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Study of Effect of Hot Forging on Microstructure and Mechanical Properties of Al-SiC+3 Wt.% AL_2O_3 Hybrid Composites

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Abstract

Particle reinforced MMC succeeds in developing the metallic matrix with ceramic particle reinforcements to result in improved strength, mainly at elevated temperatures but adversely affects the ductility of the matrix. The present study aims to disperse different weight % (3,6,9) of SiC and 3wt.% Al_2O_3 particles in aluminum melt and fabricated composite. The evolution of microstructure and morphology of composite are studied using FESEM, Optical Microscopy, EDAX and deformation characteristics of Al-SiC+Al_2O_3 composite at cold conditions was studied. Cast nd forged composite material was subjected to hardness test and tensile test. The results show that hardness and strength of fabricated Al-SiC composite improves and ductility declines as compared to Al alloy in both as-cast and hot forged conditions.

Keywords: *Rockwell hardness test , compression test, SEM, Composites, Al_2O_3, SiC, EDAX., MMC*

1.0 Introduction

Composite material is a mixture of two or more materials insoluble in one another, possessing properties which are superior to any of the component materials individually. composites are a multi-phase material which has micro or nano size particles in its composition within its structure, the dimension of reinforcing particles are selected asper the specific requirements[1-2]. The structure and the mechanical properties of these composites are controlled by the type and size of the reinforcement, nature of bonding and processing method. the high density of dislocations and extensive fine sub grains around Al_2O_3 particles are accountable for enhancement in properties. The amount, size and distribution of reinforcing particles in the metal matrix play key role in controlling the overall properties of composites[3-6]. A major objective of developing metal matrix composites (MMCs) is to take advantage of a combination of necessary properties of both metals and ceramics[7,8]. For example, reinforcing the ductile aluminium matrix with stronger and stiffer second-phase reinforcements like borides, oxides, carbides, and nitrides provides a combination of properties of both the metallic matrix and the ceramic reinforcement components resulting in enhanced mechanical properties of the composite[9-12].

2.0 Experimental Procedures

2.1 Processing of Metal Matrix Composites

The commercially available pure aluminium of 1kg is heated to desired operating temperature in a graphite coated stainless-steel crucible inside the muffle furnace. The skimming of auminium melt before addition of any reinforcement was practised to clear slag and other

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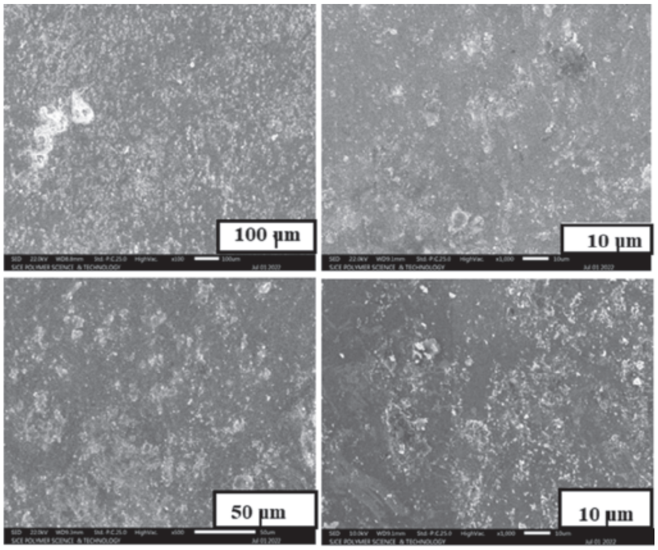

Figure 1: SEM images of cast and forged hybrid composite Al7075 (3% SiC+3% Al_2O_3) shown the different magnification (100 µm, 50 µm, 10 µm)

impurities[13]. The weighed amount of SiC powders were added into the molten aluminium. The stircasting processing temperature of 900°C was maintained during the trial and SiC particles addition with a rate of 6-8 g/min is followed[14].

A mechanical stirrer with flat blade has been efficiently used to mixing of SiC and Al_2O_3 particles into the aluminium melt. In order to confirm proper dispersion of SiC particles with matrix alloy, the two stages mixing of matrix and reinforcement was practiced during trial[15]. Initially a suitable quantity of silicon carbide particles with an same quantity of aluminium powder is mixed in dry milling for a duration of 2 hours at 300 rpm. The blended powder mixture is then added into aluminium melt during processing and stirred well. The stirrer speed of 450 rpm was maintained and the temperature of the melt is kept in ±10°C of the 780°C throughout stirring[16]. Aluminium oxide of 3 wt.% was inserted into the slurry just after the dispersion of SiC particles. The stirring of the melt is carried out for 10 minutes[17]. The split type mold is fixed right under the stopper and once after collecting the melt and then mold is allowed to cool in room temperature, no degassing practice of the melt was followed during any stage of processing. The 10 mm sample was cut from the cast specimen and polished was used for further analysis[18-20].

