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Comparative Study on Mechanical Properties of SiC and Al_2O_3 Reinforced in Al6061 Matrix by Stir casting

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***Abstract*—** Usage of aluminium based metal matrix composite is unavoidable material for many engineering applications especially to weight – strength ratio needed. In this paper, the comparative study has been done for micro-structural and mechanical characteristics of Al6061 metal matrix reinforced with Silicon Carbide (SiC) and Aluminium Oxide (Al_2O_3) discretely. Test specimens were fabricated by adding 0, 5 and 10 wt % of SiC and Al_2O_3 in Al6061. Stir casting method used for the preparation of Al6061 composites. Morphology of the reinforcement particles and fabricated part was studied by SEM and Optical Microscope respectively, to analyze the distribution of particles in the Al6061 composite. Mechanical properties such as hardness, tensile and yield strength were carried out as per ASTM standards. The result proved that the density of composite is increases by increasing wt% of reinforcements in the matrix. The hardness value of SiC reinforced composite is higher than that of Al_2O_3 reinforced composite. Also the result shows that the maximum tensile strength at 5% wt of Al_2O_3 and SiC composite were identified.

Keywords— *MMC, Stir casting, Al 6061, SEM, SiC, Al_2O_3 ,Tensil strength*

I. INTRODUCTION

Composite is the class of engineering material which composed by a discrete element called as reinforcement distributed in a continuous phase called as the matrix [1]. Generally the ferrous and non-ferrous metals have medium to high material properties since the usefulness of material has been chosen by the mechanical properties. These properties is to be improved for the life of the components or machines or structures by adding small quantity of reinforcements (ceramics, fibers, ashes) in the base materials (Matrix). Composite material can be classified as three categories like Metal Matrix Composite (MMC), Polymer Matrix Composite (PMC) and Ceramic Matrix Composite (CMC). MMC is playing major role in the field of newer material development due to its direct functional improvements in recent years. MMC's have very light weight, high strength, and exhibit good resistance to corrosion, oxidation and wear [2]. The mechanical properties of MMC is radically transforming from the base metal when varying the weight percentage of matrix and/or reinforcement. Moreover these mechanical properties of MMCs increase their usage in automobile, structural, architecture and marine industries. Aluminum Matrix Composite (AMC – a kind of MMC) are one of the advanced engineering material that have been developed for weight critical applications in the aerospace, architecture and more recently in the automotive industries due to their excellent combination of high specific strength and greater wear resistance [3]. The reinforced hard ceramic particles like SiC, Al_2O_3, and B_4C, TiC, TiO_2, etc added with AMCs to getting more strength and wear resistance.

Aluminium alloys are still the subjects of intense studies, as their low density gives additional advantages in several applications. These alloys have started to replace cast iron and bronze to manufacture wear resistance parts. MMCs reinforced with particles tend to offer enhancement of properties processed by conventional routes. Al6061 is widely used in numerous engineering applications including transport and construction where superior mechanical properties such as tensile strength, hardness etc., are essentially required [4].There are two types of processing methods available for making metal matrix composite. They are (a) Solid state process (powder metallurgy), (b) Liquid state or liquid infiltration process (stir casting, squeeze casting etc.). Stir casting is the most commonly used low cost mass production method for fabrication of AMC when comparing with other methods [5-6]. Many researchers have done and progressing their researches in AMC's by addition of ceramic reinforcement to Al 6XXX series materials [7-10]. In this comparative study Al6061 was taken as base metal and SiC, Al_2O_3 used as reinforcement to making two

different composite by stir casting technique and studied the effect of SiC and Al_2O_3 element in microstructure as well as mechanical properties of Al6061 composite.

