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Development of Aluminium Metal Matrix Composite Using Stir Casting Method

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ABSTRACT
Aluminium Metal Matrix composites were developed using AL6063 as matrix material and varying % by weight of silicon carbide particulate as reinforcement. AL6063 ingot was melted in an electric furnace, an appropriate quantity of the reinforcement (between 10% and 50% at 10% intervals) was introduced and, using the method of stir casting, the homogeneous mixture obtained were cast in to cylindrical blanks which were further machined to produce appropriate test samples. The samples were tested for tensile, compressive and impact strengths as well as for hardness. Mechanical properties test results indicated improvement, on reinforcement introduction, of up to 48%, 43% and 79% in the values of tensile, compressive, and impact strengths and an improvement of up to 42% in hardness when compared with the respective values for the composites with 0% reinforcement. Tensile strength values from 131.23MPa to 194.60MPa, Compressive strength from 103.70MPa to 167.15MPa, impact strength from 140.09KJm^{-2} to 250.37KJm^{-2} and Hardness from 39.78BHN to 56.46BHN were obtained. The research showed that composites produced by introducing SiC particulate into AL6063 alloy possess superior mechanical and metallurgical properties compared to AL6063; the composite produced can be used in automobile and aerospace industries.

Keywords: *Al6063 Alloy, Mechanical Properties, Metal Matrix composite, Silicon Carbide.*

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I. INTRODUCTION

Due to its low density, excellent anti-corrosive properties and specific strength, Aluminium has been utilized as a choice material in many fields, such as in the car industry, railway and aerospace. A large part of the aluminium is used in the alloy states, containing various alloying elements [1]. High performance requirements as well as cost effectiveness constraints coupled with stringent environmental protection policies have resulted in continuous attempts to develop composites as serious competitors to the traditional engineering alloys [2], [3], [4]. These composites traditionally use metals or their alloys as matrix material some other material, usually ceramics, as reinforcement to form metal matrix composites (MMC). Aluminium is arguably the most popular matrix material for use in MMC.

Addition of hard and stiff ceramic phase in metal matrix composites has been established to improve the modulus behaviour and strength properties of the metallic matrices. An important consideration in MMC manufacture is the nature of the interface between the matrix and the reinforcement. This often depends on the processing route and since composite formation occurs at an elevated temperature, it is more chemical than mechanical. Among the problems associated with such chemical interactions is the possible formation of deleterious products on the interface, which can act as damage nucleation sites when the bulk MMC is subjected to stress. In view of the internal stress field therefore, the finer the reinforcement particle is the better the mechanical property of composite. However, it is difficult to produce premium composites reinforced with fine particles of sizes less than 10μm using conventional liquid or semisolid stir-casting method [5].

Silicon Carbide could be added as reinforcement to aluminium to improve its physical and mechanical properties using different methods. Researchers have used various approaches including varying the type and quantity of reinforcement and temperature variation to improve the properties of the resulting MMC; also, much research have been carried out on the variability in the properties of Al-SiC composite which resulted in composites of same volume fraction having different extreme mechanical properties such as ultimate tensile stress (UTS) and fracture toughness. The occurrence was attributed to the presence of second phase particle which alter the flow properties of the matrix. Volume fraction, size and spatial distribution of the SiC particulate were found to affect the flow properties of the materials while the particle size is dependent on the type of processing used.

The research carried out by [6] on the production of SiC - AL2124 composite using powder metallurgy technique showed that the hardness change in different position within the vibrated specimen was smooth, reflecting the gradual transition in SiC content the composite produced also generally exhibited superior fracture resistance compared to conventional materials as the conventional material fracture occurred catastrophically when the maximum load was reached and crack propagation initiated.

