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Hardness and tensile behavior of AL-4.5%CU-SIC-Graphite particulates reinforced hybrid composites

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Abstract: Aluminium hybrid composites are a new generation of metal matrix composites that have the potentials of satisfying the recent demands of advanced engineering applications. These demands are met due to improved mechanical properties, amenability to conventional processing technique and possibility of reducing production cost of aluminium hybrid composites. Present work is investigating the effects of adding SiC and Graphite particulates to Al-4.5%Cu alloy in the mechanical properties of the composites.The Al-4.5%Cu alloy reinforced with 6 wt. % SiC and 6 wt. % of Graphite particulates composites were fabricated by stir casting method . Microstructure and mechanical properties such as hardness and ultimate tensile strength, yield strength were examined. Microstructure of the samples has been investigated by using optical microscope to know the uniform distribution of reinforcement particulates in the matrix. It was abserved that the hardness , ultimate tensile strength and yielding strength of the Al-4.5% Cu alloy increased with the addition of 6 wt. % of SiC and Graphite particulates .

Keywords: Al-4.5% Cu alloy, SiC, Graphite, Stir casting, Hardness, Tensile behavior

I. INTRODUCTION

Metal matrix composites (MMC's) offer 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 (MMCs) [1-3]. Composite materials are used extensively as their higher specific properties (properties per unit weight) of strength and stiffness, when compared to metals, offer interesting opportunities for new product design. MMCs are metals reinforced with other metal, ceramic or organic compounds. They are made by dispersing the reinforcements in the metal matrix [4]. Reinforcements 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 the Al MMC and is improved by intensive shearing [5]. Addition of hard ceramic particles like SiO_3, SiC, Al2O$_3$, TiB_2, B_4C etc. to Al matrix lead to strengthening of the matrix with improved properties. Ceramic particles such as Al_2O_3 and SiC are the most widely used materials for reinforcement with aluminium.

One of the major challenges processing MMCs is achieving a homogeneous distribution of reinforcement in the matrix as it has a strong impact on the properties and quality of the material [6].MMCs are generally processed with liquid metal routes such as stir casting and infiltration .a powder metallurgy route is also used for the specific application,however an stir casting route is the most commonly used method by industry and accounts for the latest volume in primary production[7, 8]

In the present work an attempt has been made to develop aluminium based metal matrix composites. Al-4.5%Cu alloy was taken as the base matrix. SiC and graphite particulates were added as the secondary phase materials. Hardness and tensile behavior of Al-Cu alloy and its composites were studied.

II. MATERIALS AND EXPERIMENTAL DETAILS

Matrix material

The matrix material used in experimental investigation is aluminium 4.5%Cu alloy. The theoretical density is taken as 2.8 gm/cm^3.

Reinforcement material

The main advantage of introducing reinforcement material to base metal or alloy is to increase the properties their by enhancing the mechanical and tribological properties of composites . In the current research Sic particulates of size 40microns and Gr particulates were used as a reinforcement material which was procured from speedfam (India) Pvt Ltd, chennai

Preparation of aluminium 4.5%Cu SiC-Gr composites

In the engineering materials , the MMCs can be manufactured by a unique technique such as casting as it is inexpensive and suitable for mass production of components the synthasis of matrix composites used in study was carried out by liquid metallurgy route in particular stir casting technique. Initially Sic and Gr particulates were pre heated for 400-500^{o}C in the present work, an attempt has been made to study the mechanical properties of cast Al-4.5%Cu and Al-4.55%Cu–Sic-Gr particulate composites.the composites containing 6wt.% of Sic and 6wt.% of Gr particulates were pre-heated. Initially required mount of charge of matrix material was placed in electric resistance furnace at a temperature around 800^o C after complete melting ofAl-4.5%Cu alloy matrix, Magnesium was added in small quantity during stirring to increase the wetting, degasing was carried out by using Solid HexaChloroethane [9], which helps to remove unwanted adsorbed gases from the melt.once degasing is over, the pre heated ceramic reinforcement particles were introduced into the matrix in a novel way which involves two stages addition of reinforcement during melt stirring. This novel two stages addition of reinforcement into matrix Al-4.5%Cu will increases wettability of the matrix and reinforcement particulates 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 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 microstructural studies. After reveling uniform distribution of Sic and Gr particulates in a matrix, tensile behavior of cast Al-4.5%Cu alloy and its composites were evaluated as per ASTM standards.figure 1 showing the cast iron die and stir casting setup used to prepare the composites for the present study.

