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STUDY ON MECHANICAL PROPERTIES OF ALUMINIUM ALLOY 2024 WITH PERCENTAGE VARIATION OF SILICON CARBIDE

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ABSTRACT

The project aims to study the mechanical properties of Aluminium Alloy 2024 with varying percentages of Silicon Carbide (SiC) particles, including 2%, 4%, 6%, and 8%. The incorporation of SiC particles in the alloy matrix is expected to enhance its mechanical properties such as strength, hardness, and wear resistance. The project involves the preparation of different samples of Aluminium Alloy 2024 with varying percentages of SiC using stir casting technique. The mechanical properties of the samples are evaluated through various tests such as tensile testing, hardness testing, and compression testing. The results of these tests are analysed theoretically and practically to determine the effect of the SiC percentage variation on the mechanical properties of the alloy. The study will provide valuable insights into the use of SiC particles as reinforcement in Aluminium Alloy 2024, which has potential applications of the composite material in various fields, including aeronautics, marine and automotive applications**.**

KEYWORDS: Aluminium Alloy 2024, SiC , Tensile Test, Hardness Test , Compression Test

1. INTRODUCTION

In recent years, researchers have explored the use of powder metallurgy techniques to fabricate Aluminium Alloy 2024 reinforced with SiC particles. The powder metallurgy techniques allow for precise control of the SiC particle percentage in the alloy matrix, leading to enhanced mechanical properties. Aluminium Alloy 2024 is a high-strength, heat-treatable alloy that is widely used in the aerospace industry. It is composed of Aluminium, Copper, Magnesium, Manganese, Silicon, and Zinc, and is knownfor its excellent strength-to-weight ratio and corrosion resistance. In addition, it is also used in the automotive, marine, and construction industries. Aluminium Alloy 2024 has excellent mechanical properties, including high strength, good fatigue resistance, and good corrosion resistance[1].It is also highly resistant to stress corrosion cracking and is relatively easy to weld. The alloy is heat treatable and can be strengthened by coldworking. It is also relatively lightweight, making it ideal for applications where weight is a concern.

Silicon carbide (SiC) is a hard chemical compound that contains silicon and carbon.Any acids or alkalis or molten salts up to 800°C do not attack silicon carbide.SiC can be utilized up to 1600°C in air and generates a protective silicon oxide covering at 1200°C. This material has remarkable thermal shock resistance due to its strong thermal conductivity, minimal thermal expansion, and high strength. SiC is a very hard and brittle material with a high melting point, excellent thermal conductivity, and chemical resistance [2]. It also has a wide bandgap, which means it can withstand high voltages and temperatures without breaking down. These properties make SiC ideal for use in high-power, high-temperature, and high-frequency electronic devices such as power electronics, LEDs, and radio-frequency components. In addition to its electronic applications, SiC is also used as an abrasive material in industries such as cutting tools, grinding, and polishing. Its high hardness and chemical inertness make it ideal for use in harsh environments, such as cutting hard metals or ceramics.The substance has now been improved to become a high-grade technical ceramic with excellent mechanical properties.In this project, the impact of SiC particle percentage modification on the mechanical characteristics of Aluminium Alloy 2024 will be investigated. Our focus will be on the alloy's mechanical characteristics when the percentage of SiC particles is 2%, 4%, 6%, or 8%. By discovering how SiC particle percentage variation affects the mechanical characteristics of Aluminium Alloy 2024.

2. MATERIALS USED

The matrix material for the metal matrix composite is Aluminium Alloy(Al2024), and the reinforcing is Silicon Carbide (SiC)[3][4].

3. EXPERIMENTAL PROCEDURE

The stir casting method, also known as the liquid state method, is used to create hybrid composite materials. Mechanical stirring is utilized to combine a dispersion phase with a molten matrix metal [1].Due to its simplicity, mass production suitability, cost-effectiveness, nearly net shaping, and ease of composite structure control, it is an appropriate technique for the manufacturing of metal matrix composites[2].

In this study Aluminium alloy 2024 and Silicon carbide (SiC) composite isprepared by using stir casting technique.

Fig.3.1: Stir Casting

The Silicon carbide percentage isvaried from 2-8%.Table 3.1 shows the detailed addition of Aluminium Alloy 2024 and Silicon carbide (SiC) in grams.

Sl No.	Al 2024 Alloy added ingrams	SiC in percentage	SiC Added in grams
1	1265	2%	25.9
2	1328	4%	53.9
3	1602	6%	96.9
4	1805	8%	114.5

Table 3.1: Addition of Aluminium Alloy 2024 and Silicon carbide (SiC) in grams

The required amount of Aluminium alloy 2024 is added to the crucible and heated in the furnace to 750˚C at the same time that the silicon carbide is preheated using an electric coil. After the Aluminium alloy 2024 reaches the molten state, degasser is added to the crucible and stirred using a mechanical stirrer at 300–400 rpm. The generated slag is manually removed, Silicon carbide that has already been preheated is added and stirred. The molten melt is poured into the mould and allowed to cool down to form asolidified part as shown in Fig.3.2. The composite is displayed in Fig.3.3

