Studies on Mechanical Properties of Al-Sic Metal Matrix Composite

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Abstract

In the present industrial scenario, composite materials are given first preference due to its high strength and less weight ratio. The project work focuses on the metal matrix composites, which are mainly used in aeronautical and automobile applications.Now a days metal matrix composites plays vital role in engineering applications. Silicon carbide is added as reinforcement in to Aluminium alloy (6061) for preparing metal matrix composite. The metal matrix composite is produced by Stir Casting method. This method is less expensive and very effective. The composites was fabricated by varying the SiC reinforcement from 3% to 18%.Six samples of the composite materials have been prepared according to the ASTM standard for tensile testing. Then the tensile test was carried out for all the specimens using the universal testing machine and results are obtained. The hardness of the specimens were also found using Rockwell hardness tester. From the results obtained, the influence of SiC reinforcement on the mechanical properties is known.

Keywords: *SiC, ASTM, UTM, Tensile, Hardness*

I. INTRODUCTION

J.P.Pathak et.al [1] was prepared by Al-Si-SiC composite by mixing of silicon carbide powder in solidifying solid-liquid slurry of hypoeutectic, eutectic and hypereutectic compositions of Al-si alloy. Requisite amount of hot SiC powder was charged into agitating metallic melt of Al-Si matrix alloy and mixing continued while dropping the temperature of the system. The mixing period was 3-4 min. during which temperature of the system dropped to 15 to 20oC below the liquids. The strength, hardness and wear resistance of composite increased with increase of silicon carbide content. K.Mahadevan et.al [2] investigated the influence of reinforcement and precipitation hardening parameters of AA 6061-SiC composites. The presence of discrete reinforcement particles in the matrix of the discontinuously reinforced metal matrix composites considerably alters the matrix microstructure and hence the precipitation hardening kinetics. Therefore, precipitation hardening schedule of Al alloys are not applicable to Al based discontinuously. In the present work, an attempt has been made to systematically study the effects of reinforcement percentage and precipitation hardening parameters on the behaviour of AA 6061-SiC composites. .k.Acharya et.al [3] investigation is aimed at processing a composite using fly ash, jute with epoxy and to study its weathering behaviour on mechanical properties such as flexural strength.the fracture surfaces of the specimen are examined under scanning electron microscope.the cracking of the fiber structure is avoided due to adherence of fly ash particles which indicates the increase in strength of interfacial bonding.it can be concluded that this composite can be successfully used as a structural material in household and automobile application. Necat Altinkok et.al [4] predicted tensile strength of Al_2O_3/SiC particle reinforced metal matrix composites,. This composites is produced by stir casting method. In the experiments Al_2O_3/SiC powder mix has been prepared by reaction of aqueous solution of aluminium sulphate, ammonium sulphate and water containing SiC particles at 1200°C. 10% vol. of this dual ceramic powder with different SiC particle size ranges was added into liquid matrix alloy during mechanical stirring between solidus and liquids under inert condition. The micro structure of alloy is dependent on the cooling.Rohatgi et.al [5] summarized attempts to incorporate fly ash into aluminium castings to decrease the energy content, material content, cost, and weight of selected industrial components, while also improving selected properties. It is shown that fly ash can be incorporated into an aluminium alloy matrix using stir casting and pressure infiltration techniques. The sand and permanent mold castings, which included differential covers, intake manifolds, brake drums, and outdoor equipment castings including post caps, demonstrate adequate castability of aluminium melts containing up to 10 vol. % fly-ash particles.Ceschini et.al [6] investigated the tensile and the low-cycle fatigue behavior of two particle reinforced aluminium based composite consisting of aluminium based composites. The micro-structural analysis showed clustering of Al_2O_3 particles, irregularly shaped and size. A significant increase of the elastic modulus and tensile strength with respect to the unreinforced alloys was evidenced by the tensile tests, while the elongation to fracture decreased.[7] an extensive overview on Experimental Investigations of Resistance Spot Welding of Duplex Stainless Steel. The Main intention is to provide a depth approaching into the nature of the Resistance Spot Welding of Duplex Stainless Steel and a summary of the infinite experimental investigative effort put into it over the years. [8] The selection of optimum process parameters is time consuming and costly process. This study mainly focuses on the selection of optimum process parameters for the combination of work material stainless steel 316L and Solid & Hollow tool electrode of Brass material having 3 mm diameter [9] the selection of optimum process parameters is time consuming and costly process. This study mainly focuses on the selection of optimum process parameters for the combination of work material stainless steel 316L and Solid & Hollow tool electrode of Stainless Steel material having 3 mm diameter. Hence the MMC Properties has been checked out the mechanical testing methods and its characteristics are categorized in the following tables.

