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Fabrication of Al-SiC Metal Matrix Composites Using Two Steps Mixing in Stir Casting

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Abstract - The applications of MMC are keep on growing day by day. Everyone requires a material which can fulfil the required designed strength criteria but it is mostly preferred to have a lighter material. Aluminium matrix composites (AMMCs) are demanded more likely than the other conventional materials due to their high strength to weight ratio, high corrosion resistance, high yield strength, high wear resistance and low economic. These AMMCs can provide versatile properties depending upon the chemical composition, type of reinforcement, particle size of reinforcement and finally, the method of fabrication. The problem mostly incorporated while fabrication is the non-homogeneous distribution of the reinforced phase in the molten matrix, which leads to the directionality in the properties of MMCs. The present paper is focussing on the fabrication of the Al-SiC metal matrix composites using two step mixing in the stir casting. The reinforcement particles of SiC are added into the molten Al-6061 in two consecutive steps with 5 wt. %. each. Different properties were studied for two step mixing technique. The microstructure results shows that there is improved homogenous mixing in the MMC using two consecutive mixing steps. Also there is considerable enhancement in the hardness upto 180% to that in case of Al-6061.
Keywords –Metal Matrix composites, Aluminium metal matrix composites, stir casting, Silicon Carbide particulates, Microstructure and hardness.

I. INTRODUCTION

A composite material is a material comprising of two or more physically and/or chemically different phases. The composites usually contain low density materials like Aluminium (Al) and Magnesium (Mg) as a matrix/solvent phase reinforced with the ceramic material particles such as silicon carbide (SiC), aluminium oxide (Al_2O_3), graphite etc. Usually the reinforcing component is dispersed in the continuous or matrix component. When the matrix is metal the composite is called as Metal Matrix Composite (MMC).

The objective involved in fabricating metal matrix composite materials is to combine the desirable properties of metals and ceramics. The addition of high strength, high modulus refractory particles to a ductile metal matrix produces a material whose mechanical properties are intermediate between the matrix alloy and the ceramic reinforcement. The high yield strength, high modulus of refractory and high stiffness ceramic particles, when added to a high ductility, high temperature resistance and low stiffness metals, the composite formed from mixing of them have the moderate properties that lies in between the two parent materials [1-3]. Aluminium and silicon carbide are the well-known composite as Al/SiC metal matrix composite. The mechanical properties obtained with the metal matrix composites(MMCs) along with their relatively low cost of production have made them most considerable for several applications in various fields including automotive, sports industries and aerospace [4,5,6].There are many methods available for production of MMCs like powder metallurgy, by stir casting, in situ development of reinforcements, and foil-and-fiber pressing techniques. But stir casting is best suited and economical method of production of MMCs. [7, 8].The major challenge incorporates with the stir casting is to get homogeneous mixing of solid reinforcement particles (like SiC) into the molten phase of metal (Al) as it has a strong impact on the properties and the quality of the material [1-8]. The non-homogeneous mixing of reinforcement results into the more density distribution, directional properties, and more variations in surface hardness.

The Stir casting technique is currently the most common practiced commercial method for producing MMCs. This methodology involves mechanical mixing of the reinforcement particles into a molten metal solute bath. A basic apparatus is shown in Fig. 1, and typically is comprised of an electric furnace with heated crucible containing molten aluminium metal, with an electric motor that drives a mixing impeller or, paddle, that is submerged into the melt. To ensure a smooth and continuous feed, the reinforcement is poured into the crucible above the melt surface and at a very controlled rate.

When the impeller rotates at reasonable speeds, it generates a vortex. The generated vortex then produce the pressure difference between the centre and the outer upper part of vortex. When the solid phase reinforced particles are added into the wall side upper part of vortex that automatically draws the reinforcement particles into the melt from the surface. Proper mixing techniques and

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optimized impeller design are required to produce adequate melt circulation and homogeneous distribution of the reinforcement [9, 10].

