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MECHANICAL CHARACTERIZATION OF AL2024/SiC METAL MATRIX COMPOSITES

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Abstract - Recently, several studies have been done in aluminium based metal matrix composites aiming towards their usage in the field of aerospace industry. Although aluminium had been the major component used in this field, the metal alone possesses several disadvantages when it comes to strength to weight ratio. Aluminium alloy, when incorporated with ceramic particles, provides better mechanical properties. In this work, aluminium alloy Al2024 is reinforced with silicon carbide ceramic particles by the mould casting process. The aim of this work is to characterise and analyse the mechanical properties of aluminium ceramic sheets. Further, the specimens were tested in Universal testing machines for mechanical properties such as tensile and flexural tests.

Keywords - Aluminium, Al2024, Metal Matrix Composites, Silicon Carbide, Flexural Strength, Tensile Strength.

I. INTRODUCTION

Composites are the new generation materials which contain different materials with different properties giving rise to materials with new and better properties. Requirement for lightweight and energyefficient materials have prompted the improvement of cast Al alloymetal matrix composites strengthened by ceramic particles. Aluminium based composites form even lightweight materials than the aluminium metal. In many engineering applications, aluminium alloys are alluring as a result of their high strength to weight ratio. There are lot of research works which are primarily oriented towards the characterization of mechanical properties of aluminium based metal matrix composites. When aluminium alloys are reinforced with ceramic particles, they provide better characteristics which result in their application in aerospace as well as automotive industries. Among the various aluminium alloys aluminium 2000 series are well-known for their excellent strength and high performance over a wide range of temperatures. Aluminium 2024alloy is such an alloy in this series which is widely used because of its high strength and good fatigue resistance. The copper content present in these alloys provide substantial increase in its strength. Al2024 in sheet forms are used in aircrafts for fuselage skins. Also Al2024 is age-hardened which contains copper as its major alloying component and heat treatment of this alloy increases its strength. Aluminium alloy metal matrix composites are composites when reinforced with other metals or ceramic particles.

Silicon Carbide (SiC) is one of the most widely used ceramic particles which has a tetrahedron structure with silicon and carbon atoms. SiC is incorporated into the Al2024 alloy in order to improve the properties of the base metal. Micro-particles of SiC are used to make the metal matrix composite by varying the weight percentage of SiC. When SiC is used as the reinforcement material, it increases the mechanical properties when compared to the metal alloy or other conventional materials.Properties of the composites depend on the amount of silicon carbide particles used in each composite material. Increasing the weight% of SiCupto increases the tensile strength and flexural strength of the composite.

Available literatures explain that the addition of SiC resulted in improving the hardness and density of the composites. Also increased percentage of ceramic particles contributed in increased hardness and density of the composites. An additional advantage of using ceramic particles was that there is a large improvement in wear resistance of the aluminium-based alloy after reinforcement with SiC particles. Addition of SiC in aluminium matrix increases natural frequency, hardness, tensile strength and compressive strength.

II. EXPERIMENTAL PROCEDURE

2.1.Materials used:

Aluminium alloy, Al2024 is used as the matrix material for the metal matrix composite and silicon carbide (SiC) ceramic micro-particle is used as the reinforcement. The composition of Al2024 is given in table1 and the properties of Al2024 and SiC are given in table 2.

Constituent	Wt.%	Constituent	Wt.%
Cu	3.8-4.9	Zn	0.25
Mg	1.2-1.8	Zr	0.2

Mn	0.3-0.9	Ti	0.15
Fe	0.5	Cr	0.1
Si	0.5	Al	Remainder

Table 1. Composition of Al2024

Materials/Properties	Density g/cc	Elastic modulus GPa	Tensile/Compressive strength MPa	Hardness (HB500)
Al2024	2.78	73.1	185(T)	47
SiC	3.21	410	3900(C)	2800

Table 2: Properties of the materials

2.2. Fabrication of the composite:

The metal matrix composite is fabricated by the mould casting process. The aluminium alloy is placed in the crucible at 500°C. The alloy melts when the temperature increases. The tensile and flexural test specimens are made according to ASTM standards.

Figure 1: Cast samples

The moulds for tensile test and flexural test specimens are made as 300 x 30 x 5 mm and 150 x 17 x 5 mm respectively. Molten Al2024 is poured into the mould and the corresponding tensile and flexural test specimens are made. Four different compositions of composites are made by varying the wt.% of SiC reinforcement as 0, 3, 6 and 9. Test samples are obtained as pure Al2024, Al2024+3%SiC, Al2024+6%SiC and Al2024+9%SiC. The cast samples are then machined and cleaned. The composites prepared from the moulds after machining contain final sizes of 250 x 25 x 3 mm for the tensile test 125 x 13 x 3 mm for the flexural test.

