FABRICATION AND MECHANICAL PROPERTIES OF STIR CAST Al-Si12Cu/B_4C COMPOSITES

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Abstract

The present study was made to understand the fabrication and mechanical properties of Al-Si12Cu/B_4C Metal Matrix Composites. The composites were fabricated by reinforcing B_4C particles with varying wt % of 2, 4, 6, 8 and 10, using stir casting process. The performance of the composites was compared with the alloy to study the improvement in mechanical properties that has been imparted by the reinforcement particles to the composites. The microstructure was examined on the composite specimens using optical microscope to confirm the homogeneous dispersion of reinforcement particles in the matrix. Mechanical properties such as hardness and tensile strength were tested on the composite using Brinell hardness tester and computerized Universal Testing Machine respectively. The results revealed that the B_4C particles were homogeneously distributed in the composite. The hardness and tensile test results showed that, by increasing wt % of reinforcement particles in the matrix, hardness and tensile strength of the composites was improved to 6.97 % and 33 % respectively compare to base alloy.

Keywords: *Metal Matrix Composite, Stir casting, Microstructure, Mechanical properties, Hardness and Tensile strength.*

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1. INTRODUCTION

Metal Matrix composites (MMCs) are the combination of two or more distinct phases that has improved properties than the monolithic alloy. Aluminium MMCs are greatly developing in the recent years due to their low cost and light weight, which replaces the high cost bronze and cast alloys in several applications [1]. Due to its unique combination of properties such as high specific strength, high corrosive resistance, high elastic modulus, good thermal stability, high hardness, high wear resistance, superior strength to weight ratio and light weight, its usage increased drastically in the automobile, aerospace and defense sectors [2].

Stir casting process is employed to fabricate aluminium composites with varying wt% (5, 10, 15, 20, 25, and 30) of Silicon Carbide (SiC) particles and inferred that uniform dispersion of reinforcement particles is successfully attained through this method, and also stated this method as the low cost effective method for fabrication of MMCs among various conventional casting techniques [3]. Microstructural observation is done on the stir cast aluminium composites and interpreted that wettability is important factor in achieving uniform dispersion of the reinforcement particles in the matrix without agglomeration, which helps in improvement of mechanical properties of the composites [4]. Selection of type of reinforcement also contributes in increasing the mechanical properties such as hardness and tensile strength of the composites. Soft reinforcements increase the tensile strength and decrease the hardness of the composite, whereas hard reinforcements increase the tensile strength as well as the hardness of the aluminium composites [5].

Hardness of the Aluminium Nitride (AlN) reinforced stir cast aluminium composite is tested and concluded that, overall hardness of the composites increased with increasing the wt % of AlN particles, as this is due to the hardness of the AlN particles that has been embedded uniformly in the composite [6]. Effect of Alumina (Al_2O_3) particles on the tensile strength of the aluminium composite is investigated and interpreted that the Al_2O_3 particles increases tensile strength of the composite up to 10% [7].

There are numerous studies found out on mechanical behaviour of particles reinforced MMCs but very few studies only have been explored on the mechanical properties of B_4C particles reinforced MMCs. Thus the present study deals with the fabrication of Al-Si12Cu alloy reinforced with B_4C particles with varying wt % of 2, 4, 6, 8 and 10, and analyzing its microstructure and mechanical behaviour.

2. MATERIAL SELECTION

The materials chosen for the fabrication of the composite are Al-Si12Cu alloy as base matrix and B_4C particle as reinforcement. This alloy is chosen because of its applications in pistons, pulleys, sheaves and bearings. The B_4C particle is selected for reinforcing with the composite due to its high hardness. The density of the alloy and B_4C particles are 2.71 g/cm^3 and 2.51 g/cm^3 respectively. B_4C particles with size of 33 microns are added as particulate to the composite for the varying wt % of 2, 4, 6, 8, and 10. The chemical composition of Al-Si12Cu aluminium alloy is shown in Table 1.