In the present work, Al6061/SiCp MMC was produced by stir casting process, whereby the solid state SiC particulates 10% by wt. were introduced into the molten metal through a vortex introduced by mechanical agitation. SiCp addition was carried out in two consecutive steps of 5% each to ensure the homogeneous mixing and to eliminate the formation of clusters of SiC particulates into the molten Al alloy. After casting the microstructure of the composite was studied by tool maker microscope. The distribution of the SiC particles in the Al matrix was observed and the hardness of the composite was studied at different points.

II. MATERIALS AND METHODS

To fabricate the metal matrix composite material, stir casting technique is used among all other available techniques due to ease of process and economical. Aluminium 6061 alloy (Al-6061) was used as a matrix material and the SiC_p with a mesh size of 200 was used as a reinforcement material. The presence of SiC_p in the metal matrix composite structure increases the hardness of the composite to a greater extent. The important physical properties of the matrix and reinforcement are shown in Table 1.

TABLE 1. PROPERTIES OF AL6061 AND SiC_p

Material	Density [g/cm^3]	Melting Point [°C]	Thermal conductivity [W/m.K]	Modulus of Elasticity [GPa]	Co-efficient of thermal expansion [m/m-^{0}C]
Al6061	2.72	620	166	70	23.4×10^{-6}
SiC_p	3.21	2730	120	410	4.1×10^{-6}

III. EXPERIMENTATION

A. Experimental Setup

The conventional stir casting setup is shown in Fig.1. The stir casting setup consists of an electric furnace, stirrer motor with stirrer, stirrer holding attachment and temperature indicating panel with thermocouples. The maximum range of temperature achieved in the furnace is 1200°c.

B. Experimental Procedure

The required amount of aluminium alloy and SiC particles can be found out by the calculations from the designed pattern volume. Aluminium 6061 alloy was taken in form of rods with diameter of 6mm, were broken into small pieces so as to accommodate them into the crucible. Electric furnace was used for the melting of the aluminium alloy as shown in figure. The melting point of the alloy is 650 and it was superheated by 100, so the temperature was set at 750°c. SiC powder (10% by weight) of mesh size 200 was placed in another crucible and was preheated to temperature of 1000 in second furnace. The preheating was done in the presence of air so that it assist in removing surface impurities, desorption of gases and formation of oxide layer around each particle which will act as protective layer and inhibit the reaction between the SiC powder and molten aluminium alloy [5].

The molten aluminium alloy was stirred continuously by using electric motorised stirrer running at 200 rpm, in the crucible. Due to the stirrer action there occurs the formation of vortex in the molten metal and this vortex produces a pressure difference along the depth and radius.

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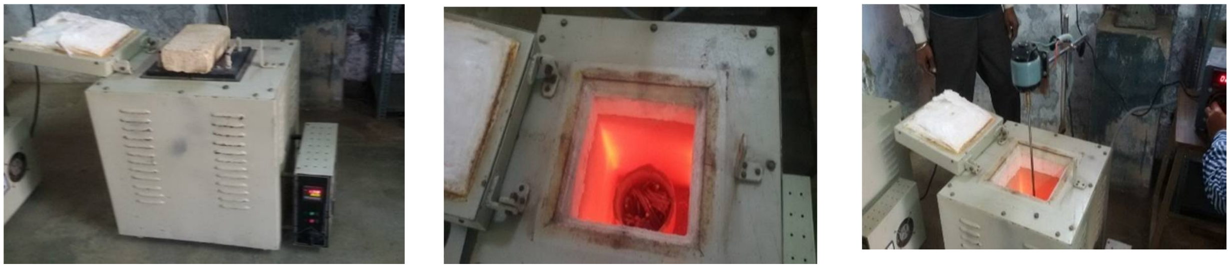

Fig. 1. Stir casting setup

The process of introducing SiCp into the molten matrix was done in two consecutive steps with 5% by weight each time. This was done to get more uniform mixing and to reduce the formation of clusters of SiCp into the molten matrix. The preheated SiCp 5% by wt. were then added to the side of the vortex formed. The pressure difference induced by vortex, works as the acting force to get the SiCp deep into the molten aluminium and across the radius of vortex. This phenomenon helps in uniform mixing of SiCp into the molten matrix. The stirring was continue for 5 min while the temperature of the furnace was set at 900°C. After completion of the first mixing step, again 5% SiCp (5% of initial Al 6061) were added to the molten aluminium that already contains 5% SiCp, to complete the final stage of mixing. So, overall 10% by wt. SiC particulates were added.