2.2 Specimens Preparation for Microstructural and Mechanical Property Analysis

In order to investigate the microstructure, the distribution of reinforcing particles and the resulting mechanical properties, the 10 mm sample was cut from the 15 mm above the bottom face of the rectangular plate. The 10 mm square block for SEM analysis and hardness test were initially polished with abrasive belt cutter to ensure the flat and even surface on each side of the specimen[21]. In the second stage samples are hand polished to 0.1 mm with fine emery papers of grit size 200, 400, 600, 800, 1200 and 2000 by changing the direction of polish on each sample, the hand polished samples were then polished on a rotating disc cloth polisher (Metco-BainPol. Co., Chennai) using a solution of alumina and diamond paste. The polished specimens were etched by Keller's reagent prepared as per ASTM standard E407 by dissolving 2 ml of hydrofluoric acid, 3 ml of hydrochloric acid and 5 ml of nitric acid with 190 ml of distilled water[22]. The height of 120 mm cast ingot below the middle part of the plate was cut and used for preparing three tensile specimens and separate three smaller specimens are used for metallographic study and hardness test specimen as per ASTM E8M and E10 standard respectively[23].

3.0 Results and Discussion

3.1 Scanning Electronic Microscopic Analysis

The hybrid composite Al7075- SiC (3%, 6% & 9%) -Al_2O_3 (3% constant) for the samples A1,B1 and C1 were cast and forged the composite materials by varying the reinforcement. The hybrid composite samples A1, B1&C1 of size 10mm diameter and 10mm thickness were prepared for the

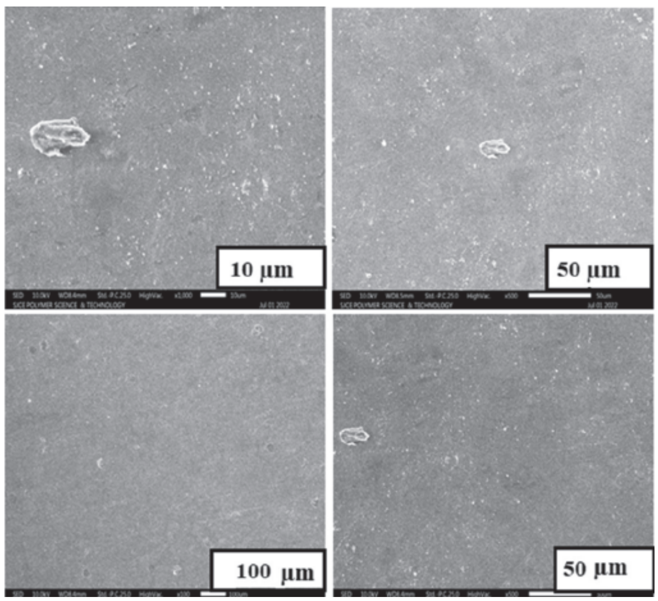

Figure 2 SEM images of cast and forged hybrid composite Al7075 (6% SiC+3% Al_2O_3) shown the different magnification (10 µm, 50 µm, 100 µm)

microstructure studies. The prepared samples generally required clean surface for the microstructure analysis and it was done by the different size of emery paper (500, 1000, 1500, 2000 and disc polishing machine). After polishing the samples polishing surface of the samples are ready to analyse the scanning electron microscopy (SEM)[23].

The Fig.2 shows the evolution of microstructure of Al7075-SiC-Al_2O_3 metal matrix composite (MMC) fabricated by dispersion 3,6 & 9 Wt.% SiC and 3 Wt.% constant Al_2O_3 particles. The Fig.1 shows the bright particles of SiC and Al_2O_3 which are of different magnification, visible at higher magnifications, the number of such particles increases with the increases in addition of SiC-Al_2O_3 particles as evident by comparison microstructure. Microstructural studies also reveals white spots at different location and magnification are due to clustering of Al_2O_3 particles[25-26].

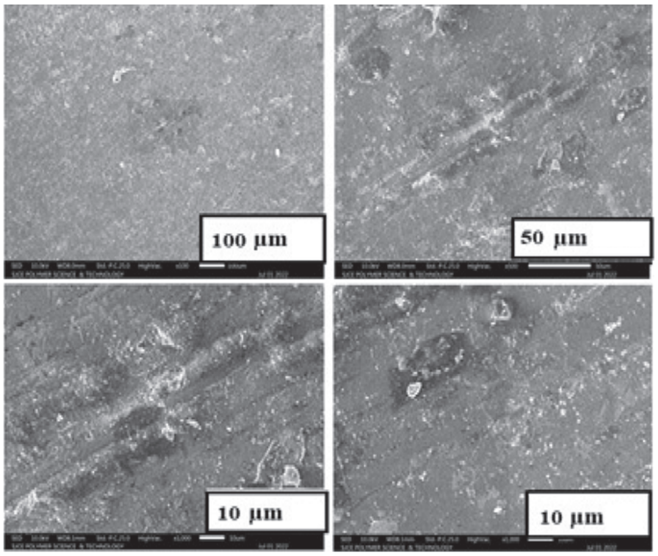

Figure 3: SEM images of cast and forged hybrid composite Al7075 (9% SiC+3% Al_2O_3) shown the different magnification (100 µm, 50 µm, 10 µm)