II. MATERIALS & AND METHODS

In this present experimental investigation Al6061 is used as a matrix material. The chemical composition of Al6061 is listed in table 1 [11]. Al6061 is basically precipitation hardening aluminium alloy, containing magnesium and silica as its major alloying elements [5]. It has good mechanical properties, specifically density is 2.7g/cm^3 and tensile strength is 130 Mpa

Table.1. Chemical composition of Al6061

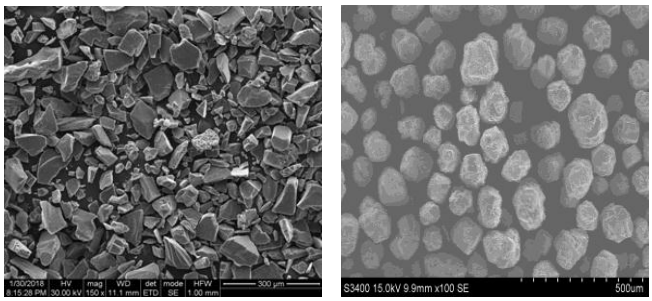
Elements	Weight %
Manganese (Mn)	0.15
Silicon (Si)	0.4-0.8
Chromium (Cr)	0.15-0.35
Copper (Cu)	0.15-0.4
Iron (Fe)	0.7
Zinc (Zn)	0.25
Magnesium (Mg)	0.8-1.2
Titanium (Ti)	0.15
Aluminium (Al)	Bal

Two ceramic materials Silicon Carbide (SiC) and Aluminium Oxide or Alumina (Al_2O_3) used as reinforcement and have different wt% used for making aluminium matrix composite. The basic properties of reinforcements are given in table 2 [9,11&12].

Table.2. Basic properties of Reinforcements

Properties	Al 6061	Silicon Carbide (SiC)	Alumina (Al_2O_3)
Density g/cm^3	2.7	3.1	3.9
Melting point (˚C)	580	2200-2700	2072
Tensile strength (Mpa)	130	240	60
Poisson's ratio	0.33	0.14	0.21

Scanning electron microscope (SEM) analysis was done to know the particle size and shape of the powder before going to use in the composites. The morphology of reinforcement materials as shown in fig.1



(a) SEM image of SiC b) SEM image of Al_2O_3

Figure 1. Morphology of reinforcements

The reinforcement powder particles used 220 mesh sizes and SEM image results that the SiC powder particles have flakey, acicular or angular shapes and discrete with non-uniform in particle size under 300µm. But in SEM image of Al_2O_3 shows that the particles are spherical, rounded shapes and discrete with uniform (average) in particle size under 500µm.

III. EXPERIMENTAL PROCEDURE

Initially Al6061 with weight percentage of SiC (0%, 5%, and 10%) was used for composite making by liquid metal vortex technique which is done through stir casting equipment. SiC particles were preheated at 500°C for 2 hours to improve the wettability by removing the absorbed hydroxide and other gases. The furnace temperature was raised to 750°C to melt the matrix completely. At this stage the preheated SiC particles were added and mixed. One wt% of magnesium is added in order to increase the wettability and flow-ability while pour in to the mould. Degassing tablet (Hexachloroethane) was used for removing hot gases from the molten metal for the purpose of avoiding porosity and blowholes defects. Mechanical stirring was carried out for 3 to 4 min at 500 rpm of stirring speed. The molten metal is then poured into the mould to get required (100 mm x 10 mm x 10 mm) shape in die. Similarly the second specimen reinforced with Al_2O_3 with same process parameters is used for making the Al6061- Al_2O_3 composites.

The density of the samples was measured by the Archimedes' method, Micro hardness test were conducted in Vickers hardness testing machine. Averages of three readings were taken for each sample. The test specimen used for tensile test made for ASTM E-8 standard as shown in fig.2 and the test were performed at room temperature using a FIE UTN40 model universal testing machine operating at a speed 3mm/min crosshead movement. From that the Ultimate Tensile Strength (UTS) and Yield strength (YS) were measured

