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Development of Aluminium 6061 Silicon Carbide (SiC) Composites using Stir Casting Technique

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***Abstract:*— Nowadays modern manufacturing system is enforced to find out the new material such as metal matrix composite or ceramic matrix composite. The aim of this research is to invent the aluminium based metal matrix composite such as 80% of Al 6061-20% of SiCp. The aluminum 6061 alloy based composite is prepared through stir casting route. Then the composite is heat treated at the critical temperature. After heat treatment, the mechanical properties of composite are compared with aluminium alloy 6061. Microstructural and fractography analysis have been done by using Optical and Scanning Electron Microscope. Mechanical properties of both heat-treated and as fabricated composites showed a high dependence on the ceramic content. The yield, ultimate tensile strength, and the elastic modulus of the material were increased with volume fraction of carbide, whereas the ductility was decreased. The tensile properties are seen to vary significantly with ageing treatment.**

***Keywords:*-- Al-SiC, Mechanical Properties, Metal Matrix Composites, Stir Casting.**

I. INTRODUCTION

Aluminum-based metal matrix composites (MMCs) offer potential for advanced structural applications because of their high specific strength and modulus, as well as good elevated-temperature resistance. Ongoing material research over the past several decades have produced some advanced materials with properties superior to conventional materials. One of those advanced materials with superior properties are metal matrix composites (MMC). MMCs have high strength-to-weight ratio, high toughness, high-impact strength, low sensitivity to temperature changes, low sensitivity to surface flaws, and high surface durability. In present manufacturing industries, MMCs are widely used in a various engineering applications, such as connecting rods, automotive drive shaft, cylinder liner and break rotor [1,2] and the worldwide MMC markets during past decades have major contribution in the ground transportation, thermal management, aerospace, and recreational industries [3]. Among the MMCs, discontinuously reinforced aluminum alloy metal matrix composites are a preferred choice for critical applications because those materials offer a number of benefits such as good strength, high stiffness, and superior wear resistance compared with the unreinforced aluminum alloys [4,5]. There are several fabrication techniques available to manufacture discontinuous MMCs, among which stir casting is generally accepted and currently practiced commercially [6,7]. The advantages of this method are its simplicity, flexibility and applicability to large quantity production.

II. EXPERIMENTAL PROCEDURE

The Al-6061:SiC composites were produced by pressureless melt infiltration of a 6061-aluminum alloy into SiC performs. The average particle size of the reinforcing SiC powder was found to be 1.12 mm as estimated by a centrifugal analyzer (Horiba, Cap-300). Micro structural characterisation studies were primarily accomplished using a JEOL JSM-6400 Scanning Electron Microscope (SEM) equipped with Energy Dispersive Spectroscopy (EDS) facility and X-ray diffractometry (SIEMENS D5000). The composite samples were metallographically polished prior to examination; micro structural characterisation of the samples was conducted in the unetched condition. Particular emphasis was placed on determining the phases present in the composite materials and on examining the precipitation behavior and segregation of copper in the metallic matrix. The composites produced were solution treated isothermally at 540°C for 2 hours to dissolve any precipitates prior to cold-water quenching. Ageing was carried out in two stages such as 170°C for 2 hours and 200°C for two hours. Tensile test specimens were machined to conform with the standards as specified in ASTM: E-8-81. Uniaxial tensile tests were performed at room temperature using an Instron testing machine (model 810). Tensile properties, namely, yield strength (YS), ultimate tensile strength (UTS), and elongation

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(EL) were evaluated. As-fractured samples of the resulting fracture specimens were examined by SEM in order to characterize the fracture surface. Vickers hardness number of the composites were determined using Vickers hardness tester (Wolpert-Wilson Instruments) with dwell time of 10 seconds. The chemical composition of aluminium alloy 6061 is shown in Table 1.