3.2 Energy Dispersive X-ray (EDAX) Analysis

EDAX (Energy Dispersion X-ray spectroscopy) result of aluminium matrix composite reinforced with SiC and aluminium oxide (Al_2O_3) with different loading using the hybrid composite Al-SiC (3%, 6% and 9%)-Al_2O_3 (3% constant) for the samples A1, B1 and C1 were cast and forged the composite materials by varying the reinforcement. The hybrid composite samples A1, B1 and C1 of size 10mm diameter and 10mm thickness were prepared for the microstructure studies. The sample was ground and polished using the emery paper (500, 1000, 1500, 2000 and disc polishing machine) until the surface was flat and smooth, which is necessary for energy dispersion X-ray analysis. EDAX analysis recognized some major elements are Al, Si, C, Cr, Fe, Mg, Cu and Zn. EDX spectra curves of SiC and Al_2O_3 reinforced composite represents the peaks of Si and Al that confirms the existence of reinforcement particles in the matrix. EDX basically detects the atomic and weight percentile of each and every element that present in composite and recognized by the formation of peaks[27].

3.3 Hardness Test: Rockwell Hardness Test

The resistance against scratch or indentation is termed as hardness of material the average hardness is obtained from the test result. The Rockwell hardness value of as a cast and forged aluminium 7075-SiC-B4C has been depicted.

The results of hardness test of the samples consisting of silicon carbide in the range of 3%, 6% and 9 wt. % and Al_2O_3

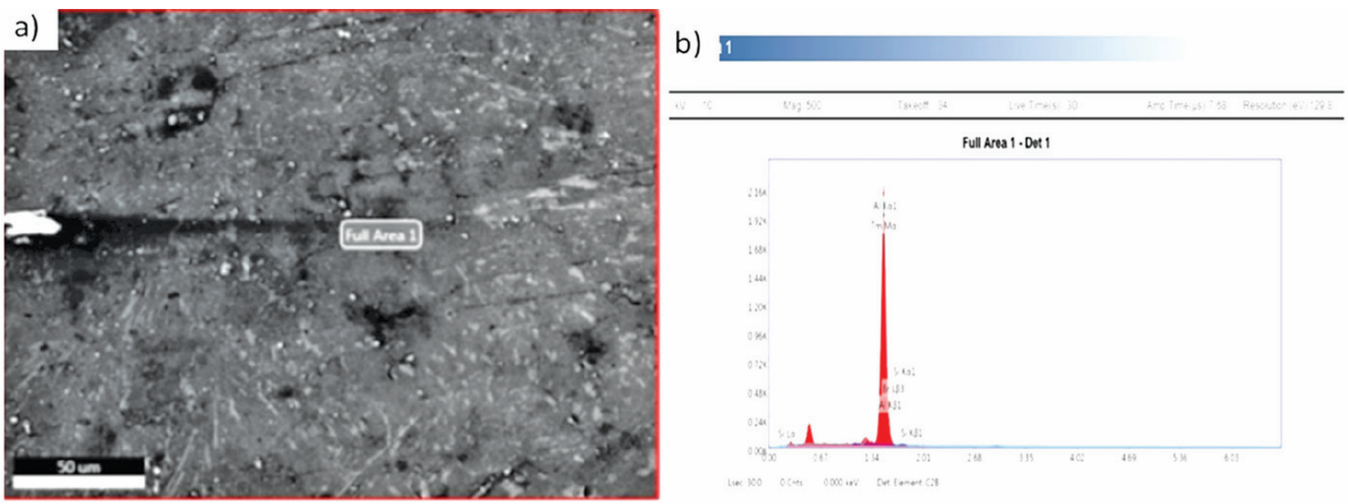

Figure 4: EDAX images of cast and forged hybrid composite Al7075 (9% Sic+3% Al_2O_3)

