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PROCESSING AND MICROSTRUCTURAL CHARACTERIZATION OF SICP REINFORCED A356 METAL MATRIX COMPOSITES

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ABSTRACT

In the present study attempts were made to fabricate the A356/ (0-20%)SiCp composites from A356 alloy through liquid metal stir casting method. Hard abrasive particle such as silicon carbide (SiCp) with average particle size 23µm was used for the study. Microstructural examination shows a better particle distribution in the A356/10%SiCp and the A356/20%SiCp composites. Mechanical and heat treatment characterization has been done to evaluate the properties of the developed composites and found that hardness improved for the composites compared to its base alloy. Tensile stress versus tensile strain graphs for the developed composites have shown that its brittle behavior is more compared to its base alloy. XRD analysis of the composites has shown the presence of major hardening phases like Mg2Si, Al2Cu etc.

Keywords: *Composites, Stir Casting Method, Microstructure and Tensile Property.*

1. Introduction

Metal matrix composites (MMCs) are becoming potential engineering materials offering excellent combination of properties such as high specific strength, high specific stiffness, electrical and thermal conductivities, low coefficient of thermal expansion and wear resistance [1-3]. Because of their excellent combination of properties these composites are being used in variety of applications in automobile, mining and mineral, aerospace, defense and other related sectors [1-3]. The most popular hard reinforcements used for making discontinuously reinforced MMCs are silicon carbide, alumina and soft reinforcement such as graphite [4, 5]. These composites have shown different strengthening mechanisms compared to conventional materials or continuous reinforced composites [6]. Moreover, the problems associated with fabrication of continuously reinforced MMCs, such as fibre damage, microstructural nonuniformity, fibre to fibre contact and extensive interfacial reactions can be avoided with discontinuous reinforcements [7]. In applications not requiring extreme loading or thermal conditions, such as in automotive components, discontinuously reinforced MMCs have been demonstrated to offer essentially isotropic properties with substantial improvements in strength and stiffness, relative to those available with unreinforced materials [7]. The family of discontinuously reinforced MMCs include dispersion strengthened alloys and cermets. Dispersion strengthened alloys consists of metal matrices with additions of hard insoluble particle constituents with sizes of the order of a microstructure and in small proportions, typically below 5 vol %. A cermet is a mixture of ceramics and metals. Its structure is composed of ceramic grains bonded in a metal matrix. The volume fraction of the metal matrix may be up to 30%. Bonding between metal and ceramic results from their mutual or partial solubility or from elemental additions that are partially soluble in both [8].

The objective of the present paper is to develop discontinuously reinforced A356/(0-20%)SiCp MMCs through stir casting method and examine the mechanical properties such as tensile strength, ductility, hardness and metallurgical characteristics using optical microscopy and X- ray diffraction study.

2. Experimental Details

2.1 Materials

The Al-Si alloy used for manufacturing of MMC was based on A356 alloy. The chemical composition of A356 alloy is shown in Table 1. This alloy provides excellent combination of strength, low coefficient of thermal expansion at elevated temperature

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and excellent wear resistance [6]. The SiC particles 10 wt. % and 20 wt. % were added to produce the composite had an average particle size of 23 µm and average density of 3.2 g/cm3. The liquid metallurgy technique was used to prepare composite. This method is most economical to fabricate composites with discontinuous fibers or particulates [7-8].

Table 1: Chemical Composition (wt. %) of the A356 Alloy

Alloy	Cu	Mg	Si	Fe	Mn	Zn	Ti	Al
356	0.2	0.45	7	0.2	0.1	0.1	0.2	Balance

2.2 Preparation of the Composites

The liquid metallurgy technique was used to prepare composite specimens [9]. In this process, matrix alloy was melted at 800°c and then the temperature was lowered gradually below the liquidus temperature at 610°c to keep the matrix alloy in the semi-solid state as shown in fig. 1. At this temperature, the preheated sic particles at 720°c were introduced into the slurry and mixed. The composite slurry temperature was increased to molten state and then stirring was continued for 5 min at an average stirring speed of 325 rpm. degassing is done by dipping and stirring with hexa chloro ethane (c_2 cl_6) to the molten metal. The melt was then superheated above liquidus temperature and finally poured into mould of cast iron of size 60x60x300 mm^3. The castings were solution heat treated at 500°c for 6 hours, water quenched at room temperature and precipitation hardened at 190°c for 12 hours. The optical microstructures of a356/10%sic_p and a356/20%sic_p heat-treated composite with uniformly distributed sic particle in alloy matrix is evident from micrograph shown in fig. 2(a, b).

Fig. 1 Photographic View of Stir Casting Set Up

2.3 Metallography

Microstructural characterization of treated samples was performed on their cross-sections, cut out from the cast material by using optical microscopy. The samples were polished using disc polishing method with diamond pastes of sizes 6µm and 3µm was used as abrasives. After getting mirror finish samples were etched using Keller's reagent and observed using Leica Optical Microscope. The images are captured at suitable magnification and recorded using computer.