2.3.Characterisation:

2.3.1. Tensile test:

The tensile testing of the composites are done in a computerized universal testing machine (UTM). The tensile test specimens are according to ASTM D-3039 standard (250x25x3mm). Four different composite specimens are made by varying the weight percentage of the reinforcement (SiC). The testing is done by placing the specimen between the jaws of the machine and tensile load is applied until fracture of the composite specimen occurs. The load vs displacement graph is plotted with the increase in the tensile load. The tensile test specimens of the composite are given in figure 2.

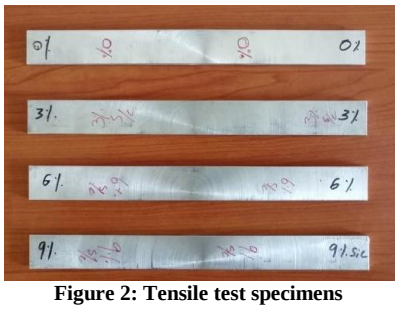

Figure 2: Tensile test specimens

2.3.2. Flexural test:

Three point bending tests of the composite specimens are done in the universal testing machine(UTM) where the specimens are made according to ASTM D-790 standard (125x13x3mm). The flexural test specimens are shown in figure 3. A concentrated bending load is applied on the mid-span of the simply supported specimen. This load is applied gradually to the specimen until fracture. This test explains the behaviour of the composite when it is subjected to a bending load and the maximum stress generated in the outermost layer of the composite is determined. The size comparison of tensile and flexural test specimens is shown in figure 4.

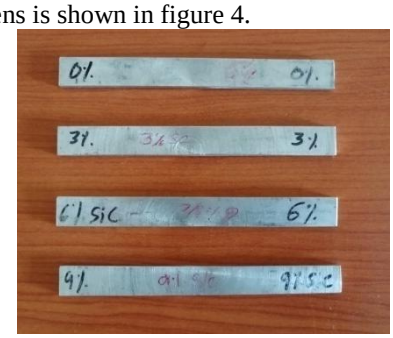

Figure 3: Flexural test specimens

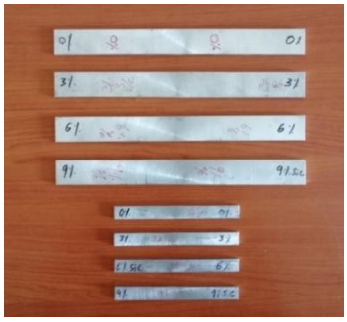

Figure 4: Size comparison of tensile and flexural test specimens

III. RESULTS AND DISCUSSION

3.1. Tensile testing:

The four different compositions of the composite specimens are tested for tensile testing and the load vs displacement graphs of the composite specimens obtained from the UTM are shown in figure 5.