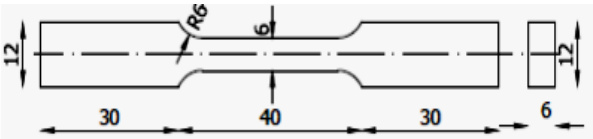
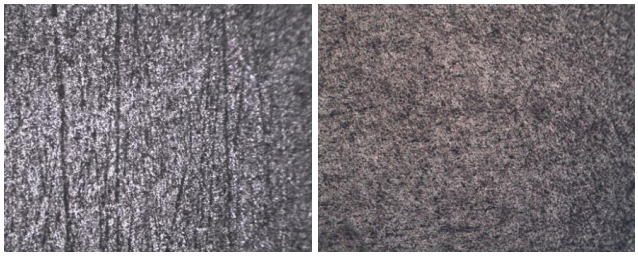


Figure. 2 Tensile Test Specimen

III RESULTS AND DISCUSION

3.1 Microstructure analysis

Microstructure and element presents in the cast specimens were studied by Optical Microscopy (OM) under the magnification of 100x

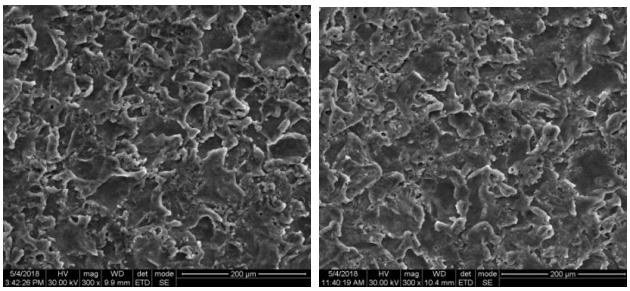


(a) Al6061 (b) Al6061 + 10% SiC

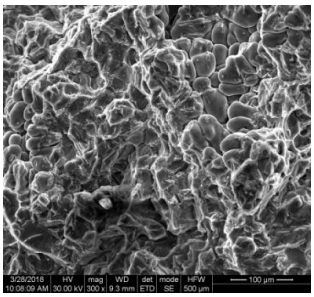
(c) Al6061 + 10% Al_2O_3

Figure 3.(a), (b), (c) Microstructure study of Al6061 Composite

Figure.3. (a), (b) and (c) shows the microstructures of fabricated Al6061 matrix reinforced with SiC and Al_2O_3 composite. Images were captured for Al6061, Al6061+SiC and Al6061+Al_2O_3 composite containing 10% weight percentage. It's clearly reveals the homogeneous distribution of the SiC and Al_2O_3 in Al6061 matrix and there is an evidence of small percentage of porosity in the aluminium composite. But there are no cracks in all composite samples. This capacity is associated to proper process parameters which can be used for the production of castings.



(a) Al6061 (b) Al6061 + 10% SiC



(c) Al6061 + 10% Al_2O_3

Figure 4.(a), (b), (c) SEM images of Al6061 Composite

SEM photographs were obtained using Scanning Electron Microscope. Fig. 4(a-c) shows the SEM photographs of Al 6061 (Fig.4a), Al 6061 with 10 wt % of SiC (Fig.4b) and Al6061 with 10 wt % of (Fig.4c) Al_2O_3 particulates. It reveals good distribution of particles and very low porosity was formed and there is no cracks are presents in the composites.

3.2 Density measurement

The density of the composite was determined by the densities of each composition of the SiC and Al_2O_3 reinforcements. The density of the cast materials was calculated by using Eq. (1). [13] that is based on Archimedes's principle

$$\rho_{comp} = \frac{M}{M-M_1} \times \rho_{water} \quad (1)$$

where, M is the mass of the composite in air, M_1 is the mass of the composite in distilled water. Table.3. shows that the results of density of composite samples fabricated by different conditions.