C. Microstructural Analysis

The test specimens required for microstructure analysis were machined to rectangular plate form specimens with the help of vertical milling machine and were then ground in successive steps using abrasive papers of various grit sizes. The ground specimens were then finely polished on a velvet cloth using a hydro sulphuric acid as an etchant. The specimens were then washed and dried with acetone before mounting. The microstructures of the prepared specimens were studied using a metallurgical microscope.

D. Hardness Test

The hardness values of the samples were tested by using the Brinell hardness tester. The Brinell hardness test was conducted with a ball of 10 mm diameter by applying 500 kg load for 10 to 15 seconds on the surface of the sample of the aluminium based SiC metal matrix composites. Then the diameter of the impression has been measured by the scale. Then the hardness was calculated by the equation (1) given below:

$$BHN = \frac{2P}{\Pi D(D-\sqrt{D^2-d^2})} \qquad \ldots\ldots\ldots\ldots\ldots (1)$$

Where D is ball diameter in mm; P is load in kg; and d is the diameter of the indentation in mm.

IV. RESULTS AND DISCUSSIONS

The sample of Al/SiC MMC was prepared to test the microstructure and hardness. The observations were taken at five different points on the surface to get the better unbiased results.

A. Microstructure Evaluation

To study the particles distribution patterns in the composites, optical microscopy images were taken on the composite samples. Fig. 2 shows the microstructures of the composites of the prepared specimen of Al/SiC MMC fabricated by stir casting method. From the Microscopic pictures it is evident that the distribution of the SiC particles in the Al matrix has been successful.

The vortex formed during mechanical motorised stirring and the addition of SiCp in two consecutive steps were the prime reasons for the inclusion and uniform distribution of SiCp in Al.

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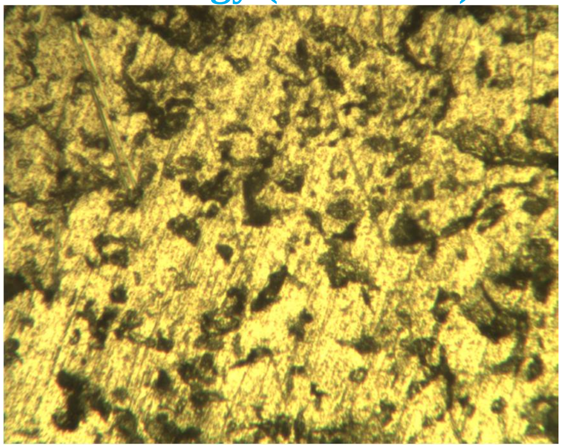

Fig. 2. Microstructure of prepared MMC

B. Hardness Evaluation

The hardness values of the composites increases to a large extent with the SiCp additions as shown in Table 2. The Brinnel hardness was tested at different points on the prepared specimen to get the accurate results. Variation was observed in the hardness due to uncertainty of occurrence of SiC particle below the pointer of Brinnel hardness tester ball.

The hardness value of Al-6061 and that of composite with 10 wt. % SiC addition is shown in table. This is noteworthy that the hardness value of the composite increased from 30 HB in case of Al-6061 alloy to 55 HB for 10 wt. % SiC additions to the Al-6061, which is about 180% that of the Al alloy.

TABLE 2. BRINNEL HARDNESS TEST VALUES

Observation no.	1	2	3	4	5	Mean hardness
Hardness value	54	55	56	53	57	55

This is certainly due to the increase in SiC additions to the composite which acts as a reinforcement for the aluminium matrix. A problem was encountered while measuring the hardness of the globular phases as it was difficult to locate the indentation exactly on the SiC particles. That is why hardness values are averages of five to six measurements. While the accuracy of the measurements may not be very high, it nevertheless suggests that upon SiC additions the metal matrix composites have higher hardness than Aluminium alloy.

