Synthesis and Characterization of SiC Reinforced HE-30 Al Alloy Particulate MMCs

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***Abstract*— Metal matrix composites have evoked a keen interest in recent times for potential applications in many areas, especially aerospace & automotive industries owing to their superior strength to weight ratio. A particle reinforced metal matrix composite consists of uniform distribution of strengthening ceramic particles embedded within metal matrix. Manufacturing of aluminum alloy based composites via stir casting is one of the prominent and economical routes for processing of metal matrix composites. An attempt has been made to synthesize HE-30 Al Alloy-SiC particulate metal matrix composite by liquid metallurgy route. Micro-structural characterization revealed fairly uniform distribution of SiC particles in the matrix. The prepared composite was subjected to the mechanical testing as per ASTM standards. The mechanical tests revealed an increase in hardness and tensile strength of the developed composites over the base metal alloy.**

Keyword- Metal Matrix Composites, Stir Casting Technique, HE 30 Al Alloy, SiC Reinforcement.

I. Introduction

Aluminium alloys are preferred engineering materials in automobile and aviation industries for various high performance components. This is due to lower strength to weight ratio and excellent thermal conductivity of these alloys. Aluminium alloys reinforced with ceramic particles exhibit superior mechanical properties over unreinforced aluminium alloys.

Metal matrix composites consist of continuous or discontinuous fibers, whiskers or particles in an alloy matrix which reinforce the matrix and provide it with requisite properties not achievable in monolithic alloys.Such tailored properties in MMCs are achieved by systematic combinations of different constituents. The matrix in these composites is a ductile metal or its alloy. The most widely used metal alloys in MMCs are aluminium, titanium, magnesium and copper. Even intermetallic compounds are finding growing interest due to their excellent resistance at high temperatures. The reinforcements in base materials improve stiffness, strength, abrasion resistance, creep resistance and dimensional stability. Different combinations of reinforcements impart diverse enhancements in base materials.

Hard particles such as B4C, Al_2O_3 and SiC are commonly used as reinforcement phases in the composites. The applications of Al_2O_3 or SiC particle reinforced aluminum alloy matrix composites are gradually increasing for pistons, cylinder heads, connecting rods etc. This is particularly true for automotive and aircraft industries, where the tribological properties of the materials are very important [1–3]. In addition, the mechanical properties of MMCs are sensitive to the processing techniques used for fabrication. Considerable improvements may be achieved by applying scientific modeling techniques to optimize the synthesis of composites. Several techniques have been employed to prepare composites including powder metallurgy, melt techniques and squeeze casting [2, 3]. However, powder metallurgy appears to be the preferred process in view of its ability to give more uniform dispersions. Hot extrusion is generally used as post-treatment to take advantage of compressive forces and high temperatures simultaneously [4]. Sajjadi et al. [5] tried to improve the wet ability and distribution of reinforcement particles within the matrix. A novel three step mixing method was used in this study. The process included heat treatment of micro and nano Al2O3 particles followed by injection of heat-treated particles within the molten A356 aluminum alloy by inert argon gas and stirring the melt at different speeds. The influences of various processing parameters on the microstructure and mechanical properties of composites was investigated. Bharath et al. [6] have worked on synthesis and characterization of 6061Al-Al_2O_3 composites. Verma et al. [7] have worked on development and characterization of 5083 Al alloy by microwave sintering method. Bhushan et al. [8] conducted fabrication and micro-structural investigations of Al 7075–SiCp MMCs. 7075 Al alloy was reinforced with 10 and 15 wt. % SiCp (size 20–40 μm) by stir casting process. The resulting cast composites were analyzed using scanning electron microscopy, x-ray diffraction (XRD), differential thermal analysis and electron probe microscopic analysis (EPMA). In the present work, synthesis of HE-30 Al Alloy-SiC metal matrix composite was carried out by liquid metallurgy route (stir casting technique). This composite contained discontinuous particulates in metal matrix. Furthermore, developed composites were characterized for mechanical properties.

II. METHODOLOGY

A. Materials

HE-30 Al Alloy was selected as the matrix material for the present study. Silicon carbide powder was used as reinforcement material in the preparation of composites. The average particle size of the reinforcing material was 25 μm. The SiC particle reinforcements were done at 3 and 5 weight percentages.