Table.3. Density values of Al 6061 composites

Sample Composition	SiC	Al_2O_3
	Density (g/cc)	Density (g/cc)
Al 6061	2.647	2.647
5 %	2.68	2.69
10 %	2.69	2.73

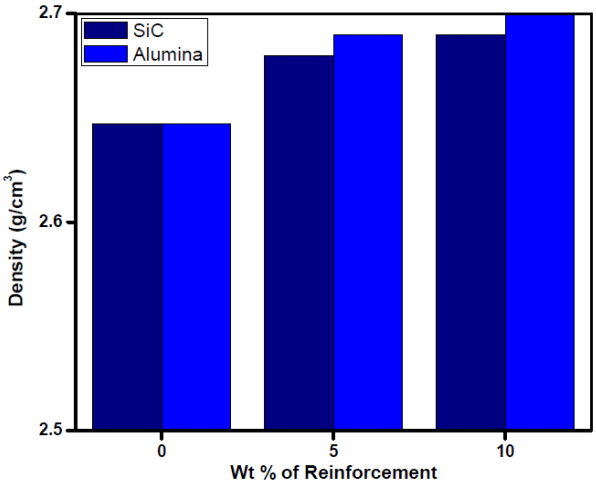


Figure.5. Density of Al6061 composite

It is indicated that the density of samples increases with increasing the weight percentage of SiC & Al_2O_3 particles as shown in Fig.5. Because of density of reinforcement is more than the density of matrix. [14].

3.3 Hardness Test

The hardness test was carried out using Vickers hardness machine applied load 1 kg for 12 seconds. The Hardness values of Al6061+SiC & Al 6061 + Al_2O_3 is presented for various weight fractions of reinforcements in Table.4.

Table.4. Hardness values of Al6061 composite

Sample Composition	Hardness SiC (HV)	Hardness Al_2O_3 (HV)
Al 6061	51	51
5 %	62	62
10 %	70	67

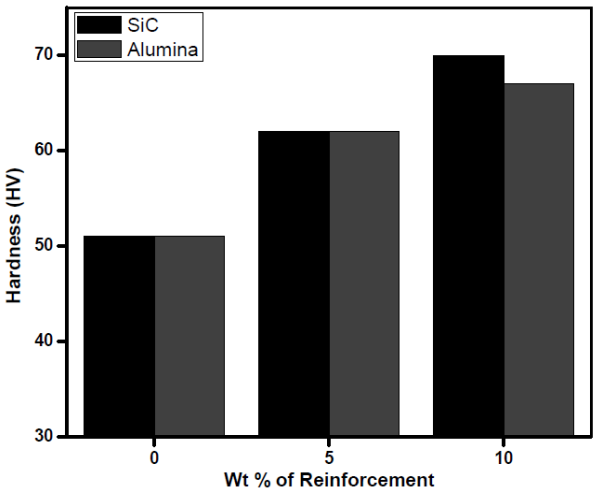


Figure.6. Hardness of Al6061 composite

Figure.6. shows that the hardness increases when wt. % of reinforcements with Al 6061 increases. It was observed that the hardness of the composite is increased gradually from 0 to 10 wt.%. The maximum Vickers hardness values at 10% weight fraction of SiC particle is 70. The similar behavior is seen in Al6061-SiC composite [15] also.

3.4 Tensile Strength test

The tensile test was carried out using FIE UTN40 model tensile testing equipment. The specimens were made as per ASTM E-8 standards. Tensile tests were carried out for SiC and Al_2O_3 reinforced composite specimens and the values were tabulated in Table 5. The Ultimate Tensile Strength is increases when addition of wt% of reinforcement particles to the base material. The tensile strength of Al6061 is 116.04 MPa which is similar behavior getting in Radha et al [15]

Table.5 Tensile strength values of Al6061 composite

Sample Composition	SiC		Al_2O_3	
	Tensile Strength (MPa)	Yield Strength (MPa)	Tensile Strength (MPa)	Yield Strength (MPa)
Al 6061	116.04	90.94	116.04	90.94
5 %	141.89	122.38	164.58	138.56
10 %	137.23	113.01	137.78	123.43

