretical density of Al6082 is taken as 2.7g/cc. It is Prefared Because of its excellent formiability.

Reinforcement Material

The main advantage of introducing reinforcement material to base metal or alloy is to increase the properties thereby enhancing mechanical and tribological properties of composites. In the current work we are using 100 micron of graphite particulates. The density of graphite is 2.2gm/cc. The Graphite Has an excellent Self lubricating property and soft in nature.

Table No.1 Chemical composition Al6082 alloy

Chemical Element	% Present
Silicon (Si)	0.70 – 1.30
Magnesium (Mg)	0.60 – 1.20
Manganese (Mn)	0.40 – 1.00
Iron (Fe)	0.0 – 0.50
Copper (Cu)	0.0 – 0.10
Zinc (Zn)	0.0 – 0.20
Titanium (Ti)	0.0 – 0.10
Chromium (Cr)	0.0 – 0.25
Other (Each)	0.0 – 0.05
Others (Total)	0.0 – 0.15
Aluminium (Al)	Balance

Preparation of Al6082- Graphite composites

In the engineering materials, the MMC's can be manufactured by a unique technique such as casting, as it is inexpensive and suitable for mass production of components. The synthesis of metal matrix composite used in the study was carried out by liquid metallurgy route in particular stir casting technique. Initially Graphite particulates were preheated for 300-400 degree Celsius. In the present work, an attempt has been made to study the mechanical properties of as cast Al6082 alloy and Al6082-Graphite particulates composites. The composites containing 3wt %, 6wt % and 9wt % of Graphite particulates were prepared. Initially required amount of charge or matrix material was placed in a graphite crucible, which was placed in electric resistance furnace at a temperature of around 730 degree Celsius. After complete melting of Al6082 alloy matrix, degassing was carried out by using solid Hexa Chloroethane tablets which helps to remove unwanted adsorbed gases from the melt. Once degassing is over, the preheated Graphite reinforcement particles were introduced into matrix in a novel way which involves two-stage additions of reinforcement during melt stirring. This novel two stage additions of reinforcement into matrix Al6082 will increase wettability of the matrix and graphite reinforcement and further, which helps in uniform distribution of the particles. A continuous stirring process was carried out during addition of reinforcement into matrix. Normally for all composite preparation, stirring speed was maintained at 300rpm. After 10 minutes of continuous stirring, entire molten metal was poured into cast iron die. The prepared composites were machined and tested for micro structural studies. After revealing uniform distribution of graphite particles in the matrix, tensile behavior of cast Al6082 alloy and its composites were evaluated as per ASTM standards. Figures 1 and 2 showing the stir casting setup and cast iron die and used to prepare the composites for the present study.

Fig. 1 Stir casting setup

Fig. 2 Cast iron die

Specimen Testing

The microstructure of the as cast Al6082 alloy and its composites reinforced with different wt% of graphite particulates were examined by using Scanning Electron Microscope(SEM), Energy Dispersive Spectroscope(EDS). The samples of cast and Al6082-Graphite composites for microstructural study were cut from casted rods and ground by means of abrasive papers followed by rotating disc cloth polishing. Keller's reagent was used as an etching agent.

The composites and base Al6082 alloy were tested for their hardness using a brinell hardness tester. The hardness testing was carried out in accordance with ASTM E10 standard at room temperature. A test load of 250kg was applied to the

specimens for 30s. The diameter of steel ball indenter was 5mm. The size of the indent (d) was determined optically by measuring two diagonals of the round indent. The brinell hardness number
(BHN) was calculated for the unreinforced Al matrix and Graphite reinforced composite using equation (1). An average of 5 reading was taken from each sample for hardness measurement.

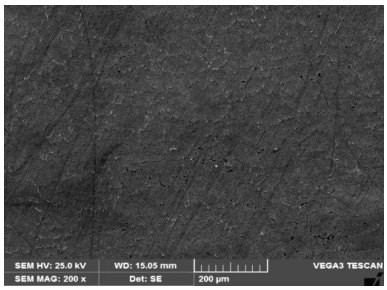
$$BHN = \frac{2P}{\pi D\left(D-\sqrt{D^2-d^2}\right)} \qquad (1)$$

Where P is applied load in kg, D is the diameter of the steel ball in mm and d is the size of the indent in mm. Each hardness value represented in an average of at least 5 symmetrical indentations.