V. CONCLUSIONS

The microstructure of the metal matrix composite with two steps SiC additions was studied in relation to the stir casting method. It can be said that stir casting method with addition of reinforcement particles is a viable option yields a composite with uniform particle distribution. The quality of the metal matrix composite improves in terms of more uniform hardness values by adding the reinforcement by this method. The addition of 10 wt. % SiC increases the hardness of the composite by 180%.

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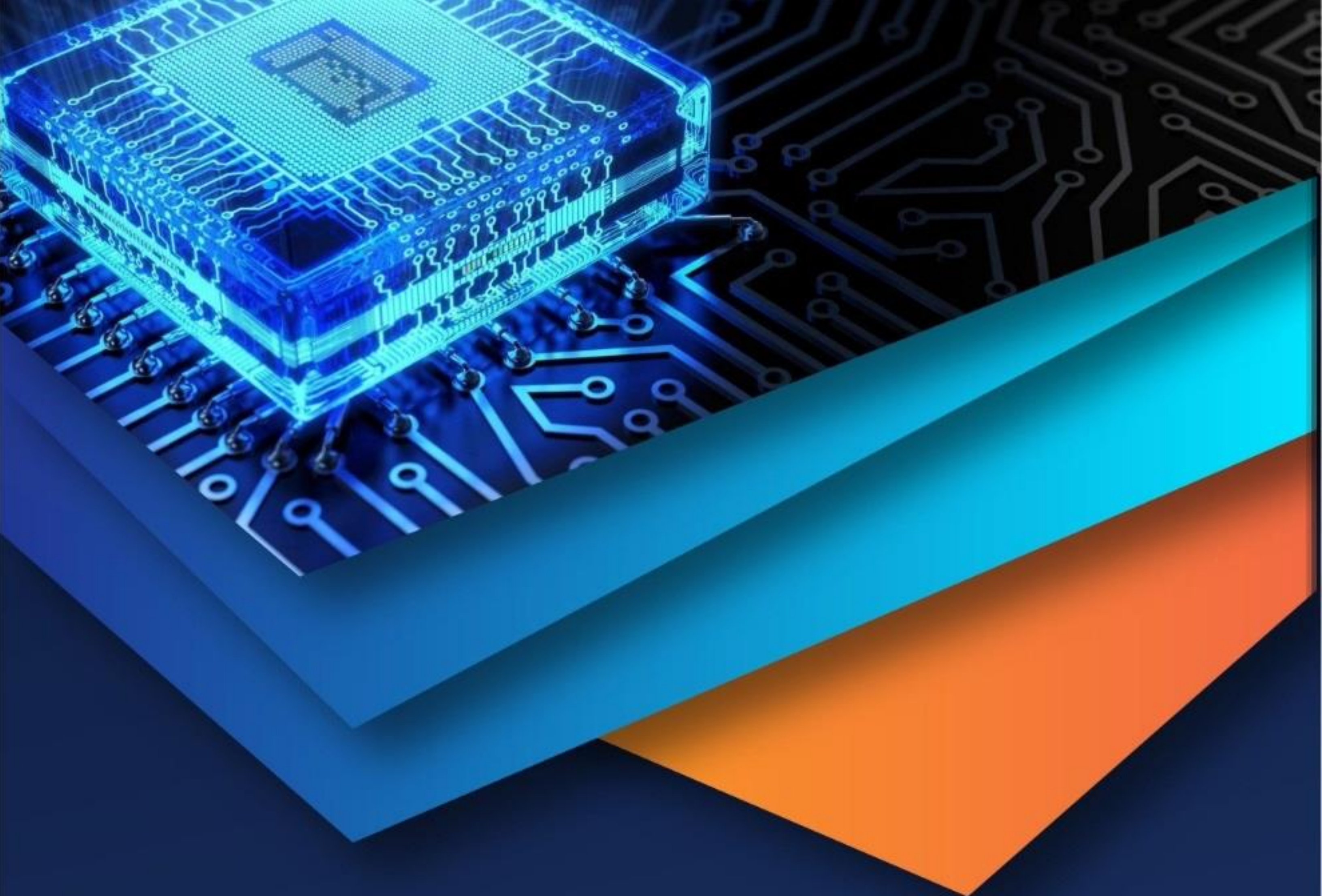

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