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Production and Properties of Silicon Carbide Particles Reinforced Aluminium Alloy Composites

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***Abstract*—** Metal matrix composites (MMC_s) are known to have wide application in parts of transportation devices such as automobiles and aircraft. In this paper, the Al–Si / SiC composites containing three different volume fractions 7, 14 and 21 weight percentage of SiC have been fabricated by stir casting technique.

The results have shown an increasing in mechanical properties such as ultimate tensile strength, yield strength and hardness at the expense of impact energy for composite material with increasing reinforcement materials content. Micro structural studies have been carried out to understand the nature of structure.

***Keywords*—** Al-Si/SiC, Aluminium alloy, Mechanical properties, Stir casting technique.

I. INTRODUCTION

ALUMINIUM metal matrix composites (AMMCs) have considerable applications in aerospace, automotive and military industries due to their high strength to wear ratio, stiffness, light weight, good wear resistance and improved thermal and electrical properties. Ceramic particles such as Al_2O_3, SiC are the most widely used materials for reinforcement of aluminium [1,2].

Different methods have been adopted for fabrication of metal matrix composites. Among them, the conventional foundry based processes are more favorable in obtaining near net shape components at high production rates and low costs. In recent years, the stir casting technique has attracted the interest of many researchers. Rheocasting, Compo casting, Disintegrated melt deposition are the variants of the stir casting technique. This Technique involves incorporating the ceramic particles into the melt and stirring by means of mechanical impeller[3,4].

W. Zhou et al. studied a composites based on two aluminum alloys (A536 and 6061) reinforced with 10% or 20% volume fraction of SiC particles were produced by gravity casting and a novel two-step mixing method was applied successfully to improve the wettability and distribution of the particles. The SiC particles were observed to be located predominantly in the inter-dendrite regions, and a thermal lag model is proposed to explain the concentration of particles [5]. K.R.Sureshet al. studied tensile and wear properties of aluminum composites fabricated by squeeze casting method and checked uniform particulate distribution. The squeeze cast composites show peak strength of 216 MPa showing an increase of 11.6% in tensile strength. The new composites also have improved wear resistance when compared to gravity cast composites [6]. Recent investigations find that the incorporation of nano-particles into the aluminum matrix could enhance the hardness, the yield and ultimate tensile strength considerably, while the ductility is retained. The great enhancement in strength values of these composites is attributed to grain refinement, strong multidirectional thermal stress at the matrix/nano particle interface, small size of nano particles, good distribution of the nano particles and low degree of porosity which leads to effective transfer of applied tensile load to the uniformly distributed strong nano particulates. The strength of composites is expected to be influenced by the dislocation density, dislocation-to-dislocation interaction and constraint of plastic flow due to the resistance offered by particles. It is reported that due to the thermal mismatch stress, there is a possibility of increased dislocation density within the matrix which leads to local stress and increasing strength of the matrix and the composite. More than 50% improvement in yield strength of A356 alloy was observed with only 2.0% (mass fraction) nano-sized SiC particles [7].

This paper adopts production matrix alloy and composite material economical technique and improving mechanical properties.

II. EXPERIMENTS PROCEDURE

The materials are used in the preparation of composite materials divided into two parts matrix and reinforcement. The chosen alloy (Al-Si) as the basis indicated chemical composition after the casting process in table (1). The reinforcement material included silicon carbide in particle size (100-150 µm). Alloy was prepared by casting in metals mold and mass information. Smelting process carried out at (750^o c) in electric furnace with high nozzle crucible made of silicon carbide, As it has been melting pieces of element aluminum, and small pieces of silicon were added to the molten aluminium, then pieces of iron are added to the molten. All elements were added to molten aluminum wrapped with aluminum foil. For the purpose of homogenizing molten is rotated continuously by rod graphite and repeat the process for the other elements. Then the metallic molten has poured in die casting made of steel and pre-heated to a temperature (250^oc) to prevent sudden cooling.