Table -1: Chemical composition of Al-Si12Cu aluminium alloy

Chemical composition	%
Al	83.39
Si	10.9
Fe	0.527
Cu	1.31
Mn	0.113
Mg	1.05
Cr	0.0065
Ni	2.32
Zn	0.275
Sn	0.0590
Ti	0.0340
Pb	0.00
Ca	0.0065

3. FABRICATION OF COMPOSITES

Al-Si12Cu/B_4C MMCs with varying wt % of 2, 4, 6, 8 and 10 are fabricated by using stir cast process. Aluminium billets are loaded in the graphite crucible and placed in an open hearth furnace. Coal is charged around the crucible in the furnace which produces heat on burning. This allows the aluminium billets to melt. One side of the furnace is connected with an electrically operated blower which sucks the air from the atmosphere and sends to the furnace for the continuous generation of heat. Once attaining the molten metal condition of the alloy, the preheated B_4C particles are added to the molten metal and the stirring action is done simultaneously for 5 min to achieve the homogeneous distribution of the reinforcement particles in the composite. Then the molten metal is poured at 800 ºC into the cylindrical sand moulds having holes dimensions of diameter 25 mm and length 150 mm. After pouring the molten metal into the moulds, it kept for some time to solidify. After solidification, composite specimens are withdrawn from the mould. The same procedure is followed for all composites with varying wt %. The schematic illustration of the fabrication process is shown in Figure 1.

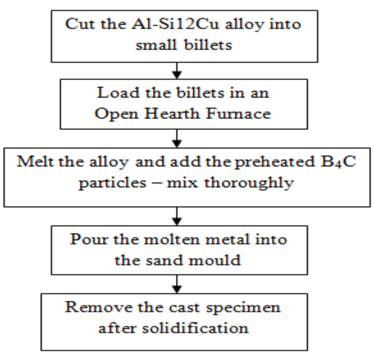

Fig -1: Schematic illustration of fabrication process

4. MICROSTRUCTURE EXAMINATION

The specimens for microstructure examination are machined from the cylindrical cast specimens. Initially, the samples are grinded in bench grinding machine to remove the burs and polished in belt grinder for the rough surface finish. Then the specimen is polished with emery sheets of grade 1/0 and 2/0. Finally it is polished using disc polisher with diluted Al_2O_3 to remove all the scratches on the surface to get good surface finish. The polished specimens are etched with general aluminium agent prior to examination using Zeiss Axiovert 25 CA Inverted Metallurgical Microscope. The microstructural examination is done for various magnifications on all the composite specimens (2, 4, 6, 8, and 10 wt %) for observing the homogeneous distribution of the reinforcement particles in the composite.

5. HARDNESS TEST

Macro hardness test is performed on alloy and all the composite with different compositions (2, 4, 6, 8 and 10 wt %) by using the Brinell hardness tester. The specimens are grinded and polished using emery sheets. The tester is equipped with hardened steel ball having diameter of 10 mm for producing indentation on the specimen surface. The specimen is placed on the test platform and the indenter is allowed to touch the specimen surface. A minor load of 10 kgf is applied on the specimen surface by operating the lever to locate the position for producing indentation. Then the major load of 1000 kgf is applied on the located point of the specimen for 30 seconds. Then the load is released and the specimen is removed from the machine. The hardness is tested at four different places on the surface of all the composite specimens and the diameter of the indentation is measured by microscopic screw gauge. The Brinell Hardness Number (BHN) is calculated and the average value is taken as the hardness value of the specimen.

6. TENSILE TEST

The specimens (Figure 2) are machined as per ASTM (E8-04) standard from the composites specimens. The machined specimens are fixed in between the jaws of the computerized Universal Testing Machine (UTM). Input data of the specimens is fed into the UTM software. The load is applied gradually on the two ends of the specimen by pulling. The specimen gets broken after the formation of neck. Then the specimen is removed from the machine. The test results are obtained through the software in the graphical form. The specimen before and after tensile test is shown in Figure 3 (a) and (b).