Fig.3.2: Die used for casting

Fig.3.3: Casted Samples

4. MECHANICAL PROPERTIES

4.1 TENSILE TEST

Tensile testing was conducted in accordance with ASTM E-8 2022 standards using a computerized UTM testing system. Standard specimens with gauge lengths of 50 mm and specimen diameters of 12.29 mm were utilized to quantify ultimate tensile strength, yield strength, and percent elongation. The machine used for tensile test is shown in the Fig 4.1.1 and the samples are shown in Fig 4.1.2

Fig 4.1.1: UTM Machine

Fig 4.1.2: Tensile Test Samples

4.2 HARDNESS TEST

The Brinell Hardness Tester (HBW 5/250) was used to measure the specimens hardness. A load of 250 kg was used to test the hardness of the specimen with a 5mm ball diameter. The machine used forassessing hardness is shown in Fig. 4.2.1 and the samples are shown in the Fig.4.2.2.

Fig 4.2.1: Hardness Testing Machine

Fig 4.2.2: Hardness Test Samples

4.3 COMPRESSION TEST

A computerized UTM testing apparatus was used for the compression testing in accordance with ASTM E-8 2022 guidelines. Compression strength, maximum load, maximum elongation, peak load, and peak elongation were assessed using standard specimens with a diameter of 17.55mm. The samples that were tested for compression are shown in Fig.4.3.1.

Fig.4.3.1: Compression Testing Machine

Fig 4.3.2: Compression Test Samples

5. RESULT AND DISSCUSSION

5.1 TENSILE TEST

THEORETICAL CALCULATION

The tensile test can be calculated using the below mentioned formula.

Tensile Strength $=\frac{\text{Load taken to break}}{\text{Cross-Sectional Area}}$ N/mm^2

The values obtained after calculations are as follows.

Sl. No	% of SiC added	Load taken to break (N)	Cross-Sectional Area (mm^2)	Tensile Strength (N/mm^2)
1	2	18620	120.37	154.689
2	4	21500	122.33	175.760
3	6	23540	123.9	189.991
4	8	24550	118.63	206.947

Table 5.1.1 : Theoretical tensile strength calculation

It is observed that the tensile strength increases with the addition of SiC and 8% shows the maximum tensile strength.

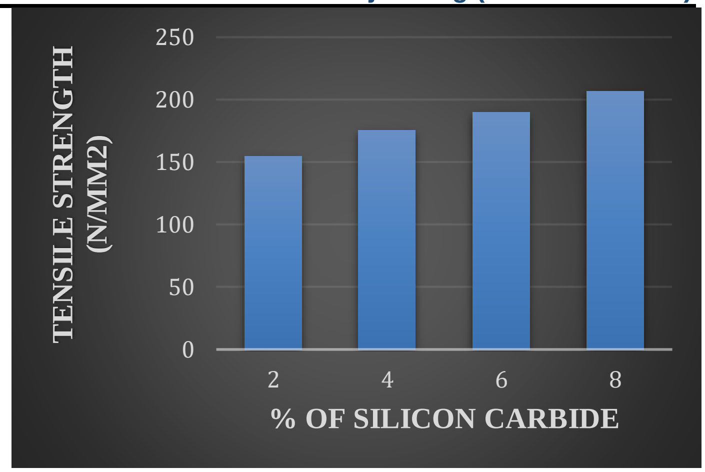

Fig.5.1.3: Graph Of Tensile Test

It can be observed from the graph that the addition of SiC increases linearly. Table 5.1.2 shows that the composite specimen with 8% SiC shows higher tensile strength.

EXPERIMENTAL RESULTS

In accordance with ASTM E-8 specifications, the specimens were machined to achieve a dog-bone structure [5]. The table below summarizes the tests observations and findings.

Sl No.	% of SiC added	Tensile strength (N/mm^2)	Yield stress (N/mm^2)	Percentage elongation (%)
1	2	154.69	124.197	1.78
2	4	175.76	134.232	2.14
3	6	190.00	138.58	2.52
4	8	206.95	155.779	2.40

Table 5.1.2: Tensile Test Results

5.2 HARDNESS TEST

THEORETICAL CALCULATION

The below mentioned formula is used for calculating the hardness of the specimen

$$\text{Brinell Hardness} = \frac{Load\ Applied}{Sperical\ Surface\ Area\ Of\ Indentation}$$

Sl. No	% of SiC added	Load Applied (N)	AVE Dia. of indentation (mm)	Brinell Hardness (HBW 5/250)
1	2	250	1.860	88.706
2	4	250	1.850	89.704
3	6	250	1.840	90.714
4	8	250	1.820	92.800

Table 5.2.1: Theoretical Hardness calculation

It can be observed from the table that hardness increases with the addition of Sic to Aluminium Alloy

2024. The table indicates that 8% SiC has maximum hardness.

EXPERIMENTAL RESULTS

A pneumatic load system applies and removes loads in a Brinell tester utilizing deadweights. Most Brinell scales can be used for operation. Unquenched steel, cast iron, non-ferrous metals, and soft bearing alloys are tested using this tester to determine their Brinell hardness.