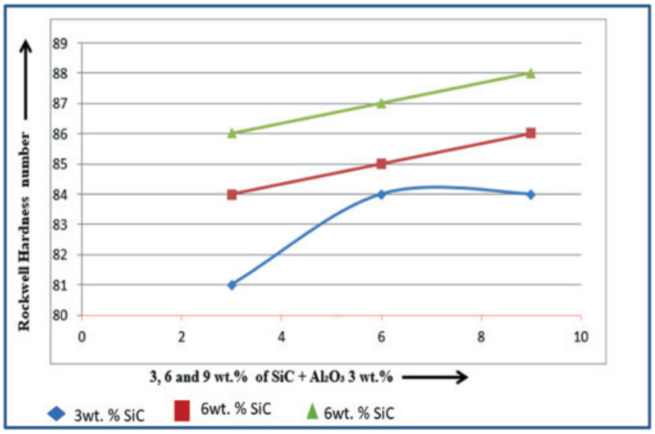

Figure 5: Variation of hardness for composites fabricated by addition of 3, 6, and 9 wt.% of SiC powder with 3wt.% constant Al_2O_3 particles

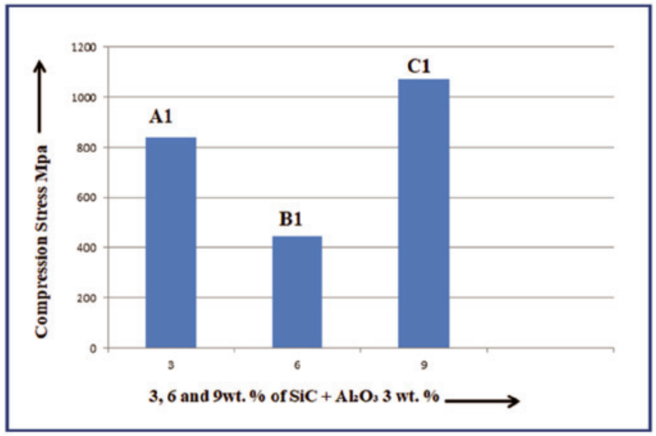

Figure 7: Variation of Compression Stress of hot forged Al7075 + Al_2O_3 3wt.% developed by increasing addition of 3,6 and 9wt.% of SiC particles for the Samples A1, B1&C1 respectively

3wt. % constant. Results are tabulated when the A1 B1 C1 samples prepared are tested using rockwell hardness testing machine to find the response of samples against indentation. It is noted that average values for each tested samples are documented. Hardness value increases with increase in SiC content and Al_2O_3 content in the matrix alloy. Higher value of hardness number is found clearly for the samples filled with 9 wt.% of a SiC and least value of RHN is observed for the sample filled with 3% SiC. The hardness test results are shown that presence of reinforcement particle in the boundaries of matrix and causing to develop intermetallic bonding between matrix and reinforcement[28].

3.4 Compression Test

The compression test was conducted on UTM machine with ASTM standard at room temperature. It can be seen that compression test of hybrid composite increases monotonically as reinforcement contents also increased. During the compression test reinforcement material such as, Sic varying with % of 3%, 6%, 9% Wt.% and at constant value of 3% of Al_2O_3 with pure aluminium alloy. In the compression strength was in respect to SiC content and aluminium oxide content for aluminium alloy and its hybrid composite. It is seen that with increasing in SiC content from 3% to 9% and Al_2O_3 3% constant value, the compression strength tends to increasing gradually. The comparison of A_1, B_1, C_1 specimens with elongation strength, Compression strength, load at peak value, which is C_1 specimen is greater than A_1 specimen and also greater than B_1 specimen compared to these 3 specimens. For mathematically, $C_1 > A_1 > B_1$ specimens[29].

Figure 6: Specimen after Compression Test

4.0 Conclusions

The conclusions of the present study are outlined below:

1. The stir casting technique was successfully adopted in the fabrication of Al7075 composites by addition of 3, 6 & 9 wt% (SiC) and 3wt% (Al_2O_3) of inset generated as reinforcement.
2. A round Al7075 matrix composite reinforced with SiC (3%, 6% & 9%) and Al, O*f* (3% Constant) bar, with a starting diameter Φ = 20 and length 150 was forged to obtain a ûrst diameter reduction to 100 mm and then, with a multiple hot-forging step, to a final rectangular section shaped plate (100×14 mm).
3. The hardness of the composite synthesized by addition of different amount of SiC 3, 6 & 9wt% increases with increase in wt.% of 3wt% (Al, O*f*) addition shows maximum hardness.
4. Compressive strength increases with increase in Sic+Al_2O reinforcement addition compared unreinforced aluminium it exhibits a maximum compressive strength of A1 840.404 MPa, B1 450.201MPa & C1072.429MPa.
5. SEM images of cast and forged hybrid composite shows the bright particles of SiC and Al_2O which are of different

magnification, visible at higher magnifications, the number of such particles increases with the increases in addition of SiC-Al_2O particles as evident by comparison with microstructure.

6. EDAX analysis identified some major elements are Al, Si, C, Cr, Fe, Mg, Cu and Zn. EDX spectra curves of SiC and Al_2O_3 reinforced composite indicated the peaks of Si and Al that revealed the existence of reinforcement particles in the matrix.

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