Investigations on Mechanical Properties of Al-4.5% Cu-SiC and Al-4.5% Cu-Graphite Composites

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Abstract—This paper deals with the investigation of mechanical properties by introducing micro size SiC particulates and Graphite particulates into Al-4.5% Cu alloy matrix. SiC and Graphite particle reinforced Al alloy metal matrix composites were prepared by stir casting method. Al-Cu alloy was taken as the base matrix to which SiC and Graphite particulates were used as reinforcements. 6 wt. % of SiC and Graphite particulates were added to the base matrix to fabricate Al-4.5Cu – 6 wt. % SiC and Al-4.5% Cu – 6 wt. % Graphite composites. For each composite, the reinforcement particles were pre-heated to a temperature of 600°C and then dispersed in steps of two into the vortex of molten Al-Cu alloy to improve wettability and distribution. The Micostructural study was done by using optical microscope, which revealed the uniform distribution of SiC and Graphite particles in matrix alloy. Mechanical properties like hardness, tensile and impact strength were evaluated as per ASTM standards. Hardness and tensile strength increased with addition of 6 wt. % of SiC particulates in the base matrix Al-Cu alloy compared to Al-Cu-6wt. % Graphite composites.

Index Terms—Al-4.5% Cu, Graphite, Mechanical Properties, SiC.

I. INTRODUCTION

Metal matrix composites (MMCs) provides many added benefits to the designers, as they are particularly suited for applications requiring good strength at high temperatures, good structural rigidity, dimensional stability, and lightweight. They are well known for their superior mechanical and tribological properties [1]. For commercial applications aluminium based composites find extensive uses in several sectors such as automotive, aerospace, space and structural applications. Although composites are widely accepted materials, they have certain limitations with regard to secondary forming process aluminium based composites. Anisotropic in nature is the limitation mainly due to the formed composites.

Al-alloy matrix composites (AMCs) containing hard dispersoids are gaining immense industrial importance because of their excellent combination of physical, mechanical and tribological properties over base alloys. These include high wear and seizure resistance, improved high temperature strength, high specific strength and stiffness, controlled thermal expansion coefficient and high damping capacity [2]. This leads to the use of these composites in several automobile and engineering components where wear, tear and seizure are the major problems in addition to the weight saving [3].

II. MATERIALS AND EXPERIMENTAL DETAILS

A. Matrix Material

The matrix material used in experimental investigation is aluminium 4.5% Cu alloy. The theoretical density is taken as 2.8 gm/cm³.

B. Reinforcement Material

The main advantage of introducing reinforcement material to base metal or alloy is to increase the properties thereby enhancing the mechanical properties of composites. In the current research SiC and Graphite particulates of size 40 microns were used as reinforcement materials which were procured from Bio-aide Scientific Industries Pvt. Ltd., Bangalore.

C. Preparation of 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 synthesis of Al-Cu matrix 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 600°C. In the present work, an attempt has been made to study the mechanical properties of as cast Al-4.5% Cu alloy, Al-4.5% Cu-6 wt. % SiC and Al-4.5% Cu-6 wt. % Gr particulate composites. Initially required amount of charge of matrix material was placed in electric resistance furnace at a temperature around 750°C after complete melting of Al-4.5% Cu alloy matrix, magnesium was added in small quantity during stirring to increase the wetting, degassing was carried out by using Solid HexaChloroethane [9], which helps to remove unwanted adsorbed gases from the melt. Once degassing 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 5 minutes of continuous stirring entire molten metal was poured into cast iron die. The prepared
composites were machined and tested for microstructural studies. After revealing uniform distribution of SiC and Gr particulates in a matrix, hardness, tensile and impact behavior of cast Al-4.5%Cu alloy and its composites were evaluated as per ASTM standards. Fig. 1 showing the stir casting setup used to prepare the composites for the present study.

![Stir casting process used to prepare the composites](image)

**D. 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 as cast and Al-4.5%Cu-SiC and Al-4.5%Cu-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 as an etching agent and examined with optical microscope.

Hardness test were performed on as cast Al-4.5%Cu alloy, Al-4.5%Cu-SiC and Al-4.5%Cu-Gr composites to know the effect of SiC and Gr particulates in the matrix material. The polished specimens were tested for hardness, using Brinell Hardness testing machine having ball indenter 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 was conducted in accordance with the ASTM E8 standard on round tension test specimens of gauge diameter 9mm and gauge length of 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.

III. RESULTS AND DISCUSSION

A. Microstructural Studies

The optical micrographs of as cast Al-4.5% Cu alloy, Al-4.5% Cu alloy reinforced with 6 wt. % of SiC only, Al-4.5% Cu alloy reinforced with 6 wt. % of Graphite composites are shown in fig. 2a, 2b, and 2c respectively. Optical micrographs of Al-4.5% Cu alloy composites revealed the uniform distribution of SiC and Graphite 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 and Graphite particles and Al-4.5% Cu alloy matrix.

![Optical micrographs of (a) as cast Al-4.5%Cu alloy (b) Al-4.5%Cu-6 wt. % SiC (c) Al-4.5%Cu-6 wt. % Graphite composites](image)

**B. Hardness Measurements**

From the fig. 3, it is observed that there is a decrease in the hardness as the graphite reinforcement content is added. This drop in the hardness is due to softness of the graphite particles, which being soft dispersed do not contribute to the hardness of the composite as they cannot act as barriers to the movement of dislocations within the matrix whereas the SiC particles do the contrary; since SiC particles are harder than the base matrix, act as barriers to dislocations.
C. Ultimate and Yield Strength

From the fig. 4, it is observed that the ultimate tensile strength and yield strength are increased with SiC-Graphite content. The SiC-Graphite particles in the matrix alloy provide protection to the softer matrix. The addition of hard ceramic particle improves the mechanical properties mainly by stress transfer from the Al-4.5% Cu alloy matrix to the SiC-Graphite reinforced particles. This is because of dislocation mechanism by which a dislocation bypasses impenetrable obstacles where a dislocation bows out considerably to leave a dislocation loop around a particle. This interaction between the dislocations and SiC-Graphite results in an improved strength. Further, from the graph Al-4.5Cu – 6 wt. % SiC composites are showing more ultimate tensile strength and yield strength compared to as cast Al-Cu alloy and Graphite reinforced composites.

It is also observed from the graph 4, ultimate tensile strength and yield strength of Al-Cu-6 wt. % SiC composites have shown more compared to as cast Al-Cu alloy and Graphite reinforced composites.

IV. CONCLUSIONS

The present work on mechanical properties of Al-4.5% Cu- with 6 wt. % SiC and 6 wt. % Graphite reinforced metal matrix composite by two stage melt stirring has led to some important conclusions. Stir casting technique is successfully adopted in the preparation of Al-4.5%Cu-SiC and Al-4.5%Cu-Graphite composites. The micro structural study revealed the uniform distribution of SiC and Graphite particulates in the Al-Cu alloy matrix system. The hardness of base matrix Al-Cu alloy increased by adding 6 wt. % of SiC particulates. Further, hardness decreases in the Al-Cu alloy – 6wt. % graphite composites. The ultimate tensile strength and yield strength increased with the increase in SiC-Graphite content. The extent of improvement in ultimate tensile strength by adding 6 wt. % of SiC particulates is 31.8 %. In the case of 6 wt. % of graphite reinforced composites, it is 29.6 %. Al-Cu-6 wt. % SiC composites exhibited superior mechanical properties compared to Al-Cu-6 wt. % Graphite composites and as cast Al-Cu alloy.

REFERENCES

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