Characterisation of Aluminium Metal Matrix Composites reinforced with SiC (Carborundum) & Al2O3 (Corundum)

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Abstract. Aluminium alloys are widely used in aerospace and automotive industries due to their advantages of physical and mechanical properties. This paper presents a study on the performance of stir cast SiC & Al2O3 reinforced Aluminium metal matrix composite materials. The particulate reinforcement of SiC & Al2O3 is in the ratio of 3:2. The mechanical characterization of AMMC indicates that the composite exhibit improved physical and mechanical properties such as low coefficient of thermal expansion, high ultimate tensile strength, high impact strength and hardness. Through scanning electron microscope, the microstructure of AMMC & distribution of SiC & Al2O3 particles in Aluminium alloy (Al 1350) is uniform. By experimental analysis, it is observed that AMMC with 15% of particulate reinforcement of SiC & Al2O3 with a ratio of 3:2 (9% of SiC & 6% of Al2O3) is the optimum mixture for AMMC to obtain better mechanical characteristics. This AMMC has good potential for the applications in automotive industry to manufacture engine components.

1. Introduction

Composites are materials in which two phases are combined with strong interfaces between the base metal & reinforcement. They usually consist of a continuous phase called the matrix and discontinuous phase in the form of fibers or particles called the reinforcement. The reinforcing component is distributed in the continuous or matrix component. When the matrix is a metal, the composite is termed as metal matrix composite (MMC). The matrix holds the reinforcement to form desired shape while the reinforcement improves overall mechanical properties of the matrix. Composite materials have high stiffness, high strength, low weight / density, high temperature stability, high electrical and thermal conductivity, corrosion resistance and improved wear resistance. In this paper, aluminium metal matrix composites with silicon carbide (SiC) and Aluminium Oxide (Al2O3) as reinforcement particles in the ratio 3:2 are studied to evaluate their physical and mechanical properties. Aluminium 1350 alloy is used as matrix which has 99.5% aluminium, 0.4% iron, 0.1% silicon, 0.05% copper, 0.05% Zinc, 0.05% Tin and 0.01% Manganese. The mechanical properties of aluminium metal matrix composites are affected by the volume fraction of the reinforced SiC & Al2O3 particles.

2. Problem Formulation

Through the analysis of literature survey, it is hypothesized that AMMC with SiC & Al2O3 particle reinforcement could be reliable materials to replace grey cast iron in the automotive industry. To improve the mechanical properties of AMMC the volume fraction of the reinforcement particles are varied compared to previous developments.
3. Objectives of Work

To reduce the weight of AMMC & to increase the tensile and yield strength with minimum ductility and toughness.
To increase creep resistance at higher temperatures compared to other alloys.
To improve corrosion resistance property.
To increase modulus of elasticity during tensile and compressive load.
To reduce thermal elongation of the material.

4. Methodology

The methodology used for stir cast of SiC & Al2O3 reinforced Aluminium metal matrix composite materials is shown in figure 1.

5. Stir Casting

Stir casting is a liquid state method of composite material fabrication in which a dispersed phase is mixed with a molten matrix metal by means of mechanical stirring. The aluminium alloy 1350 in the form of wire, used as base metal is melted in the crucible by heating it in a muffle furnace at 750°C for 3 hours. The SiC particles and Al2O3 particles are preheated at 1000°C for one hour to make their surfaces oxidized. The different specimens for tensile test, compressive test, impact test, hardness test and for microscopic study through SEM as per ASTM standards prepared with different composition and percentage of particulate reinforcement by weight in the ratio 3:2 as table 1 and shown in figure 2, 3, 4, 5 and 6 respectively.
Table 1. Composition and Percentage of Particulate Reinforcement