A research, [7], performed on Aluminium-Silicon Carbide composite in which the mechanical properties and corrosion behaviour of the composites exposed to sea water and acid water of various acid concentrations and at various temperatures revealed that corrosion damage of composites exposed to sea water medium was mainly localized in contrast to uniform corrosion observed for base alloy in acid water. Further, composites were found to corrode faster than the base alloy even though the attack was mainly confined to the interface, resulting in crevices or pits. A study on the Electrical Discharge Machining (EDM) studies on aluminium alloy-silicon carbide composites developed by vortex technique and pressure die casting was carried out in [8]. The authors reported that, the Material Removal Rate (MRR) and the surface roughness are greatly influenced by the current and per cent weight silicon carbide. The MRR was found to increase with increase in the current and decrease in the per cent weight of silicon carbide in the composite. The surface finish improves with decrease in the current and increase in the per cent weight of silicon carbide.

In their work, [5] presented the development of particulate reinforced aluminium MMC using 240, 420, 840 and 4,200 microns grain sizes. The composites were made by liquid metallurgy route in an oil fired cupola furnace with two varying charging modes using the comp-casting method. The results of their study showed that the strength, hardness and fracture resistance of the composite increased with increase in volume fraction of SiC particles in the aluminium MMC. The results further showed that when ductility is the requirement coarse particulate of SiC would be preferred at low volume fraction of particles. Also with decrease in grains size improved ductility can be achieved by increasing the volume fraction. Both volume fraction and particle size were reported to affect the strength, hardness, Young modulus and fracture resistance of the tested composites [5].

II. MATERIALS AND METHOD

2.1. Materials

Aluminium 6063 was the matrix used in this study, silicon carbide particulate was used as the reinforcement and magnesium was used as wetting agent.

2.2. Methods

2.2.1. Composite production

The composites were produced, using stir casting method, in a carbolite furnace at a temperature of 800^{o}C. The silicon carbide content was varied from 10wt% to 50wt% at 10wt% interval. The aluminium and silicon carbide were placed together in the crucible and were heated together. This procedure was done to remove gas porosity and to improve substantially the wet-ability.

2.2.2. Samples Preparation and Experimental Procedure

Tensile Test samples were machined according to ASTM D638 standard and the tensile test was conducted on an Ingstron automated machine which plotted the stress-strain graph. For impact test (Izod Type), the samples were machined according to ASTM D256 standard. The samples were notched to a depth of about 3 mm at an angle of 45^{o}. Thereafter, the impact test was done in an Izod machine. Compressive test samples were machined according to ASTM E9-09 Standard then the test was conducted on a Mosanto Tensometer.

III. RRESULTS AND DISCUSSION

Figure 1 presents the results of the Compressive strength, UTS and impact strength tests. From the figure, it is seen that the investigated properties tended to improve with increase %wt content of SiC in the composite up to a peak after which increase in SiC content resulted in worsening of the mechanical properties. At the peak, improvements by 43%, 48% and 79% were observed from the respective values for the matrix material of compressive strength, UTS and impact strength.

The initial improvement observed in the tensile and impact strength tests could be due to the fact that when there are less reinforcement, the reinforcement material gets trapped in the ductile alloy material which effectively isolates the reinforcing particulates from each other, thereby maintaining or increasing the ductility of the composites this way, the adhesive force between the matrix and the reinforcement is retained and any possible crack development during test is effectively localized. As the %wt of SiCp increases, the particulates clustering grows bigger and the possibility of crack arrest in the matrix material reduces and cracks thus propagate more easily in the composites giving rise to the observed decrease in the strength for composites with %wt SiCp higher than the peak value [9].