Table 1: CHEMICAL COMPOSITION OF ALUMINIUM ALLOY 6061

Chemical Composition											
Al 6061	**Al**	**Si**	**Fe**	**Cu**	**Mn**	**Mg**	**Cr**	**Zn**	**Ti**	**Others each**	**Others total**
Weight (%)	95.8-98.6	0.4-0.8	0.70 max	0.15-0.40	0.15	0.80-1.20	0.04-0.35	0.25 max	0.15 max	0.05	0.15 max

III. MECHANICAL STRUCTURE

3.1 Microstructural Aspects

The microstructural analysis of the as-fabricated and heat-treated composites are shown in the Fig.1. Even though the Al4C3 phase was not detected by XRD, the presence of this phase in the composites is feasible. Micro structural examination of the as-fabricated composites revealed a complete infiltration of the preforms. Visual examination of the reinforcing phase of these polished samples reveals that the materials exhibit spheroidization phenomena of the reinforcing SiC grains. This fact is attributed to an erosive mechanism of the interconnected ceramic necks due to the motion of the molten metal that facilitates the mass transfer process. Micro structural characterization studies of heat treated samples revealed the presence of CuAl2 and SiC particulates as the two most predominant phases distributed in the metallic matrix. The phases found in the composite containing 20% SiC reinforced material, showed a major content of the aluminum matrix and CuAl2 precipitates due to the lower amount of the reinforcing phase.

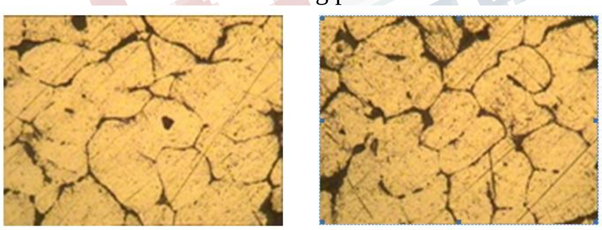

Fig.1. Microstructural observation of as-fabricated and heat treated composites

3.2 Fractography Analysis

Fractography analysis of the as-fabricated and heat-treated composites are shown in Fig.2. Fracture surface of as cast composites exhibit of cleavages due to brittle fracture. In SEM images of composite samples for Al 6061(80%)-SiC (20%), dimples represents ductile fracture that increases the percentage of elongation which results in improvement of mechanical properties.

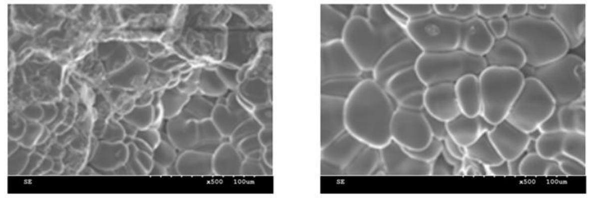

Fig.2. Fractography analysis of as-fabricated and heat treated composites

IV. MECHANICAL PROPERTIES

The influence of heat treatment on the mechanical properties of the composites was studied. To select the time for solution treatment, the 20%SiC content composites were solutionised at 540°C after a soaking period of two hours, followed by ageing for 2 hours . Once the samples were naturally aged, it is clear that composite hardness increases rapidly to reach the peak solutionzing time at 150 min. After this time, the ageing process of the composites was decreased as solution time increased.

4.1. Tensile Properties

Ultimate tensile strength was as 142 MPa for Al 6061(80%)-SiCp (20%) composites.
Al 6061(80%)/SiC (20%)
Elongation =1.1/20=0.055
Load - 410 kgf
Gauge length - 20 mm
Diameter of specimen - 6 mm
Ultimate tensile strength - 142 MPa

4.2. Hardness

The hardness value of Al 6061(80%)-SiC (20%) composite is 107 VHN. From this it was observed that hardness of composite is increased with SiC quantity. The measured hardness values are tabulated in Table 2.

Table 2: Measured Hardness values

For Al 6061 (80 %)/SiC$_p$ (20)	
Reading	Hardness
72	107
72	107
70	106

V. CONCLUSIONS

The primary conclusions that may be derived from this work are described below.

- Al-6061 matrix can be reinforced successfully with SiC particulates up to 20% (volume) using pressureless melt infiltration route.

- The as-fabricated materials showed the presence of $CuAl_2$, $SiAl_3$, Si_3AlC, and $AlSi_3$ phases, the formation of which is attributed to the slow cooling during composite infiltration. Nevertheless, the effect of solution heat treatment and ageing of the composites helped to redisperse the intermetallic $CuAl_2$ phase.
- Mechanical properties of both heat-treated and as fabricated composites showed a high dependence on the ceramic content. The yield and ultimate tensile strength, and the elastic modulus of the material, increase with volume fraction of carbide, whereas the ductility decreases. The tensile properties are seen to vary significantly with ageing treatment.
- The highest strengths were obtained for the solution heat-treated Al-6061: SiC composites containing 20 vol.% SiC.
- Fracture differs with the ceramic content in the composite and the heat treatment was performed. However, transgranular fracture was observed throughout the $CuAl_2$ agglomerated precipitates.

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