B. Preparation of the Composite

The liquid metallurgy technique was used to prepare composite specimens. This method is most economical to fabricate composites with discontinuous fibers or particulates. In this process, matrix alloy (Al- HE-30) was firstly superheated over its melting temperature. Then temperature was lowered gradually below the liquidus temperature to keep the matrix alloy in the semi-solid state. At this temperature, the preheated (800°C) SiC particles were introduced into the slurry and mixed. The composite slurry temperature was increased to obtain fully liquid state. Stirring was continued for 10 minutes at an average stirring speed of 500 rpm. The melt was then superheated above liquidus temperature (760°C) and finally poured into preheated permanent metallic moulds. The pouring temperature was maintained at 700^0C. The melt was then allowed to solidify. Fig.1 shows the setup diagram of stir casting technique. After removing the cylindrical specimens from moulds, the specimens were machined to the required size to carry out tensile, hardness and microstructure tests.

Fig.1 Stir Casting Set-Up

C. Testing of composites

To study the microstructures of specimens, the central portion of the casting was cut by an automatic cutter. The specimen surfaces were prepared by grinding through 300, 600 and 1000 grit papers and then by polishing with 3μm diamond paste. Microscopic examination of the composites was carried out by optical microscopy. To investigate the mechanical behavior of the composites the hardness and tensile tests were carried out using Brinell hardness tester and computerized uni-axial tensile testing machine as per ASTM standards. Fig.2 shows the tensile test specimen as per ASTM standard, with overall length of 80mm and gauge diameter of 8mm.

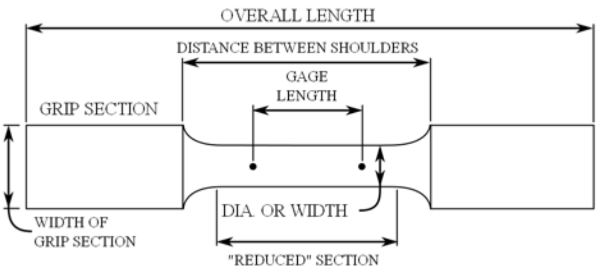

Fig.2 Tensile Test specimen as per ASTM Standard

III. RESULTS AND DISCUSSIONS

A. *Micro-structural Studies*

The optical micrographs of unreinforced alloy and of the composites with 3% and 5% volume fractions of reinforcements are shown in Fig.3. The microstructure analysis of these specimens shows that the SiC particles are uniformly distributed in the matrix. However, a presence of porosity around the SiC particles was detected. This observation may be attributed to the wetting behavior of aluminum alloy. It is also observed from the optical micrographs that the porosity of the specimens increases with increasing volume fractions of the particulate reinforcements.

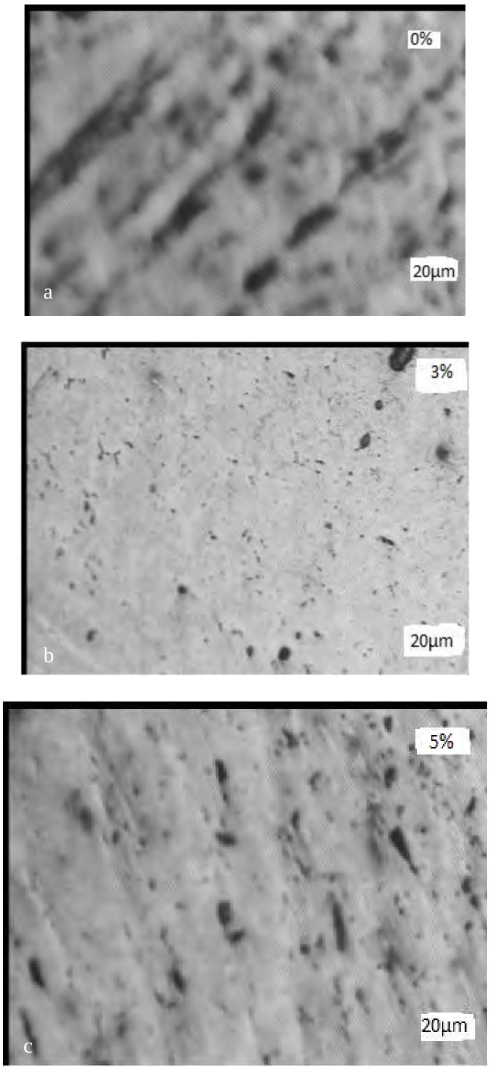

Fig.3 Optical micrographs of (a) unreinforced HE-30 Al Alloy (b) HE-30 Al Alloy + 3% SiC (c) HE-30 Al Alloy + 5% SiC

B. *Hardness Measurements*

Fig.4 shows the results of Brinell hardness tests conducted on HE-30 alloy and the HE-30 aluminum alloy composites containing different weight percentages of SiC particles. The Brinell hardness was measured on the polished samples using steel ball indenter of 10mm diameter with a load of 500kgf. The reported value is an average of 5 readings taken at different locations on the specimens. A significant increase in hardness of the alloy matrix was seen with the addition of SiC particles. This indicated that the existence of particulates in the matrix improved the overall hardness of the composites. This is due to the fact that aluminum is a soft material and the reinforced particles being hard, contribute positively to the hardness of the composites. The presence of stiffer and harder SiC reinforcement leads to the increase in resistance to plastic deformation of the matrix.