Composite materials are prepared by stir casting, as the base alloy cut into small pieces for the purpose of weighting and calculating weight fraction of silicon carbide by 5%, and then the weighted pieces were placed in crucible inside furnace electric fixed temperature at (750^oc) to ensure full melting ingot, then ceramic particles (SiC) enveloped aluminium foils are added to the molten and pre-heated to (250^oc) in order to remove moisture and improving the dispersion of particles within the molten. A small amount of Mg was added to ensure good wettability of particles with molten metal. The electric mixer enters in crucible furnace which it spins rapidly at speed (900 rpm) to improve homogenizing molten for (3-5 min), then the molten poured into metallic mold. The processes were repeated several times according weight percentages of silicon

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carbide as shown in table (1).

Aluminium alloy (Al-Si) composites containing various SiC contents, namely 7,14 and 21% by weight were fabricate and tested, and their properties were compared with those of unreinforced matrix. All tested were conducted in accordance with ASTM standards. Tensile tests were performed at room temperature using machine in accordance with ASTM E8-95 standards and. The tensile specimens of diameter 12.5 mm and gauge length 62.5 mm were machined from the composite with gauge length of specimen parallel to longitudinal axis of the casting. The Rockwell hardness values were conducted in accordance with ASTM E18-79 standards. A Rockwell hardness tester was used steel ball indenter diameter of 1.56 mm, minor load 10 Kg and major load of 100 Kg.

C .Ultimate Tensile and Yield Strength

Charpy impact tests were conducted on notched specimens according to ASTM E32-02A standard. The dimensions of the specimens machined for the impact tests were 55×10×10 mm with notch depth of 2 mm and notch tip radius of 0.25 mm at 45^o angle.

Samples for the microscopic examination were prepared by standard metallographic procedures etched with killer's agent and examined under optical microscope.

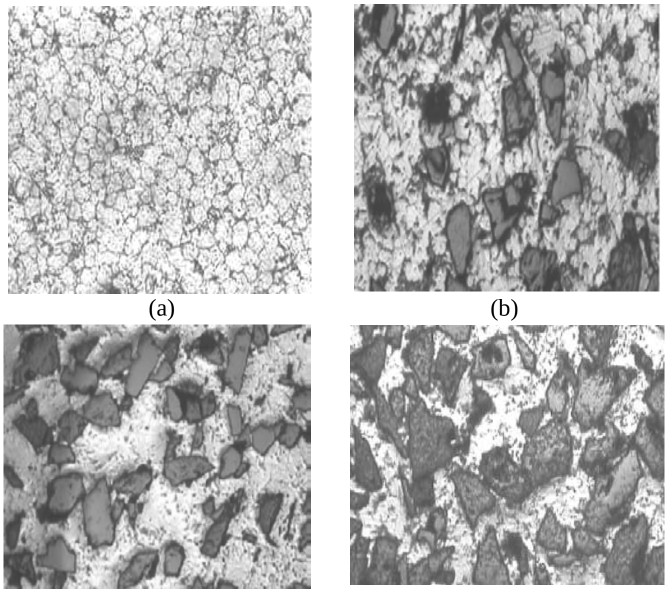
III. RESULTS AND DISCUSSION

A. Microstructural Analysis

Fig.1 shows the microstructure as cast of Al-Si matrix alloy and Al-Si/SiC composites with different weight percentage of SiC. From figures it can be observed that, the distributions of reinforcements in respective matrix are fairly uniform. The ceramic phase is shown as dark phase, while the metal phase is white. Further these figures reveal the homogeneity of the cast composites. The microphotograph also clearly revels the increased filler contents in the composites.

Table (1) Chemical composition of matrix alloy by (Wt.%).

Si	Mg	Fe	Cu	Mn	Zn	Ti	Al
6.55	0.40	0.35	0.015	0.003	0.002	0.009	Balance



(a) (b)

(c) (d)

Fig.1 Optical micrographs at X50.(a) Unreinforced Al-Si Alloy. (b) Al-Si Alloy with 7% SiC. (c) Al-Si Alloy with 14 % SiC. (d) Al-Si Alloy with 21 % SiC.

B .Hardness

From figure (2) the hardness value of cast composite increase as the weight percentage of SiC increases from 7wt% to 21wt% in the alloy. The hardness of Al Al-Si/SiC_P increased about 69 percentage as the reinforcement content of silicon carbide 21 weight percentage. This is due an increase in the percentage of the hard and brittle phase of the ceramic body in the alloy.