composites

Specimen Testing

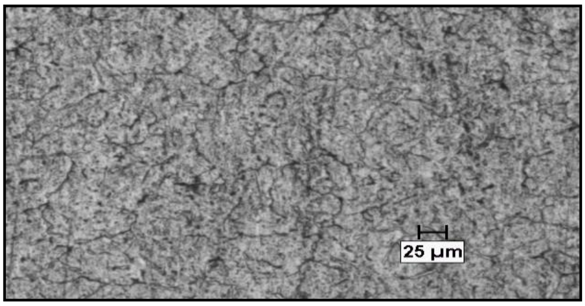
The microstructure of the cast Al-4.5%Cu alloy and its composites reinforced with 6wt.% of Sic and 6wt.% of Gr particulates were examined by using optical microscope.the sample of cast and Al-4.5%Cu with Sic and Gr composites for microstructural study were cut from casted rods and ground by means of abrasive papers followed rotating disc cloth polishing. Keller's reagent was used has an etching agent and examined with optical microscope. Hardness test were performed on as cast Al-4.5%Cu alloy and Al-4.5%Cu with Sic and Gr composites to know the effect of Sic and Gr particulates in the matrix material. The polished specimens were tested there hardness, using Brinell Hardness testing machine having ball indentor for 62.5kg load and dwell time of 15sec.5 sets of readings were taken at different places of the specimen and an average value was used for calculation.

Tensile testing of the prepared samples were conducted in accordance with the ASTM E8 std on round tension test specimens of guage diameter 9mm and guage length is 45mm.tension test was conducted by using instron made servo hydraulic machine, with cross head speed set at 0.280mm per minute. The experiments were conducted at room temperature. Stress versus strain graph was plotted to know the effect of Sic and Gr particulates on tensile behavior of Al-4.5%Cu alloy.

III. Results and Discussion

Microstructural Studies

Figure 2 (a) - (b) shows the optical micrographs of as cast Al-4.5% Cu alloy and its composites. Figure 2 (a) shows the optical micrograph of as cast Al-4.5% Cu alloy. Figure 2 (b) shows the optical micrograph of Al-4.5% Cu and 6wt. % SiC and 6 wt. % graphite composite. Microphotograph clearly showing the reaction free interface between matrix and reinforcement. A clean and distinct interface seen in the micrograph is an obvious evidence for reaction free interface and excellent bond that exist between matrix and reinforcement. Homogeneous distribution of SiC and graphite particles within the base matrix alloy.



(a)

(b)

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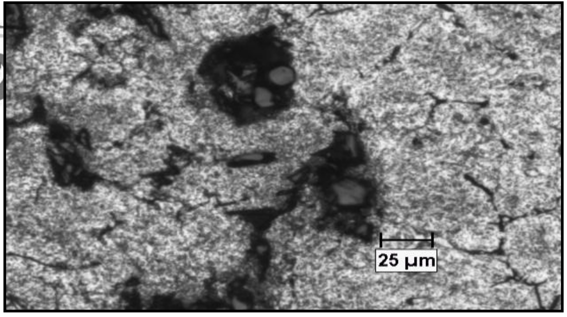

Figure 2. Optical micrographs of (a) as cast Al-4.5Cu alloy (b) Al-4.5% Cu-6 wt. % SiC & 6 wt. % Graphite composites

Hardness Measurements

From the figure 3, it is observed that there is an increase in the hardness of Al-4.5% Cu alloy with addition of 6 wt % of SiC and graphite particulates. The graph shows the variation of hardness of Al-4.5% Cu alloy with SiC and graphite reinforcement particulates. It can be concluded that the addition of 6 w.t % of SiC particulate results in increasing the hardness. The effect of graphite on hardness of base alloy is negative, usually decreases the hardness. In the present study, from the graph effect of SiC particulates is more on the hardness. Due to this hardness of base alloy is increased from 97 BHN to 122 BHN.