II. EXPERIMENTAL PROCEDURE

A. Specimen Preparation

The specimen is prepared by considering various process parameters and all the steps for the preparation of Al-SiC composites are followed. The steps include Weight Calculation, Fabrication (Casting and machining) and Experiment conduct.

Table 2.1: Properties of Al 6061 and Sic

Properties	**Al 6061**	**SiC**
Elastic Modulus (GPa)	70-80	410
Density (g/cc)	2.7	3.1
Poisson’s Ratio	0.33	0.14
Hardness (kg/mm^2)	95	2800
Modulus of rigidity (GPa)	26	140
Shear strength (MPa)	83	-
Tensile Strength (MPa)	115	390

Table 2.2 : Aluminium 6061 Composition

Component	Amount (Wt. %)
Aluminium	Balance
Magnesium	0.8-1.2
Silicon	0.4 – 0.8
Iron	Max. 0.7
Copper	0.15-0.40
Zinc	Max. 0.25
Titanium	Max. 0.15
Manganese	Max. 0.15
Chromium	0.04-0.35
Others	0.05

FORMULAE:
Weight = Volume x Percentage x Density
Density of Al alloy=2.72g/cm^3
Density of SiC alloy=3.21g/cm^3
Volume (area X length) = ((2X2) X30) =120cm3

<u>Addition of 3% SiC</u>
Weight of aluminum alloy = (97/100)X120X2.72=316.6 grams
Weight of SiC = (3/100)X120X3.21=11.55 grams

<u>Addition of 6% SiC</u>
Weight of aluminium alloy = (94/100)X120X2.72=306.8 grams
Weight of SiC = (6/100)X120X3.21=23.1 grams

<u>Addition of 9% SiC</u>
Weight of aluminium alloy = (91/100)X120X2.72=297.0 grams
Weight of SiC = (9/100)X120X3.21=34.6 grams

<u>Addition of 12% SiC</u>
Weight of aluminium alloy = (88/100)X120X2.72=287.2 grams
Weight of SiC = (12/100)X120X3.21=46.22 grams

<u>Addition of 15% SiC</u>
Weight of aluminium alloy = (85/100)X120X2.72=277.4 grams
Weight of SiC = (15/100)X120X3.21=57.78 grams

<u>Addition of 18% SiC</u>
Weight of aluminium alloy = (82/100)X120X2.72=267.6 grams
Weight of SiC = (18/100)X120X3.21=69.33 grams

B. Experimental Setup

Figure 2.1 and Figure 2.2 shows the preheating furnace and stir casting furnace. Stir casting method is used to melt the Aluminium ingots.

Fig.2.1 Pre Heating Furnace

In a stir casting process, the reinforcing phases are distributed into molten matrix by mechanical stirring. The melting capacity of the stir casting furnace is 3 kg. SiC preheated in preheating chamber around 850^{0}C. A stirrer positioned at the top of the furnace is used to mixing the reinforcement in the molten metal. An electric motor is used to rotate the stirrer through belt drive, at 1200 rpm. As Stirrer has to rotate at 600 rpm, the shaft and the stirrer have large pulley which reduce the rpm. In this process, the matrix material is heated to above its liquids temperature so that the metal is totally melted.