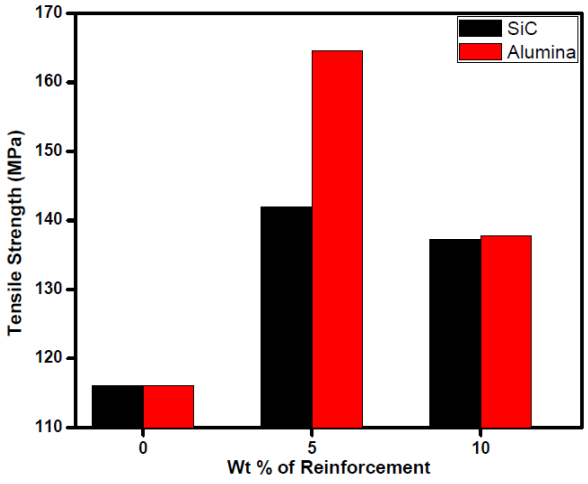


Figure.7. (a) Tensile strength of Al6061 composite

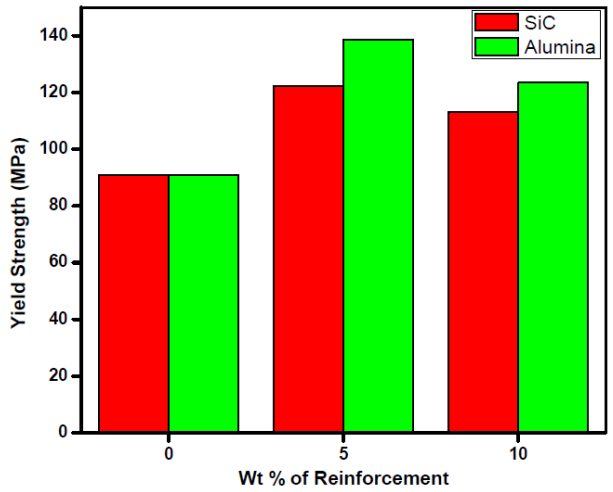


Figure .7 (b) Yield strength of Al6061 composite

The maximum tensile value of Al6061+SiC composite noted as 141.89 MPa at 5 wt % of SiC and it is revealed that there is increase in strength of composite than unreinforced Al6061. This is due to the SiC particles which uniformly distributed in the matrix and the interfacial bonding between particle and the matrix phase. Further it decreases slightly at 10% of SiC particles due to less wettability and increasing the wt% of ceramic particles. The Al6061-Al_2O_3 composite reached maximum as 164.58 MPa at 5 wt % of composite. While comparing to Al6061-SiC composite the tensile strength of Al_2O_3 reinforced composite is slightly increases. The bar line represents in fig.7 (a) about the tensile strength of unreinforced Al6061 and the values increases upto Al6061 + 5 % of SiC further it decreases due to initializing the ultimate breaking. In other hand upto 5% of SiC and Al_2O_3 has gradual increment in tensile values. Hence it is about 22%, 41.8% respectively the improvements taking place over that of the unreinforced Al6061 matrix. In such a way that the yield strength graph (fig.7-b) for SiC as well as Al_2O_3 reinforced in Al6061 composite also behaving the same root with increment around 34 and 51% respectively, then unreinforced material.

IV. Conclusion and Future Scope

Al6061 reinforced by 0, 5 and 10 wt. % SiC & Al_2O_3 reinforcement particles were fabricated successfully by stir casting method. From the experimental results the following conclusion were obtained. From the microstructure analysis, it is found that the hard ceramic particles were uniformly distributed in the metal matrix. Hardness of the composite increases with respect to the wt% of reinforcement particle increases. The addition of weight fraction of ceramic particles results in the significant improvements in tensile strength. The superior tensile strength is obtained at 5 wt. % of SiC and after that tensile strength is reduced. Subsequently 5 wt% of Al_2O_3 composite increases the tensile strength then it is reduced. Ductility of the composite reduces marginally as the reinforced increases.

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