Studies on Al6061-B_4c Metal Matrix Composites Fabricated By Stir Casting Process

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Abstract - The present study is to evaluate the mechanical properties of aluminum metal matrix composite (AMMC). An effort is made to enhance the mechanical properties like hardness, tensile strength, yield strength, % of elongation of AMMCs by reinforcing AA6061 matrix with Boron carbide (B4C) particles. AMMCs were made, AA6061 as matrix material and B_4C as reinforcement material, through stir casting method. AMMCs with varying percentage by different wt. %, 1%, 2 %, 2.5%, 3%, 4%, 5%, 7.5%, 10%, 15%, 20% B_4C were considered. A systematic study of the matrix metal and AMMCs were done to evaluate the mechanical properties (hardness, yield strength and tensile strength) in as cast and heat treated condition. It was observed that in comparison to the matrix metal, the precipitation kinetic was accelerated by adding the B_4C particles. It was noticed that, mechanical properties are increase with the increase in wt. % of the reinforcement up to 4% B_4C further addition there is a diminution in both the conditions. It was also thought- out that 4% B_4C composite shows better mechanical (hardness, yield strength and tensile strength) properties and low % of elongation than all other compositions in both the conditions. Optical microscopy and Scanning electron micrographs were carried out to authenticate the mechanical properties of the matrix metal and AMMCs.

Keywords*:* *Metal Matrix Composites, powder metallurgy, heat treatment, mechanical testing, ASTM standards*

I. INTRODUCTION

A composite material is a 'material system' composed of a combination of two or more micro or macro constituents that differ in form, chemical composition and which are essentially insoluble in each other. One constituent is called as Matrix Phase and the other is called reinforcing phase.

Composites are engineered or naturally occurring materials made from two or more constituent materials with significantly different physical or chemical properties that remain separate and distinct within the finished structure. The bulk material forms the continuous phase that is the matrix(e.g .,metals, polymers) and the other acts as the discontinuous phase that is the reinforcement (e.g. ,ceramics, fibers, whiskers, particulates).While the reinforcing material as usually carries the major amount of load& the matrix enables the load transfer by holding them together. Composite materials are gaining wide spread acceptance due to their characteristics of behaviour with their high strength to weight ratio.

Aluminium-matrix composites are family of materials whose stiffness, strength, density, and thermal and electrical properties can be tailored. Recent success in commercial and military applications of AMCs is based partly on such innovative changes made in the component design. Aluminium composites offer the advantage of low cost over most other MMCs. Among aluminium alloys AA6061 is quite a popular choice as matrix material. It is primarily due to its better formability characteristics and option of modifying strength of the composite by employing optimal heat treatment.

This paper aims to analyze the mechanical properties and microstructure evolution of Aluminium metal matrix composites prepared by stir casting.

II. SPECIMEN PREPARATION

STIR CASTING PROCESS:

In a stir casting process, the reinforcing phases are distributed into molten matrix by mechanical stirring. Stir casting of metal matrix composites was initiated in 1968, when S. Ray introduced alumina particles into aluminum melt by stirring molten aluminum alloys containing the ceramic powders. Mechanical stirring in the furnace is a key element of this process. The resultant molten alloy, with ceramic particles, can then be used for die casting, permanent mold casting, or sand casting. Stir casting is suitable for manufacturing composites with up to 30% volume fractions of reinforcement.