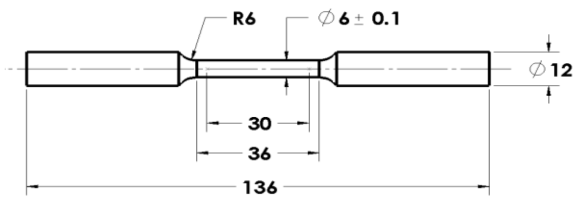

Fig -2: Specimen prepared for tensile test

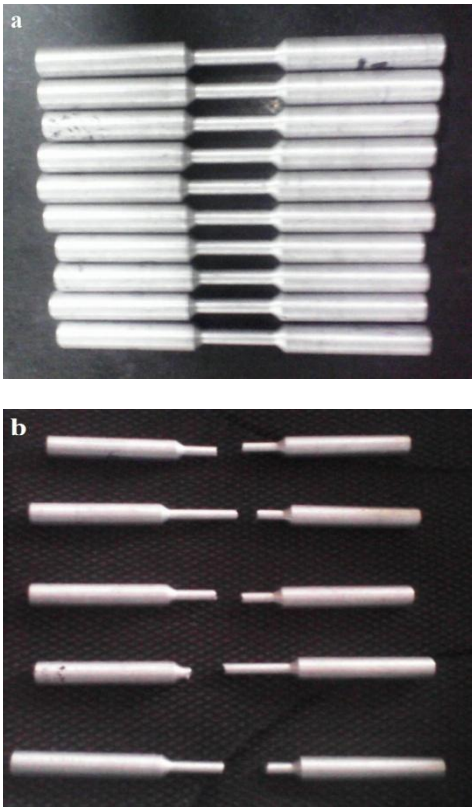

Fig -3: Specimen (a) before test and (b) after test

7. RESULTS & DISCUSSIONS

The microstructure evaluation and the mechanical properties of the composites are detailed in the further sections.

7.1 Microstructure Evaluation

The microstructure of the Al-Si12Cu/B_4C (2, 4 and 10 wt %) composites are shown in Figure 4(a), (b) and (c). The homogeneous distribution of the reinforcement particles in the composite is observed due to the greater wettability of the B_4C particles with the aluminium alloy. This greater wettability of B_4C with the aluminium alloy might be due to the formation of liquid B_2O_3 layer on the B_4C particles. This liquid layer forms above certain temperature on the surface of B_4C and the wettability gets increased as there is a liquid–liquid reaction, whereas the same pattern is resulted [8]. From the microstructure (Figure 4 (c)), it is observed that white area is aluminium matrix and remaining dark grey area are the B_4C reinforcement particles. The better interfacial bonding between the matrix and reinforcement particles is observed because of less porosity, whereas same behaviour is observed [9].

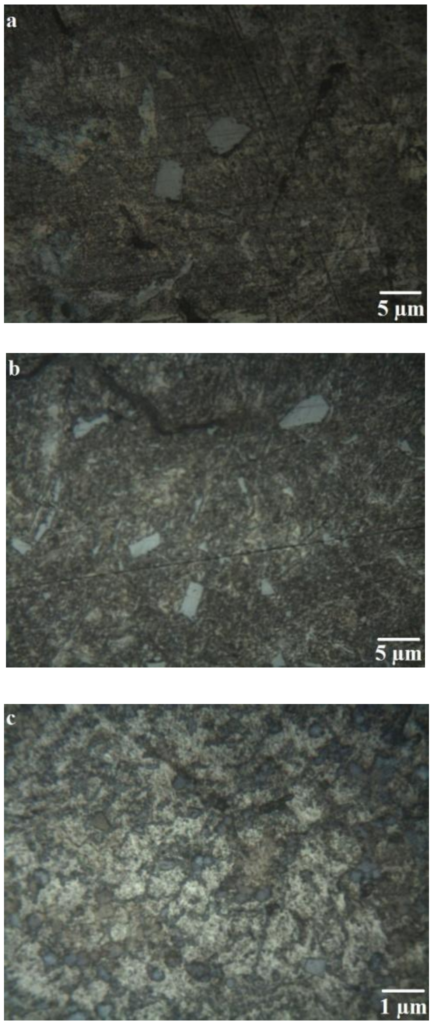

Fig -4: Microstructure of the Al-Si12Cu/B_4C composites (a) 2 wt % (b) 4 wt % and (c) 10 wt %

7.2 Mechanical Properties

The mechanical properties such as hardness and tensile strength of the Al-Si12Cu/B_4C composites is discussed briefly in the following sections