C .Ultimate Tensile and Yield Strength

The figure (3) reveals that the ultimate tensile strength of composite increases about 98 percentage by addition the reinforcement. Similarly figure (4) shows the increase in yield strength of Al-Si/SiC about 97.7 percentage as the reinforcement carbide silicon content increases from 0 to 21 weight percentage. In both cases the addition of SiC to Al-Si matrix is increasing the tensile properties of composite material. It is believed that the great enhancement in tensile properties observed in these composites is due to good distribution of the SiC particles and low degree of porosity, which leads to effective transfer of applied tensile load to the uniformly distributed strong SiC particulates. The grain refinement and strong multidirectional thermal stress at the Al/SiC interface are also important factors which play a significant role in the high strength of the composites. SiC particles have grain refined strengthening effect, which is improved with increasing volume fraction since they act as the heterogeneous nucleation catalyst for aluminum. The difference between the coefficient of thermal expansion (CTE) values of matrix and ceramic particles generates thermally induced residual stresses and increases dislocations density upon rapid solidification during the fabrication process. The interaction of dislocations with the non shearable particles increases the strength level of the composite samples. According to the Orowan mechanism, the SiC particles act as obstacles to hinder the motion of dislocations near the particles in the matrix. This effect of particles on the matrix is enhanced gradually with the increase of particulate volume fraction [7, 8].

D. Impact Energy

Figure (5) is a graph showing the effect of reinforcement content on the impact energy of Al-Si matrix alloy. It can be seen that as the carbide silicon content increase, the impact energy of the composite material decreases. Quantitatively as SiC content is increased from 0 to 21 weight percentage, is a reduction in impact energy 59%. The brittle nature of the reinforcing materials (SiC) plays a significant role in degrading the impact energy of the composite, since the unreinforced alloy have the highest impact energy, indicating that it is the toughest of them all.

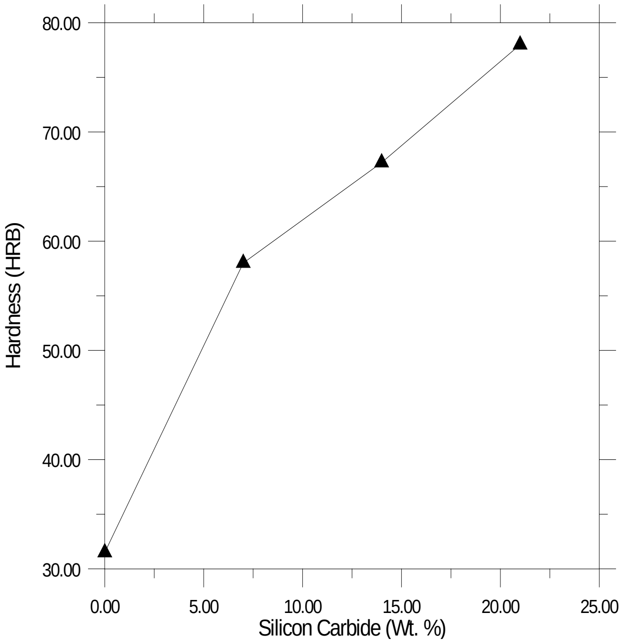


Fig. 2 Effect of Silicon Carbide on hardness of Al-Si alloy.