Fig 1:Stir casting setup

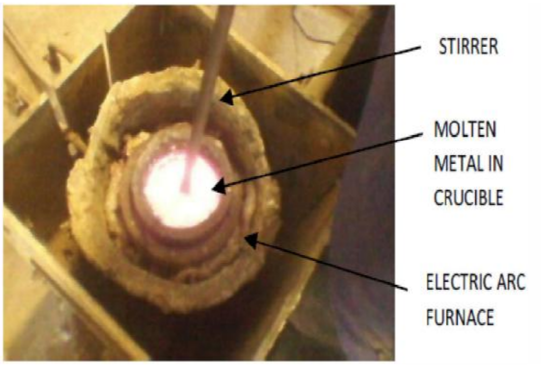

Fig 2:stirring of molten metal

Fig 3:pouring the liquid metal into the casting

Fig 4: casted components

The cast composites are sometimes further extruded to reduce porosity, refine the microstructure, and homogenize the distribution of the reinforcement. A major concern associated with the stir casting process is the segregation of reinforcing particles which is caused by the surfacing or settling of the reinforcement particles during the melting and casting processes. The final distribution of the particles in the solid depends on material properties and process parameters such as the wetting condition of the particles with the melt, strength of mixing, relative density, and rate of solidification .The distribution of the particles in the molten matrix depends on the geometry of the mechanical stirrer, stirring parameters, placement of the mechanical stirrer in the melt, melting temperature, and the characteristics of the added particles.

An interesting recent development in stir casting is a two-step mixing process. In this process, the matrix material is heated to above its liquids temperature so that the metal is totally melted. The melt is then cooled down to a temperature between the liquids and solidus points and kept in a semi-solid state. At this stage, the preheated particles are added and mixed. The slurry is again heated to a fully liquid state and mixed thoroughly. This two-step mixing process has been used in the fabrication of aluminum. Among all the well-established metal matrix composite fabrication methods, stir casting is the most economical. For that reason, stir casting is currently the most popular commercial method of producing aluminum based composites.

III. SPECIMEN PREPARATION

The specimens are prepared as the metal matrix composites of base metal as aluminium 6061with reinforcement of boron carbide consists of percentages of 1, 2, 2.5, 3, 4, 5, 7.5, 10, 15, 20 %.

MATRIX	REINFORCEMENT	PERCENTAGE OF WEIGHT
AL6061	B_4C	1, 2, 2.5, 3, 4, 5, 7.5, 10, 15, 20 %

In this work, the specimens to be tested are prepared according to the respective ASTM standards. The base material used is SS 304. Following tests are performed on the raw and welded specimens.

1. ***Tension Test***: The specimens are prepared according to the ASTM standard E8/E8M-11. The shape and size of the geometry are given in fig. 1.

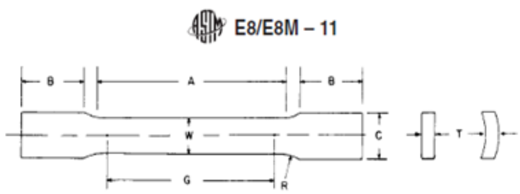

Fig.5 Tension test specimen

In this work, Specimen-5 dimensions according to the E8/E8M-11 are considered.

Fig.6: ASTM standeredspecimens

2. Hardness Test: Resistance of a material to deformation, indentation, or penetration by means such as abrasion, drilling, impact, scratching, and/or wear, measured by hardness tests such as Brinell, Knoop, Rockwell, or Vickers.

The Vickers hardness test method consists of indenting the test material with a diamond indenter, in the form of a right pyramid with a square base and an angle of 136 degrees between opposite faces subjected to a load of 1 to 100 kgf. The full load is normally applied for 10 to 15 seconds. The two diagonals of the indentation left in the surface of the material after removal of the load are measured using a microscope and their average calculated. The area of the sloping surface of the indentation is calculated. The Vickers hardness is the quotient obtained by dividing the kgf load by the square mm area of indentation.

Fig. 7 : Vickers hardness testing machine

3.Microstructure: Microstructure is the small scale structure of a material, defined as the structure of a prepared surface of material as revealed by a microscope above 25× magnification. When describing the structure of a material, we make a clear distinction between its crystal structure and its microstructure. The term 'crystal structure' is used to describe the average positions of atoms within the unit cell, and is completely specified by the lattice type and the fractional coordinates of the atoms (as determined, for example, by X-ray diffraction).

III. TESTING OF SPECIMENS

All the specimens are machined according to ASTM standards for testing it for tensile strength using universal testing machine. Similarly the specimens are reduced to the shape required for finding the hardness and impact strength.