2.4 Mechanical and physical properties

The tensile properties of the alloy and two composites were measured at room temperature by a computer-controlled tensile testing machine (Hounsifield, H25KS/05, England) at a strain rate 1.67 x 10-4/s. The cylindrical test specimens of round cross section were machined according to ASTM E8 standard for tensile testing. The average values of ultimate tensile strength, yield strength and percentage elongation obtained using the above analysis. Hardness of the alloy and composites were measured by using Brinell hardness testing machine. Brinell hardness number (BHN) was calculated using the formula

$$BHN = 2F / \pi D(D-(D2 - d2)0.5) \quad (1)$$

Where F is in Newton (N), D is the diameter of the ball indenter (mm) and d is diameter of indentation (mm).Indentations were made on samples using ball indenter at 500 kg of load for 30sec dwell time. The surface of the specimens were machined and polished to 400 grit size. The distance between the centers of indentations was maintained greater than half the diameter of the indentation. The indentation diameter was converted in to the hardness values from a standard table for a particular load and type of indenter. The density of the alloy and composite was measured by archmedian principle.

3. Results and Discussion

3.1 Microstructure

Aluminium alloy A356 was used as matrix for the development of two types of A356/ (10-20%) SiCp composites. The microstructures of heat treated A356 alloy is depicted in Fig.2 (a). The microstructure of A356 alloy exhibits primary alpha-Al dendrites and fine eutectic mixture in interdentritic region (Fig. 2 (a)). The microstructures of heat treated A356/10%SiCp and A356/20%SiCp composites showed uniform distribution of SiC particles in the matrix of the alloys (Fig 2(b) and 2(c)). Apart from the SiC particles other micro constituents present in the matrix are same as described above. The micrographs of A356/10%SiCp,

A356/20%SiCp composites mainly showed α-Al, eutectic mixture and SiC particles.

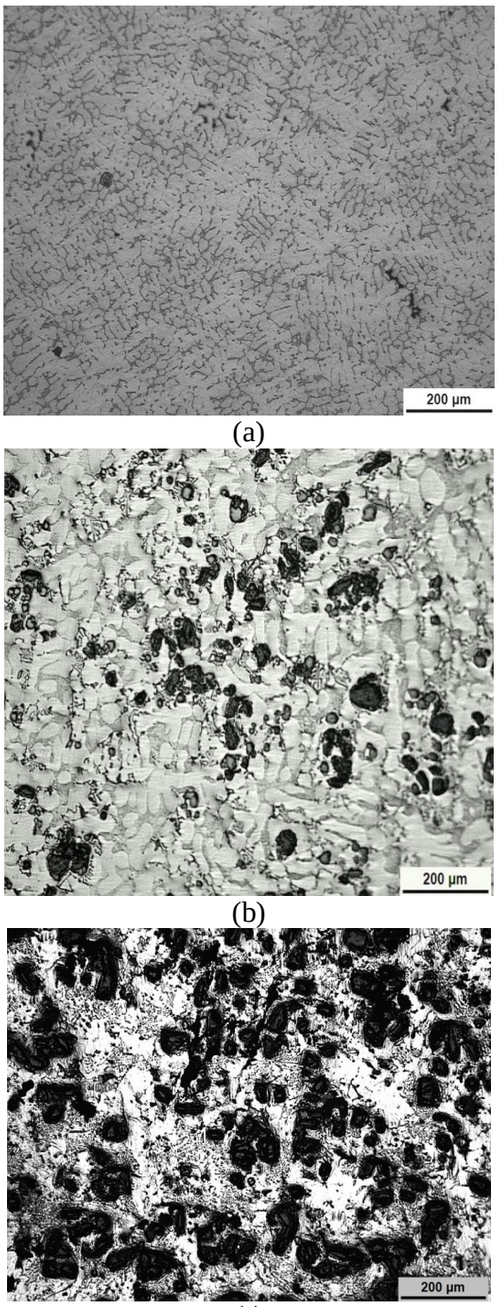

Fig. 2 Optical Micrograph of Heat Treated (a)A356 Alloy, (b)A356-10%SiC Composite and (c)A356-20%SiC Composite

3.2 Hardness

Brinell hardness test has been conducted to find the hardness of the heat treated composites. It was found that the Brinell hardness of the composite specimen increases with the percentage of SiC content in it as shown in Fig. 3. Also it was found that the heat treated composite samples have more hardness compared to as cast condition. This is due to the fact that during precipitation hardening, hardening phases such as Al2Cu and Mg2Si were formed which is evident from the XRD result of A356 alloy and composite as shown in Fig. 4. In composites, Mg2Si is the precipitation hardening phase formed as indicated in the XRD analysis report. Heat treatment of composites causes precipitation hardening (Mg2Si), spherodization of silicon crystals, increased bonding between the hard second phase silicon particles and aluminium. These factors in turn increase the hardness of composites. Better distribution of refined and spheroidized silicon crystals would retard the crack nucleation and propagation propensities and therefore can be attributed to improvement of wear resistance of alloys after the heat treatment [10]. The higher dislocation density in the composites could also increase the solute diffusivity. This enhanced diffusivity of Mg atoms has been suggested [11] as the reason for the higher growth rate of Mg2Si precipitates. Since dislocations are the favorable sites for the nucleation of the precipitates [11], finer precipitates are expected in the composites having a high dislocation density in the matrix. The hardness of A356-20%SiCp composite (127BHN) is found to be higher than A356-10%SiCp composite (114 BHN) and A356 alloy (104 BHN). The increase in higher hardness of the two A356 (0-20%) SiCp composites with their matrix alloy is due to the presence of hard SiC particles and the formation of hardening precipitates like Mg2Si, CuAl2 as revealed by XRD analysis as shown in Fig. 4.