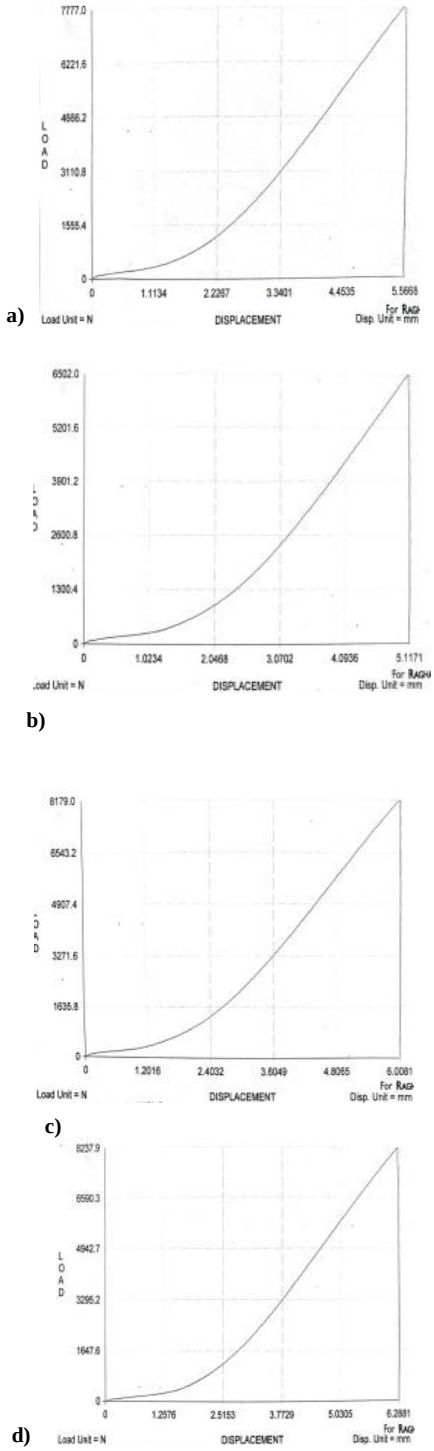

Figure 5: a) Al2024+0%SiC; b) Al2024+3%SiC; c) Al2024+6%SiC; d) Al2024+9%SiC

The various tensile properties of the composite specimens are given in table 3 and the tensile strength results are plotted in a graph and are shown in figure 6. It can be observed clearly that the addition of SiC increases the overall tensile properties of the composite. Table shows that the composite specimen with 9% SiC shows higher tensile strength.

Composite	Max. Displacement (mm)	Break Load (N)	Ultimate Tensile Strength (MPa)
Al2024 + 0% SiC	5.533	7776.951	93.361
Al2024 + 3% SiC	5.083	6502.041	79.256
Al2024 + 6% SiC	5.974	8179.026	101.463
Al2024 + 9% SiC	6.254	8237.880	102.193

Table 3: Tensile test results

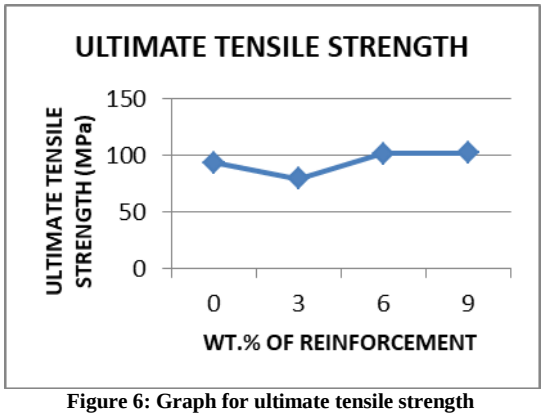

Figure 6: Graph for ultimate tensile strength

3.2. Flexural Testing:

Three point bending test is carried out in order to calculate the bending load and the flexural strength when the composite is subjected to bending. The flexural properties of silicon carbide reinforced aluminium metal matrix composites are shown in table 4 and the variation in the flexural strength of the specimens with increasing wt.% of SiC is shown in figure 7.

Composite	Flexural load (N)	Average flexural strength (MPa)
Al2024 + 0% SiC	336.4	7.626
Al2024 + 3% SiC	376.6	8.374
Al2024 + 6% SiC	448.2	10.384
Al2024 + 9% SiC	416.8	9.854

Table 4: Flexural test results

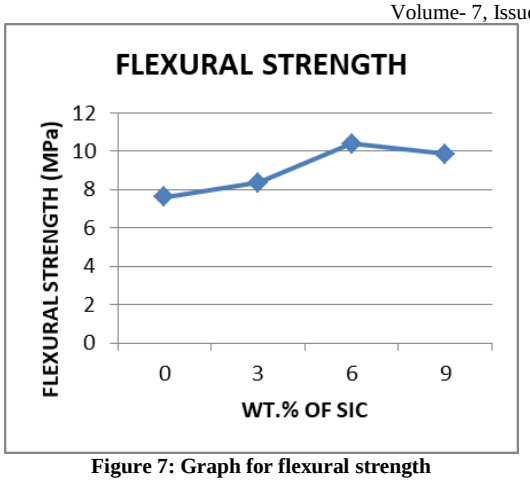

Figure 7: Graph for flexural strength

The addition of SiC increases the flexural strength properties of the composite specimens as shown in table 4. Also the flexural strength is found out to be decreasing from 6 to 9 wt.% of the reinforcement. The addition of SiC above 9% decreases the overall flexural properties of the composite.

IV. CONCLUSION

The effect of addition of SiC into the composite is studied in depth to 0, 3, 6 and 9 wt.% of the composite .Based on the above study, the following conclusions are made for the aluminium 2024 based metal matrix composites with SiC as the reinforcement. More amount of SiC (9% of the weight of the composite) in the composite material shows greater tensile strength which is a promising result that can be used for aerospace and automobile applications where the strength of the component is a major factor to be considered.

Further, when the flexural strength results are considered, 6% SiC shows the higher flexural properties. Increasing the reinforcement (SiC) decreases the flexural properties of the aluminium, Al2024 based metal matrix composites above 6%.

Thus, this study where SiC is used as the deciding material for the calculation of the mechanical properties of the composite, increasing the amount of SiC increases the overall mechanical performance of the composite.

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