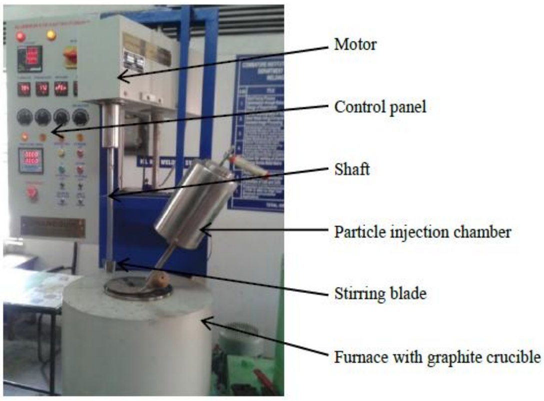


Fig.2.2 Stir Casting Furnace

The melt is then cooled down to a temperature between the liquids and solidus points and kept in a semi-solid state. At this stage, the preheated particles are added and mixed. The slurry is again heated to a fully liquid state and mixed thoroughly. This two-step mixing process has been used in the fabrication of aluminum.

C. Fabrication

Aluminium particle is charged into the crucible and kept inside the furnace and covered. Switch on the furnace and temperature is gradually raised up to 900°C.

Pre heated reinforcement (around 850°C) is adding into molten metal in main furnace crucible and Stirrer with 5minutes.

From the stirring action of 5 minutes the reinforced material is evenly distributed entire liquid metal.

Clean the die before pouring the liquid metal, so that it reduces the solidification rate. Magnesium is added to the liquid metal which increases the wet ability of the matrix and assisted particle incorporation.

The liquid stage metal matrix composite is taken out and poured in to the die then cooled. Cast specimen shown in Figure 4.3 is turned in lathe as per ASTM standard.

Fig.2.3 Cast specimen

D. Machining

After casting the work piece is machined by ordinary lathe in required dimensions of 10mmx10mmx150mm.

III. TESTING

A. Tensile Test

The tensile test is the most widely used test to determine the mechanical properties of materials. In this test, a piece of material is pulled until it fractures. During the test, the specimen elongation and applied load is measured. Strain and stress are calculated from these values, and are used to construct a stress-strain curve.

From this curve, the elastic modulus and yield strength are determined. The highest load in the tensile test gives the tensile or ultimate strength. After fracture, the final length and cross-sectional area of the specimen are used to calculate the percent elongation and percent reduction of area, respectively.

B. Experimental Procedures

- For each specimen, all the dimensions were measured such as Diameter and the Length.
- With a pencil, two lines were drawn on the straight section of the specimen so that the lines were two inches apart. This is the gauge length, Lo.

Fig. 3.1 Specimen Fixed Between the Jaws of Tensile Testing Machine

- The testing machine has already been set up and calibrated.
- The specimen was fixed in the top grip and tightened in its place.
- The specimen was also fixed in the bottom grip and tightened. It was carefully fixed so that the specimen was not bending while tightening.
- The crosshead speed has been given.
- Started the test by pressing the "up" button.
- After the specimen has broken, stop button has been invoked. Then removed the two halves of the specimen.
- The final Diameter was the minimum Diameter which occurred at the neck.
- Kept the two halves of the broken specimen together and measured the distance between the lines that scratched on the specimen. This distance was the final length, Lf.
- Made a sketch of the failed specimen (by sketching the flat side). The broken specimens were to identify the neck and fracture regions.
- A cylindrical tensile specimen that showed a typical cup and cone fracture.

C. Hardness Test

This is basic and very important property of materials. This property is very closely related to the strength of a material. A common way of defining this property is in terms of the capacity or ability of a material to resist permanent indentation. Such on scratching, wear, penetration, abrasion, cutting etc. several types of tests are used to determine the hardness of materials. The most commonly used tests are Brinell, Rockwell, and Vickers hardness tests. These tests give numbers which are indicative of the relative hardness of the materials under test.