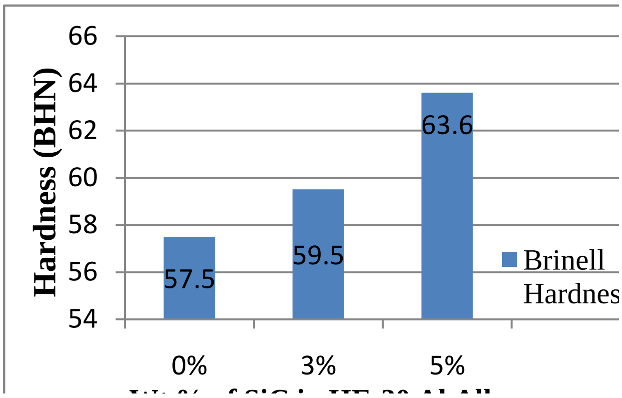

Fig.4 Hardness of HE-30Al before and after addition of SiC particulates

C. *Tensile Properties*

To investigate the mechanical behavior of the composites, tensile tests were carried out using computerized uni-axial tensile testing machine as per ASTM standards. Three test specimens were used for each run. The tensile properties such as tensile strength and percentage elongation were analyzed from the stress -strain curves as represented in Table I. It was observed that fracture strength of composites (both 3 and 5 wt %) was greater as compared to that of HE-30 aluminum cast alloy. It is also clear from the tensile test results that with increase in reinforcements, the tensile strength improves whereas ductility deteriorates. As mentioned above, a thermal mismatch between the metal matrix and the reinforcements is a major mechanism for increasing the dislocation density of the matrix and thereby increasing the composite strength. However, the composite materials exhibited lower elongation than unreinforced specimens. It is obvious that plastic deformation of the mixed soft metal matrix and the non-deformable reinforcement is more difficult than the base metal itself. Therefore, the ductility of the composite must be lower than that of unreinforced material. Fig.5 shows histogram for tensile strengths of unreinforced HE-30 Al alloy and reinforced metal matrix with 3and 5 wt pct SiC particulates.

Table I
Tensile Test Results

Sl No	Wt pct of SiC particles (%)	Percentage Elongation (%)	Ultimate Tensile strength (N/mm^2)
1	0	4.76	100.05
2	3	3.61	130.34
3	5	3.15	138.43

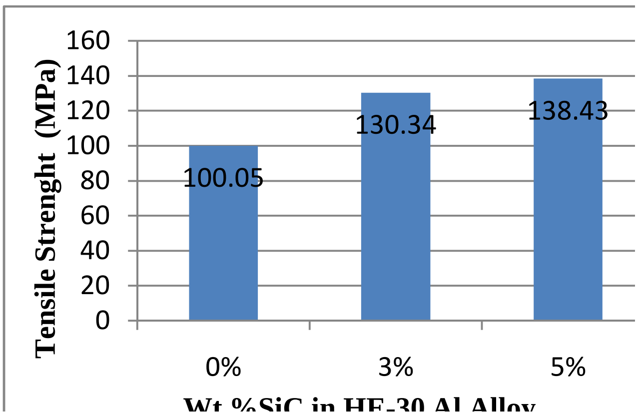

Fig.5 Tensile Strength of HE-30Al before and after addition of SiC particulates

IV. CONCLUSIONS

The present work on synthesis and characterization of HE-30 Al- SiC composites led to the following conclusions:

1. The composites containing HE-30 aluminum alloys having 3 and 5 wt% of silicon carbide particulates were successfully synthesized by melt stirring method.

2. The optical micrographs of composites produced by stir casting method showed fairly uniform distribution of silicon carbide particulates in the HE-30 aluminum metal matrix.
3. It was revealed that the hardness of composite samples increased with increasing weight percentages of silicon carbide particles.
4. Strength of prepared composites was higher in case of composites, while ductility of composites was lesser when compared to cast HE-30 aluminum alloy.
5. The tensile strength shows an increasing trend with increasing weight percentage of silicon carbide.

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