IV. RESULTS AND DISCUSSION

(i) Hardness

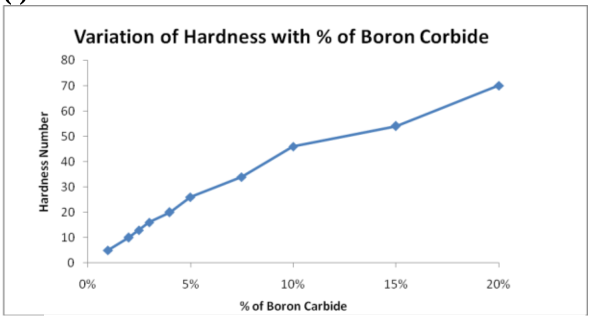

Fig. 8.Variation of Hardness with percentage of boron carbide (B_4C)

As the percentage of boron carbide is increasing, the hardness is increasing as shown in the fig.7.

(ii) Micro Structures :

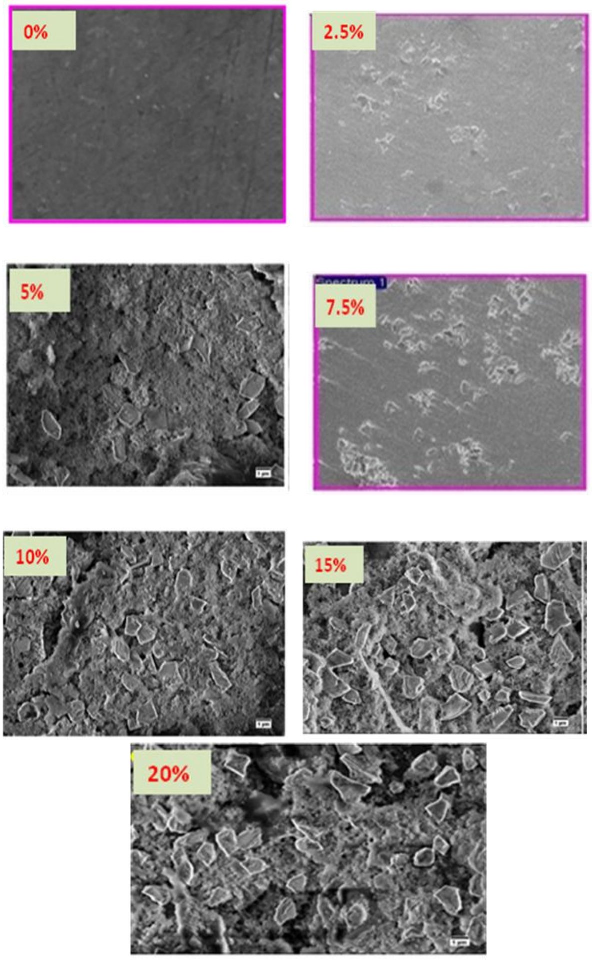

Fig.8. Microstructures of composites for various percentages

The reinforcement material is uniformly mixed in the base material as shown in fig.8. The distribution of particles in the aluminum matrix was relatively homogeneous and uniform. Particles were distributed between the dendrite boundaries with small scale clustering and agglomeration at higher wt.% of B4C. A clear and sharp interface was observed between the particle and matrix with no evidence of reaction products at the interface.

(iii) Ultimate Tensile Strength:

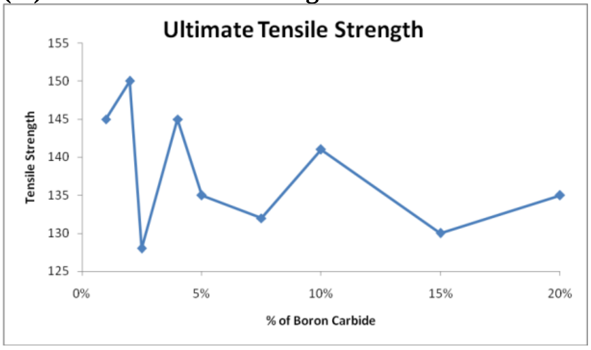

Fig. 9: variation of ultimate tensile strength for boron carbide reinforcement.

V. CONCLUSION

The Al 6061-B_4C composites of various combinations of 0%, 2.5%, 5%, 7.5% 10%, 15% & 20% were produced through stir casting method.

- The ultimate tensile strength is maximum of 153 MPa is at 2.5 % of reinforcement.
- The distribution of reinforcement material is uniform.

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