Fig. 3.2 Rockwell hardness test setup

It is a very widely used test because of its speed and also because it is free from personal errors. The Rockwell hardness is determined through an indentation made under a static load and in this sense it is similar to Brinell hardness test. But it differs from the in that it employs the use of much similar smaller indenters and application of much smaller loads than those used in Brinell hardness test. The penetrater can be in the shape of a small ball or a diamond cone, known as brale. Specimen tested in Rock Well hardness tester is shown in figure 3.2.The Rockwell harness machine is used in this work because of its speed and also because it is free from personal errors to test the various composition of Al-SiC metal matrix composite. The two position of the indenter shown in dotted represent the position attained by the indenter after the application of the minor load and major load. The increment in the depth of the indentation (t) is a linear measurement and is used as the basis of determining Rockwell hardness number (R). Mathematically

$$R = 100\text{-}500\, t \quad \text{------------------} \; (3)$$

IV. RESULTS AND DISCUSSIONS

A. Results Calculation

Area Of Specimen $= (\pi/4)(d^2)$

$= (\pi/4)(10^2)$

$= 78.5\ mm^2$

Tensile Stress of 1^{St} Specimen(3% OF SiC)

= load/ area

$= (10x10^3)/78.5$

$= 127.38\ N/mm^2$

Tensile Stress of 2^{Nd} Specimen(6% OF SiC)

= load/ area

$= (9.6x10^3)/78.5$

$= 122.2\ N/mm^2$

Tensile Stress of 3^{Rd} Specimen(9% OF SiC)

= load/ area

$= (9.1x10^3) /78.5$

$= 115.9\ N/mm^2$

Tensile Stress of 4^{Th} Specimen (12% OF SiC)

= load/ area

$= (8.5x10^3) /78.5$

$= 108.2\ N/mm^2$

Tensile Stress of 5^{Th} Specimen(15% OF SiC)

= load/ area

$= (8.3\ x10^3) /78.5$

$= 105.7 N/mm^2$

Tensile Stress of 6^{Th} Specimen(18% OF SiC)

= load/ area

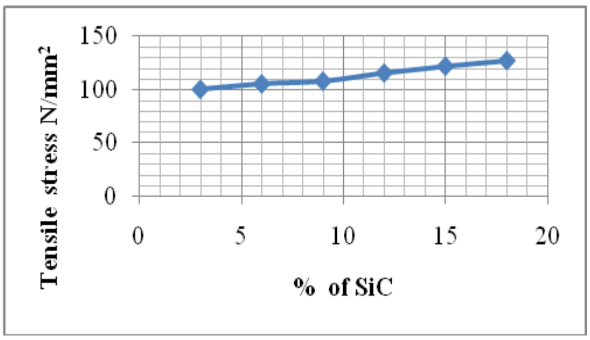
$= (7.9x10^3) /78.5$

$= 100.6\ N/mm^2$

Table 4.1 Measurement Values of Tensile Strength and Hardness

SPECIMEN	TENSILE STRENGTH (N/mm^2)	HARDNESS (HRC)
1^{st} (3% SiC)	127.38	62
2^{nd} (6% SiC)	122. 2	66
3^{rd} (9% SiC)	115.9	69
4^{th} (12% SiC)	108.2	72
5^{th} (15% SiC)	105.7	74
6^{th} (18% SiC)	100.6	76

V. GRAPH



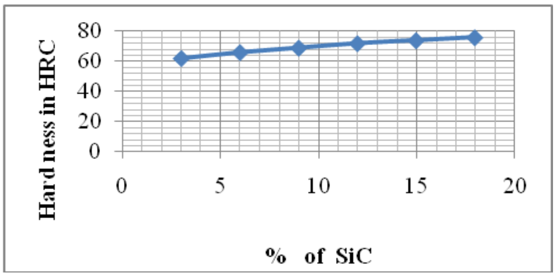


Figure 5.2 Hardness of Various Composition of SiC

Figs. 5.1 and 5.2 shows the variation of tensile stress and hardness for various percentage of reinforcement (SiC).

VI. CONCLUSION

The metal matrix composite specimens were fabricated successfully by stir casting method by varying SiC from 3% to 18% in weight of aluminium.

The mechanical properties such as tensile strength and hardness of various composition of reinforcement were found.

All the specimens were tested in tensile testing machine and hardness testing machine. The test result shows that as the percentage of weight in reinforcement increases the tensile strength and hardness also increases.

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