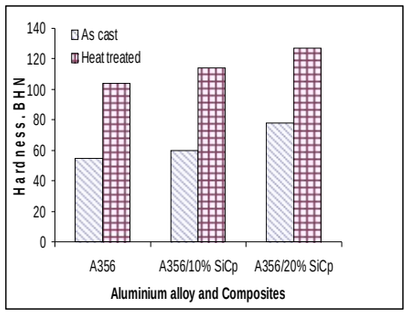

Fig. 3 Hardness of matrix alloy and their composite systems in as cast and heat treated (T6) conditions

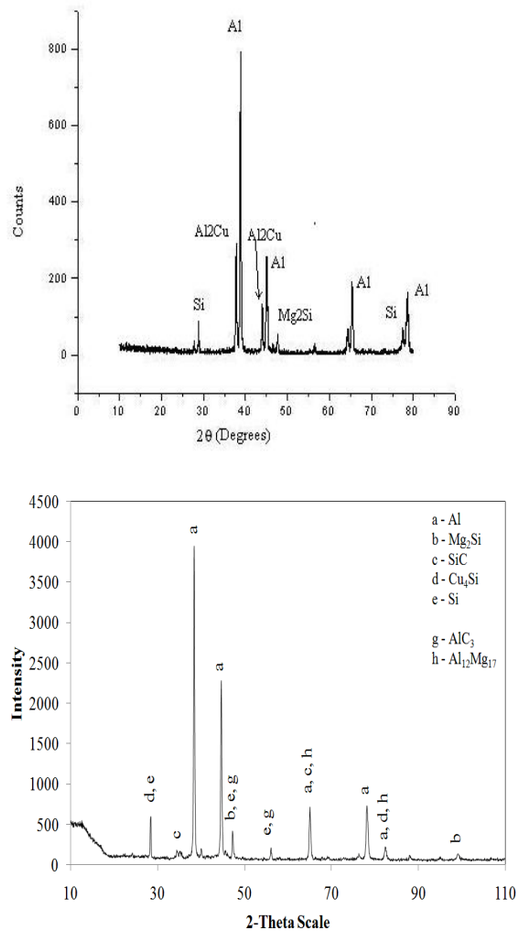

Fig. 4 XRD Patterns of (a) A356 Alloy and (b) A356-10%SiCp Composites

3.3. Tensile test

The tensile strength of the A356 (0-20%) SiCp composites were evaluated using universal testing machine. It can be observed that the tensile strength of A356-20%SiCp, A356-10%SiCp composites and A356 alloy is 116 N/mm2, 193 N/mm2 and 239N/mm2 respectively ads shown in Table 2. The ductility (% elongation) of A356 alloy was found to be 3.2 %. It can be noticed that A356-20%SiCp and A356-10%SiCp composite exhibit brittleness than the alloy. This shows the presence of SiC particles in the A356-10%SiC and A356-20%SiCp composites and is responsible for the decreased tensile strength of the composites

Table 2: Mechanical Test Results of Alloy and Composites

Composites	A356/20wt%SiCp	A356/10wt%SiCp	A356alloy
Mechanical properties	Heat treated	Heat treated	Heat treated
Tensile strength, N/mm^2	116	193	239
Density, g/cc	2.60	2.64	2.69
Ductility (%)	-	-	3.2

4. Conclusions

i. Composites of matrix alloy (A356) reinforced with 10% and 20% weight fraction of SiC particles (23µ) were successfully produced by stir casting method with uniform distribution of SiC particles in the matrix of the alloy. The micrographs of A356 alloy mainly showed α-Al and eutectic mixture whereas the micrograph of A356-10%SiCp, A356-20%SiCp composites exhibited three micro constituents namely α-Al, eutectic mixture and SiC particles. SiC particles were located predominantly in interdendritic regions.

ii. The strength of the heat treated A356-10%SiCp and A356-20%SiCp composites were higher than as cast matrix alloy. The ductility of composites decreased with the increase in weight percent silicon carbide content. The hardness of composite increased with the increase in silicon carbide content in it. Higher hardness and tensile strength of the two A356/(10-20%) SiCp composites as compared to matrix alloy is due to the presence of hard SiC particles and the formation of hardening precipitates like Mg2Si and CuAl2 as confirmed by XRD analysis.

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