Sl No.	% of SiC added	AVE Dia. of indentation	Brinell Hardness (HBW 5/250)
1	2	1.860	88.7
2	4	1.850	89.7
3	6	1.840	90.7
4	8	1.820	92.8

Table 5.2.2: Hardness Test Results

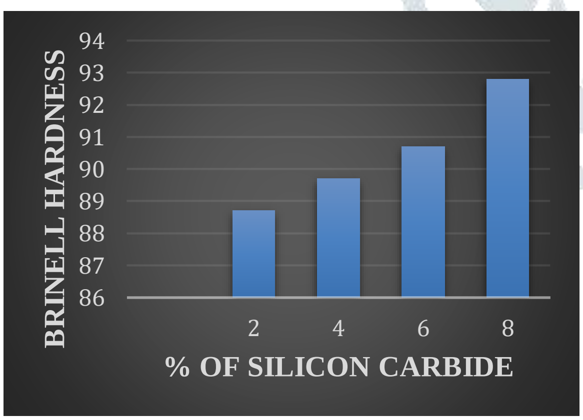

Fig. 5.2.3: Graph Of Hardness Test

The measuring range is from 5-250 HBW. It is observed from the graph that maximum hardness is observed at Al+8% SiC with 92.8 HBW

5.3 COMPRESSION TEST

THEORETICAL CALCULATION

The below mentioned formula is used for calculating the Compressive Strength of the specimen.

Compressive Strength=

$$\frac{Applied\ Force}{Area\ Of\ the\ Specimen}\ \text{N/mm}^2$$

Sl. No	% of SiC added	Area Of Specimen (mm^2)	Applied Force (N)	Compressive Strength (N/mm^2)
1	2	255.6	133234	517.3474
2	4	254.47	133332	523.9596
3	6	252.21	134556	533.5077
4	8	241.9	131498	543.6047

Table 5.3.1: Theoretical Compression Strength calculation

The table 5.3.1 indicates that the compressive strength increases with the addition of SiC to Aluminium alloy 2024. The specimen with 8% has the maximum compressive strength.

EXPERIMENTAL RESULTS

Compression testing methods for composite materials usually employ either shear loading or end loading to apply the compressive load to the specimen [6]. The four different compositions of the composite specimens are tested compression testing and the Compression Strength vs% of SiC added graph has been plotted.

Table 5.3.2 : Compression Test Results

Sl No	% of SiC added	Compression Strength (N/mm^2)
1	2	517.5
2	4	523.9
3	6	533.6
4	8	543.7

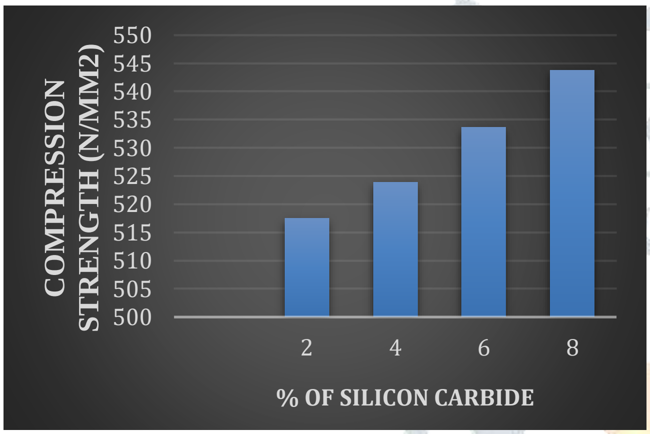

Fig.5.3.3: Graph of Compression Test

The maximum load applied is 600kN and maximum elongation is 250mm. It is observed from the graph that maximum compressive strength is obtained at Al+8%SiC with compressive strength of 543.7 N/mm^2

6. CONCLUSION

The effect of addition of SiC into the composite is studied in depth to 2, 4, 6 and 8 wt.% of the composite. Based on the above study, the following conclusions are made for the Aluminium Alloy 2024 based metal matrix composites with SiC.

The tensile strength of aluminium alloy 2024 is 140N/mm^2, compressive strength is 283N/mm^2 and hardness number is 120.

1.The tensile strength is maximum for Aluminium alloy 2024 with 8% SiC and its value is 206.95 N/mm^2. The tensile strength is linearly increased with increase in % of SiC.

2.The Brinell hardness is maximum for Aluminium alloy 2024 with 8% SiC and its value is 92.8 . The Brinell hardness is linearly increasing with increase in % of SiC.

3.The compression strength is maximum for Aluminium alloy 2024 with 8% SiC and its value is 543.7 N/mm^2. The compression strength is linearly increasing with increase in % of SiC.

From the above shown results and discussions it is observed that, theoretical calculations matches with the experimental results . From the graph it is concluded that mechanical properties increase with increase in % of SiC.

6.1 FUTURE SCOPE

The study can be further extended by adding other materials with Aluminium Alloy 2024 and SiC. The test such as wear and and corrosion can be conducted for different percentage variation.

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