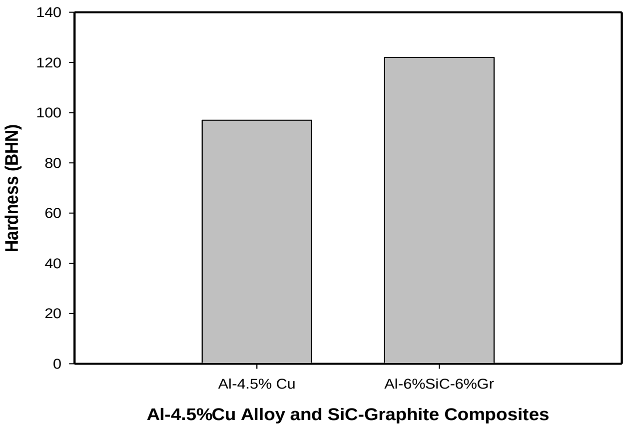

Figure 3. Hardness of Al-4.5%Cu alloy and its composites

Ultimate Tensile and Yield Strength

Figure 4 shows the variation of ultimate tensile strength (UTS) of base alloy, when reinforced with 6 wt. % of SiC and 6 wt. % of Graphite particulates. The ultimate tensile strength of Al-Cu- SiC-Graphite composite material increases as compared to the cast base alloy. The microstructure and properties of hard ceramic SiC and graphite particulates control the deformation of the composites. Due to the strong interface bonding, load from the matrix transfers to the reinforcement resulting in increased ultimate tensile strength. This increase in ultimate tensile strength mainly is due to presence of SiC particles which are acting as barrier to dislocations in the microstructure [10]. The improvement in ultimate tensile strength may also be due to alloy strengthening of the matrix, followed with a reduction in grain size of the composites, and the formation of a high dislocation density in the Al-4.5% Cu alloy matrix due to the difference in the thermal expansion between the metal matrix and the SiC and graphite reinforcement.

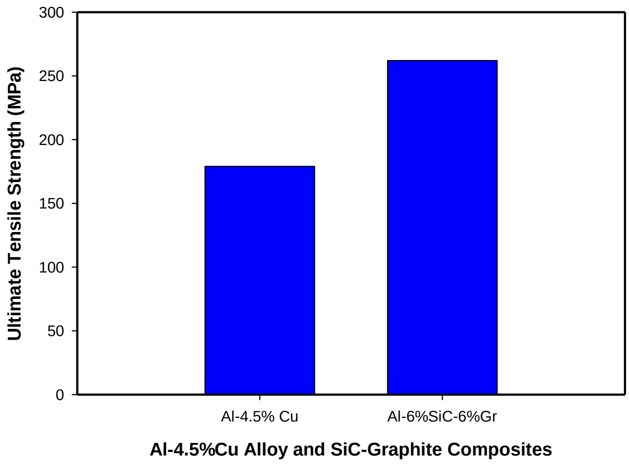

Figure 4. Ultimate tensile strength of Al-4.5%Cu alloy and its composites

Figure 5 shows variation of yield strength (YS) of Al-4.5% Cu alloy matrix with 6 wt. % SiC and 6 wt. % of graphite particulates reinforced composite. It can be seen that by adding 6 wt. % of SiC particulates yield strength of the Al alloy increased from 122 MPa to 206 Mpa. This increase in yield strength is in agreement with the results obtained by several researchers, who have reported that the strength of the particle reinforced composites is highly dependent on the volume fraction of the reinforcement. The increase in YS of the composite is obviously due to presence of hard SiC particles which impart strength to the soft Aluminum matrix resulting in greater resistance of the composite against the applied tensile load [11]. In the case of particle reinforced composites, the dispersed hard particles in the matrix create restriction to the plastic flow, thereby providing enhanced strength to the composite.

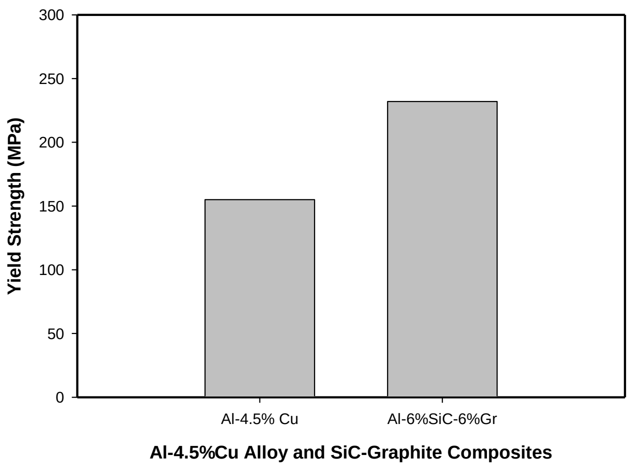

Figure 5. Yield strength of Al-4.5%Cu alloy and its composites

VI. CONCLUSIONS

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The present work entitled, "Hardness and tensile behavior of Al-4.5% Cu-6 wt. % SiC and graphite Metal Matrix Composites",has led to following conclusions:

- Al-4.5% Cu – 6wt. % SiC and 6 wt. % Graphite particulates composites were successfully produced by liquid stir casting route.
- Aluminum based metal matrix composites have been successfully fabricated by liquid stir casting method by two step addition of reinforcement combined with preheating of particulates.
- The hardness of Al-Cu increased with the addition of SiC and graphite particulates in Al base alloy.
- Improvements in ultimate tensile strength of the Al-4.5% Cu alloy matrix were obtained with the addition of SiC and graphite particulates.
- Improvements in yield strength of the Al-4.5% Cu alloy matrix were obtained with the addition of SiC and graphite particulates. The extent of improvement obtained in Al-Cu alloy after addition of 6 wt. % SiC and 6 wt. % graphite particulates is 49%.

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