7.2.1 Hardness of the Composites

The hardness results of the Al-Si12Cu alloy and Al-Si12Cu/ B_4C (2, 4, 6, 8 and 10 wt %) composites are shown in Chart 1. Hardness value is increased by increasing the wt % of B_4C reinforcement particles in the composites. By adding the reinforcement particles to the composites, surface area of the reinforcement gets increased and grain sizes of the matrix get decreased. The presence of such hard reinforcement particles on the surface resists the plastic deformation of the material. The strength of the grain boundaries increases to maximum level and dislocation of atoms are decreased by increasing the wt % of reinforcement, which gives strength to the matrix and thereby hardness of the composite gets increased. The same phenomenon is observed [10]. The 10 wt % B_4C reinforced composite yields better hardness than unreinforced alloy by 6.97 %.

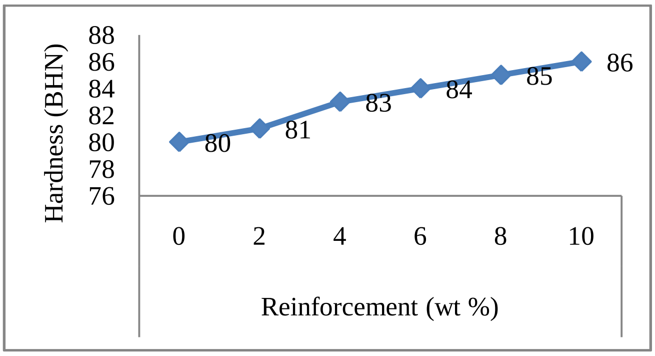

Chart -1: Hardness of Al-Si12Cu alloy and Al-Si12Cu/B_4C composites

7.2.2 Tensile Strength of the Composites

The tensile strength of the Al-Si12Cu alloy and Al-Si12Cu/ B_4C composites is shown in Chart 2. From Chart 2, it is observed that ultimate tensile strength is increased by increasing the percentage of B_4C particles in the composite. This is due to the better interfacial bonding between the matrix and the reinforcement which transfers and distributes the load from the matrix to the reinforcement. Therefore the reinforcement particle tends to bear the entire load that has been acted upon the matrix. The tensile strength is observed to get increased drastically up to 8 wt % of reinforcement and after that, amount of increase in tensile strength gets reduced as this might be due to the formation of clustering in a matrix, same pattern is resulted [11]. The 10 wt % B_4C particles reinforced composite shows an increase of 33 % tensile strength more than the Al-Si12Cu alloy.

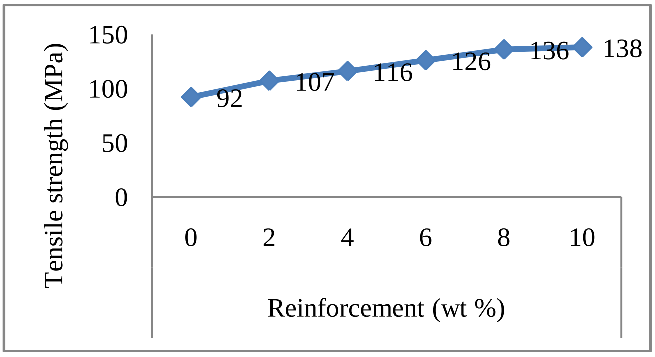

Chart -2: Tensile strength of Al-Si12Cu alloy and Al-Si12Cu/B_4C composites

8. CONCLUSIONS

Al-Si12Cu/B_4C metal matrix composites with varying wt % of 2, 4, 6, 8 and 10 are successfully fabricated using stir casting process. The homogeneous distribution of the reinforcement particles in the composite is attained due to the greater wettability of the B_4C particles with the aluminium alloy. By increasing the wt % of B_4C particles in the aluminium matrix, hardness of the composites gets increased than the alloy due to the resistance offered by the reinforcement particles to the plastic deformation. The tensile strength of the composites increases greatly up to 8 wt % of reinforcement and after that, level of increasing in tensile strength gets reduced due to the clustering of reinforcement particles. The results obtained from this study can be used effectively for development of the structural and automotive components that requires better mechanical properties.

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