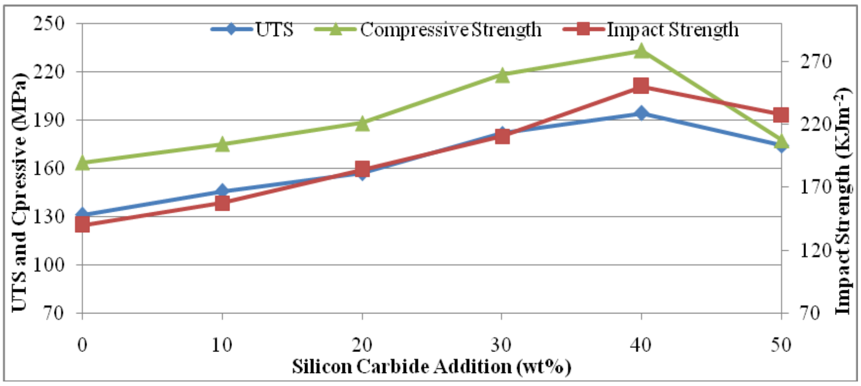

Figure 1: Variation of UTS, Compressive and Impact Strengths with %SiC Addition

Figure 2 shows the result of hardness test carried out on the samples. As can be seen, the Brinell Hardness Number (BHN) increases from 40 for the control sample to 57 for sample with 40%wt SiCp after which it started decreasing. The increase in hardness value could be attributed to the increased distribution of hard and brittle ceramic phase (SiC) in the ductile metal matrix [10], [11]. In the hardness test, severe plastic flow has been concentrated in the localized region directly below the indentation, outside of which the material still behaves elastically. Directly below the indentation the density of the particles increased locally, compared to regions away from the depression. As the indenter moves downward during the test, the pressure was accompanied by non- uniform matrix flow with localized increase in particle concentration, which tends to increase the resistance to deformation. Consequently, the hardness value increases due to local increase in particulate concentration associated with indentation up to 40wt% SiCp. Beyond this weight fraction the hardness trend started decreasing as SiC particles interact with each other leading to clustering of particles and consequently settling down. Eventually the density of SiC particles started decreasing locally thereby lowering the hardness.

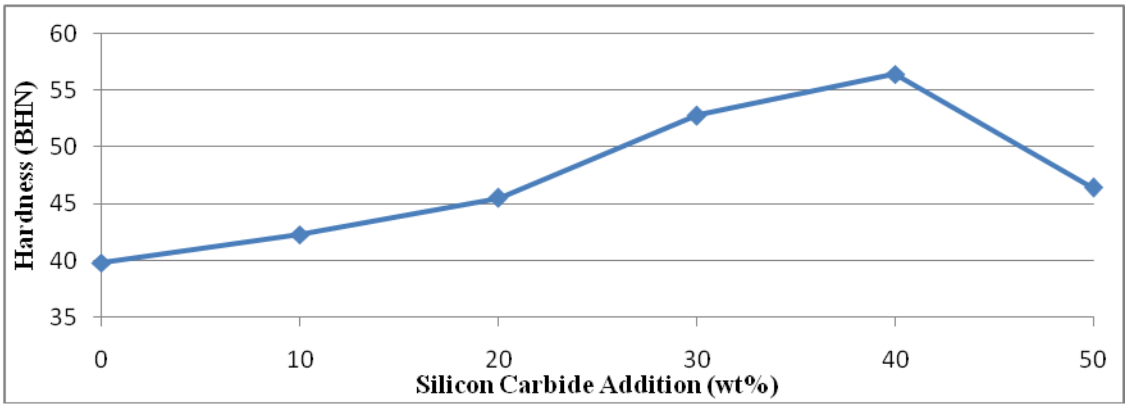

Figure 2: Variation of BHN with %SiC Addition

IV. CONCLUSION

The results of the research reveal that increase in the percentage weight of silicon carbide improves the mechanical properties tested. Increase in the quantity of SiC reinforcement positively impacts on the said properties only up to a 40%wt SiC beyond this, increased clustering of the reinforcement negatively tell on the mechanical properties. Furthermore, the improvement in the mechanical properties as compared with the 0wt% SiC at 40wt% SiC addition was up to 43%, 48%, 79% and 42%, respectively for compressive strength, UTS impact strength and hardness.

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