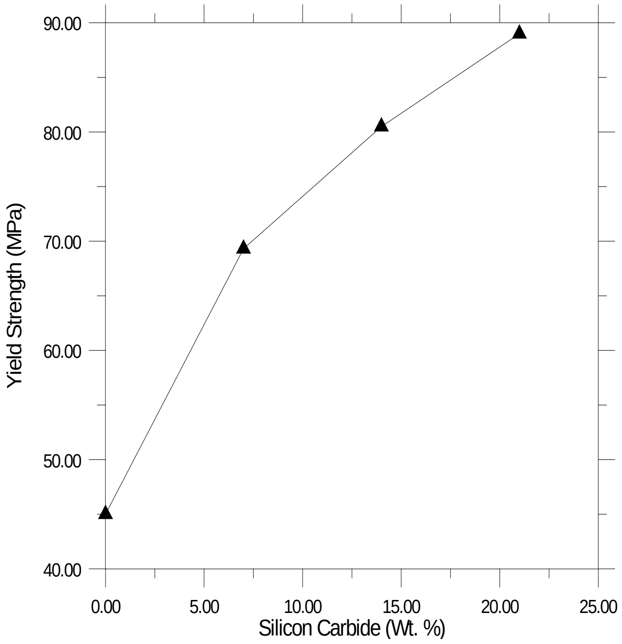


Fig. 4 Effect of Silicon Carbide on yield strength of Al-Si alloy.

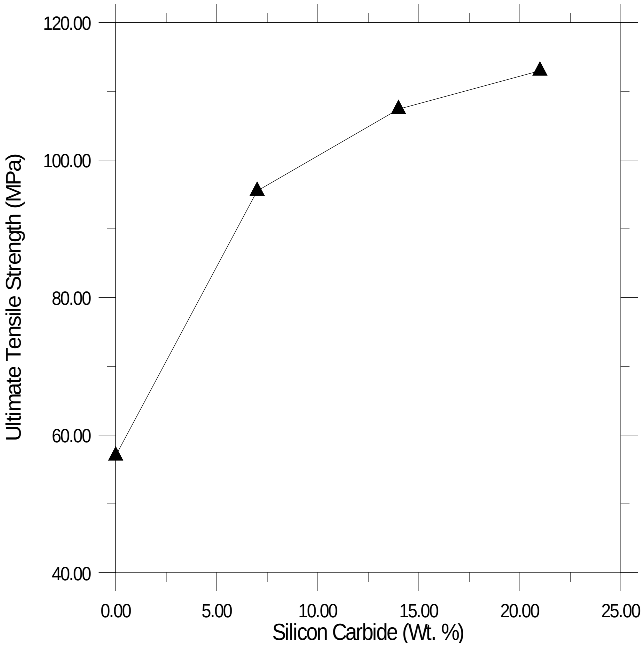


Fig. 3 Effect of Silicon Carbide on ultimate tensile strength of Al-Si alloy.

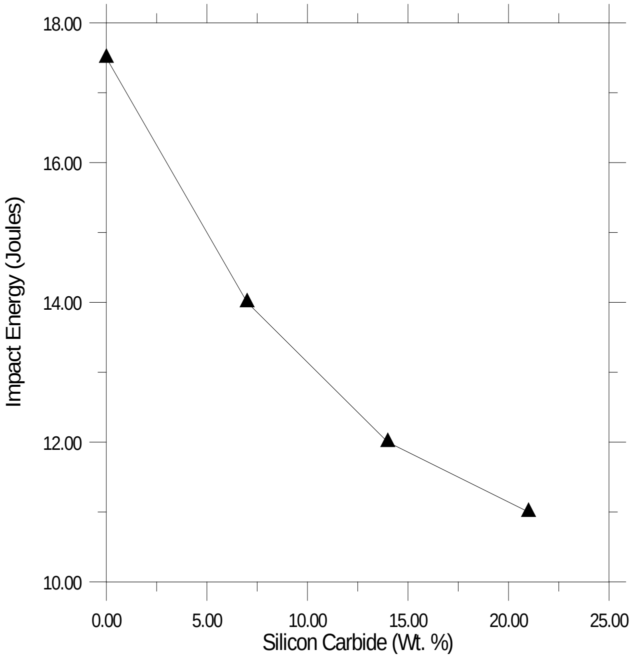


Fig. 5 Effect of Silicon Carbide on impact energy of Al-Si alloy.

IX. CONCLUSIONS

The following major conclusion can be drown from the present paper.

1) The aluminium alloy composites containing different amounts of silicon carbide particles were produced by stir casting method successfully.
2) Mg addition to matrix alloy before SiC addition improved wettability& facilitated homogeneous distribution.
3) The hardness, ultimate tensile strength and yield strength of composite found increasing with increased reinforcements in the composites.
4) Increasing the amount of SiC particles in composites caused the impact energy to decrease.
5) The microstructural studies revealed the uniform distribution of the particles in the matrix system.

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