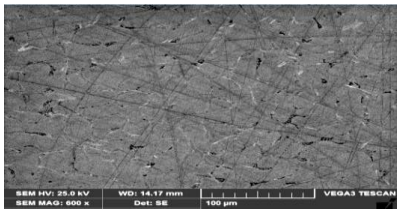
Tensile testing of the prepared samples were conducted in accordance with the ASTM E8 standard on round tension test specimens of gauge diameter 9mm and gauge length 54mm. Tension test was conducted by using digital universal testing machine. The experiment was conducted at room temperature. Stress v/s strain graph was plotted to know the effect of graphite particulates on tensile behavior of Al6082 alloy composites. Compression testing of the prepared samples was conducted in accordance with the ASTM E8 standard on round compression test specimens of gauge diameter 20mm and gauge length 30mm. Compression test was conducted by using universal testing machine. The experiments were conducted at room temperature**.**

RESULTS AND DISCUSSION

Microstructural Studies



(a)



(b)

Fig. 3: Showing the optical microphotographs of (a) as cast Al6082 alloy (b) Al6082-6wt. % Graphite particulates Composite

Figures 3a and 3b shows the scanning electron microscope (SEM) of cast Al6082 alloy and Al6082- 6wt % Graphite particulate respectively. The grain structure of the composite was much smaller than that of the alloy because particles act as nucleation sites. Figure 3b shows the good & uniform distribution of reinforcements and their no cluster formation in the composite. From the scanning electron microscope, it is clear that a good crack free bonding was formed at discrete locations between the reinforcement and matrix alloy. In the second figure the black marks represent the graphite particulates.

The optical micrographs of as cast Al-4.5 Cu alloy alloy and Al-Cu alloy reinforced with 6 wt. % of SiC particulates are shown in fig.1 a and b respectively. Optical micrographs of Al-Cu alloy composites revealed the uniform distribution of SiC particulates in the matrix, and no void and discontinuities were observed. Common casting defects such as porosity and shrinkages were not found in the micrographs. There was a good interfacial bonding between the SiC particles and Al-Cu alloy matrix

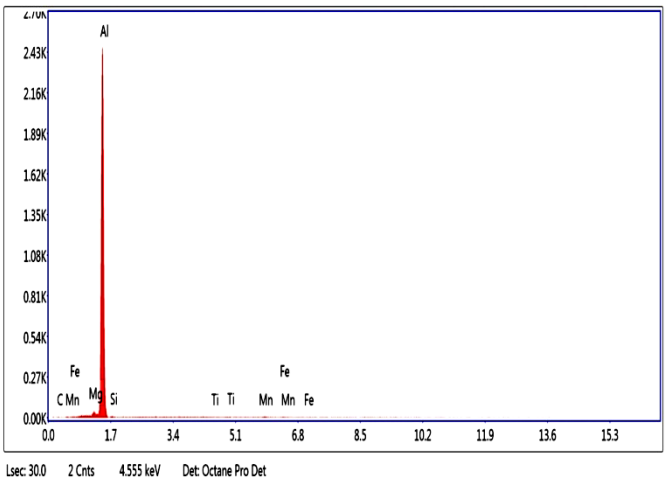


Fig. 4 Energy Dispersive Spectrograph of Al6082-6% Graphite composites

Fig. 4, shows the Energy Dispersive Spectrography of Al6082-wt 6% Graphite particulates. Which confirms the presence of the different alloying elment which includes Al, Mg, Si, Fe, Mn, Ti, C.

However the Mg and Si are major alloying element.

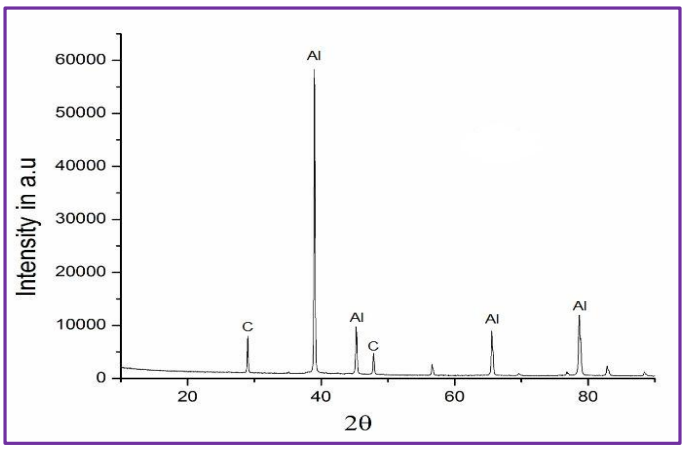


Fig. 5 XRD Pattern of Al6082-6% Graphite composites

Fig. 5 shows the X-Ray Diffractometer images of the Al6082-wt 6% of Graphite particulates which shows the presence of the different alloying element in different direction by there intensity as shown in the Fig. 5