| Composition                                   | Aluminium Alloy 1350 % | SiC % | Al2O3 % | Total particulate SiC&Al2O3 reinforcement % |
|-----------------------------------------------|------------------------|-------|---------|-------------------------------------------|
| Pure aluminium alloy 1350                     | 100                    | 0     | 0       | 0                                         |
| Al.alloy 1350 with 3 % SiC & 2% Al2O3          | 95                     | 3     | 2       | 5                                         |
| Al.alloy 1350 with 6 % SiC & 4% Al2O3          | 90                     | 6     | 4       | 10                                        |
| Al.alloy 1350 with 9 % SiC & 8% Al2O3          | 85                     | 9     | 6       | 15                                        |
| Al.alloy 1350 with 12 % SiC & 8% Al2O3         | 80                     | 12    | 8       | 20                                        |
| Al.alloy 1350 with 15 % SiC & 10% Al2O3        | 75                     | 15    | 10      | 25                                        |

Figure 2. Tensile Test Specimens

Figure 3. Compression Test Specimens

Figure 4. Hardness Test Specimens

Figure 5. Impact Test Specimens
6. Experimental Results

6.1 Tensile Test results
Experimentally obtained tensile test for different particulate reinforcement percentage in AMMC is carried out and results are shown in table 2.

| Particulate reinforcement (SiC + Al₂O₃) | Ultimate tensile strength N/mm² (MPa) | Percentage Elongation | Total percentage Particulate reinforcement (SiC + Al₂O₃) (3:2) |
|---------------------------------------|-------------------------------------|-----------------------|-------------------------------------------------------------|
| Pure Al. alloy 1350                   | 83.10                               | 16.37                 | 0                                                           |
| Al. alloy 1350 + 3 % SiC + 2% Al₂O₃  | 94.74                               | 27.1                  | 5                                                           |
| Al. alloy 1350 + 6 % SiC + 4% Al₂O₃  | 83.15                               | 11.87                 | 10                                                          |
| Al. alloy 1350 + 9 % SiC + 6% Al₂O₃  | 61.01                               | 14.8                  | 15                                                          |
| Al. alloy 1350 + 12% SiC + 8% Al₂O₃ | 43.005                              | 3.83                  | 20                                                          |
| Al. alloy 1350 + 15% SiC + 10% Al₂O₃| 49.091                              | 5.78                  | 25                                                          |

The comparative results of UTS (MPa) for different percentage of particulate reinforcement is as shown in figure 7.
6.2 Compression Test results

Experimentally obtained compression test for different particulate reinforcement percentage in AMMC is carried out and results are shown in table 3.

| Al. alloy 1350 | Load (KN) | Compressive Strength (N/mm²) |
|----------------|-----------|-----------------------------|
| Pure Al. alloy 1350 | 30.93 | 393.81 |
| Al. alloy 1350 + 3% SiC + 2% Al₂O₃ | 29.18 | 371.53 |
| Al. alloy 1350 + 6% SiC + 4% Al₂O₃ | 29.18 | 371.53 |
| Al. alloy 1350 + 9% SiC + 6% Al₂O₃ | 30.64 | 390.12 |
| Al. alloy 1350 + 12% SiC + 8% Al₂O₃ | 30.32 | 386.04 |
| Al. alloy 1350 + 15% SiC + 10% Al₂O₃ | 30.33 | 386.17 |

The comparative results of compression test for different percentage of particulate reinforcement is as shown in figure 8.

![Figure 8. Comparison of Compression Strength](image)

6.3 Impact Test results

Charpy impact test is a standardized high strain rate test which determines the amount of energy absorbed by the material during fracture. Experimentally obtained impact test for different particulate reinforcement percentage in AMMC is carried out and results are shown in table 4.
The comparative results of impact test for different percentage of particulate reinforcement is as shown in figure 9.

![Comparison of Impact Strength](image)

### Table 4. Impact Test Results for Different Composition

| Al. alloy 1350               | Absorbed energy in Joules |
|-----------------------------|----------------------------|
| Pure (Al. alloy 1350)       | 40                         |
| Al. alloy 1350 + 3% SiC + 2% Al2O3 | 56                         |
| Al. alloy 1350 + 6% SiC + 4% Al2O3 | 38                         |
| Al. alloy 1350 + 9% SiC + 6% Al2O3 | 70                         |
| Al. alloy 1350 + 12% SiC + 8% Al2O3 | 46                         |
| Al. alloy 1350 + 15% SiC + 10% Al2O3 | 70                         |

6.4. Hardness Test Results

Experimentally obtained Hardness test for different particulate reinforcement percentage in AMMC is carried out and results are shown in table 5.