Hardness

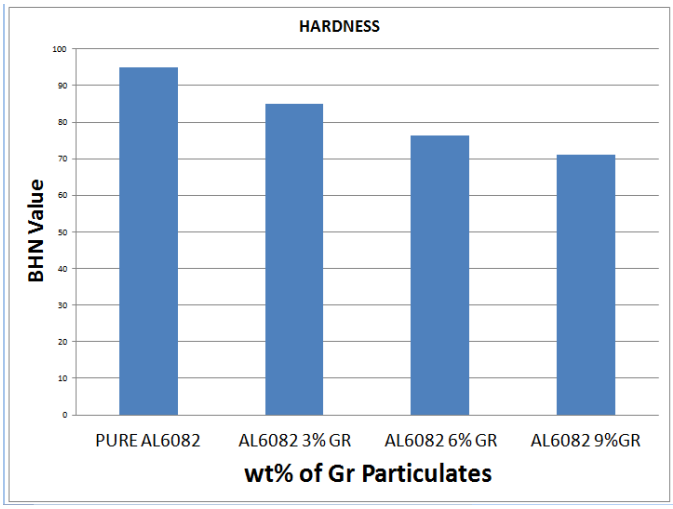


Fig.6 Variation in hardness with different wt. % of Graphite particulates.

Ultimate Tensile Strength

The fig.7 shows variation of ultimate tensile strength (UTS) with cast Al6082, 3wt %, 6wt % and 9wt % of graphite particulates. The ultimate tensile strength of Al6082- 6wt % graphite composite material increased when compared with cast Al6082 alloy matrix. The microstructure and properties of graphite particulates control the mechanical properties of the composites. Due to the strong interface bonding load from the matrix transfers to the reinforcement exhibiting increased ultimate tensile strength. This increase in UTS mainly due to graphite particles acting as barrier to dislocations in the microstructure. The Ultimate tensile stress increases from 154.92 MPa to 180.52 MPa from cast Al6082 to 6wt % Graphite particles. Improvement in UTS may be due to the matrix strengthening following a reduction in Al6082-Graphite grain size, and the generation of a high dislocation density in the Al6082 alloy matrix a result of the difference in the thermal expansion between the metal matrix and the graphite reinforcement.

Table No.2 Tensile Properties of Al6082-Gr composites

Sl.No	Material	UTS (MPa)	YS (MPa)	Elongation (%)
1	Al6082 (cast)	154.92	92.57	8.08
2	Al6082 (3% Gr)	169.04	138.00	8.36
3	Al6082 (6% Gr)	180.12	133.09	10.33
4	Al6082 (9% Gr)	182.52	157.41	9.86

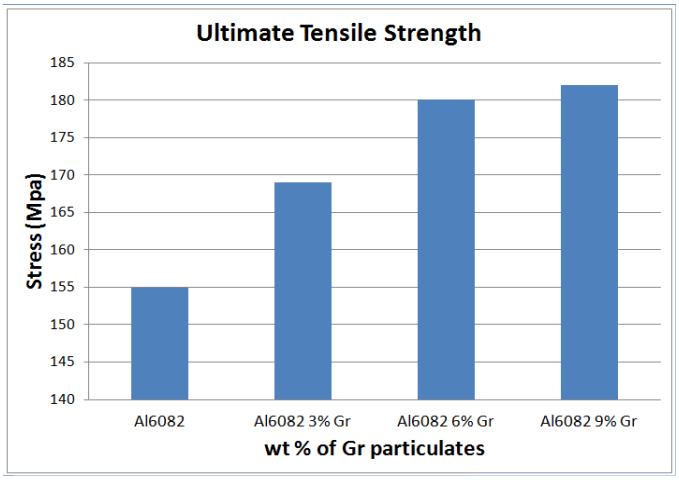


Fig. 7 Variation of Ultimate Tensile Strength with different wt. % of Graphite particulates

(a)

(b)

Fig.8 Tensile Specimen before applying load and after applying load (specimen is ASTM E8 standard)

Fig.10a & 10b shows the tensile specimen before applying load and after carrying the ensile test in the UTM the specimen will fracture under some load.

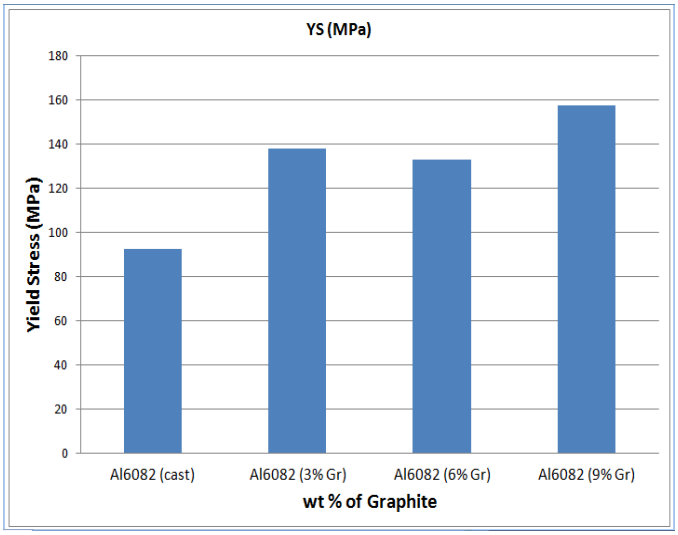


Fig.9 Yield Strength of Al6082 and its composites

Compression Test

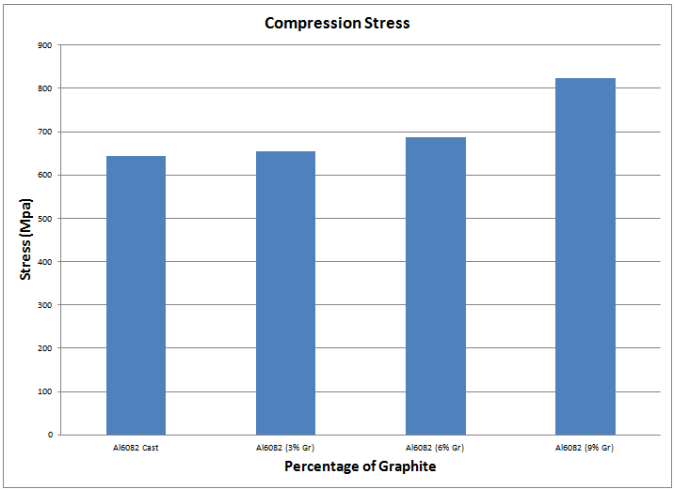


Fig.11 Stress for Compression

Percentage Elongation

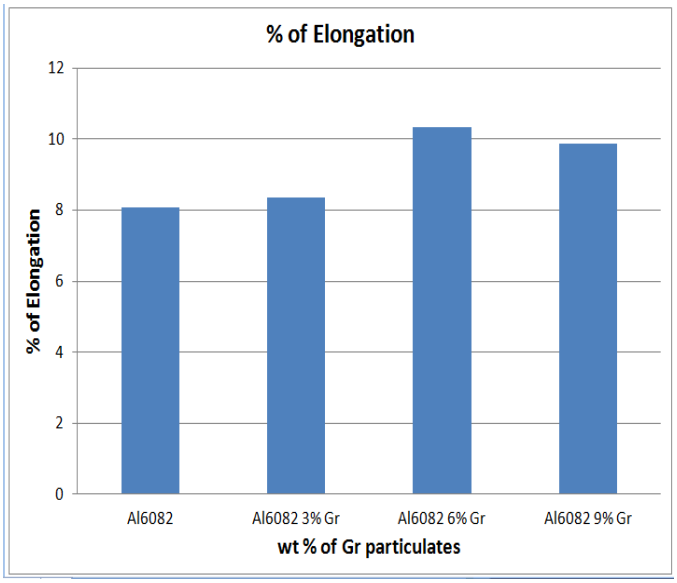


Figure 10. Percentage Elongation of Al6082 and its composites

Figure 10 is a graph showing the effect of graphite content on the percentage elongation (ductility) of the composites. It can be seen from the graph that the ductility of the composites increases significantly with the 6wt % graphite reinforced composite compare to the other different percentage of graphite. This increase in percentage of elongation in comparison with the base alloys is a most commonly occurring advantage in particulate reinforced metal matrix composites. The enhanced ductility in Al6082- 6wt % composites can be attributed to the presence of graphite particulates which may get elongate. The formability property will get enhance due to ductility of graphite particles.

In many application the components will undergo the crushing failure hence it is important to determine the crushing stress of the components. The crushing stress will be high for the Cast Alloy and it will go on decreasing as the reinforcement addition will increases. The test carried has shown that Al6082 6wt % of Graphite has the desired property. The Graph will show that variation of stress v/s strain diagram for different composition.

The Compression stress increases because the graphite paticles are soft in nature as the addition of Graphie particles increases the ductility increasese.

CONCLUSION

The results of the study of microscopic structure and mechanical properties of Al6082-6wt % Graphite composites materials produced by stir casting are remark as below.

- The liquid metallurgy technique was successfully adopted in the preparation of Al6082-6wt % Gr composites.
- The microstructural studies revealed the uniform distribution of the Gr particulates in the Al6082 alloy matrix.
- Hardness of the Al6082-Gr composite decreases as per Al6082 cast.
- The Ultimate Tensile Strength and Yield Strength properties of the composites found to be higher than that of base matrix. The improvements in UTS and YS by adding 6wt % of Gr was increased by 16.27% and 43.80% respectively.
- It was observed that the percentage elongation increased for Al6082-6wt % of Graphite composite as compared to base Al6082 alloy matrix.

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