### Table 5. Hardness Test Results for Different Composition

| Al. Alloy 1350               | Rockwell Number (HRB) | Hardness | Mean Hardness |
|-----------------------------|------------------------|----------|---------------|
|                             | 1          | 2          | 3          |               |
| Al. alloy 1350              | 37.1       | 37.1       | 36.8       | 37            |
| Al. alloy 1350 + 3% SiC + 2% Al2O3 | 37.4       | 37.4       | 37.1       | 37.3          |
| Al. alloy 1350 + 6% SiC + 4% Al2O3 | 37.4       | 37.4       | 37.1       | 37.3          |
| Al. alloy 1350 + 9% SiC + 6% Al2O3 | 37.7       | 37.7       | 37.4       | 37.6          |
| Al. alloy 1350 + 12% SiC + 8% Al2O3 | 37.1       | 37.1       | 36.8       | 37            |
| Al. alloy 1350 + 15% SiC + 10% Al2O3 | 37.4       | 37.4       | 37.1       | 37.3          |
The comparative results of hardness test for different percentage of particulate reinforcement is as shown in figure 10.

![Comparison of Hardness Strength](image)

**Figure 10.** Comparison of Hardness Strength

### 6.5 SEM Analysis

SEM analysis is carried out for different particulate reinforcement percentage as Al. alloy 1350, Al. alloy 1350 + 3% SiC + 2% Al₂O₃, Al. alloy 1350 + 6% SiC + 4% Al₂O₃, Al. alloy 1350 + 9% SiC + 6% Al₂O₃, Al. alloy 1350 + 12% SiC + 8% Al₂O₃, and Al. alloy 1350 + 15% SiC + 10% Al₂O₃, and results are the obtained images are shown in figure 11, 12, 13, 14, 15, 16 and 17.

![Image](image)

**Figure 11.** Pure Al. alloy 1350

**Figure 12.** Al. alloy 1350 + 3% SiC + 2% Al₂O₃
Conclusions

The mechanical characterization of aluminium metal matrix composites reinforced with varying weight fraction, particulate reinforcement of SiC & Al₂O₃ in the ratio 3:2 and total particulate reinforcement percentage of 5%, 10%, 15%, 20% & 25% reveals the following conclusions.

a) The casting of Al. alloy 1350 with SiC & Al₂O₃ reinforcement composites has better tensile strength, compressive strength, impact strength as well as hardness.

b) Dispersion of SiC & Al₂O₃ particles in AMMC improves the hardness of the matrix material.

Figure 13 Al. alloy 1350 + 6% SiC + 4% Al₂O₃

Figure 14 Al. alloy 1350 + 9% SiC + 6% Al₂O₃

Figure 15 Al. alloy 1350 + 12% SiC + 8% Al₂O₃

Figure 16 Al. alloy 1350 + 15% SiC + 10% Al₂O₃
c) Optical micrographs of AMMC through SEM shows uniform distribution of SiC & Al2O3 particles, fabricated through stir casting technique.

d) The ultimate tensile strength & yield strength of AMMC tends to increase with increase in particulate reinforcement of SiC & Al2O3 in the matrix.

e) The hardness of AMMC increases with the addition of SiC & Al2O3 particles in the matrix.

f) The impact strength of AMMC increases with the increase in weight fraction of SiC & Al2O3 particles.

g) It is found that AMMC with 9% SiC & 6% Al2O3 particulate reinforcement shows better mechanical characteristics as compared to other percentages of particulate reinforcement and can be used in manufacturing automotive engine parts, due to improved strength to weight ratio.

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