Experimental Analysis of Al-359 reinforced with B₄C and Al₂O₃ composite

G AshwinPrabhu¹, K Muninathan², R Raja Srinivasan ³, S Jayaganesan⁴ and M Adithiya Kumar⁵

¹²Faculty of Department of Mechanical Engineering, St. Joseph’s College of Engineering, Chennai -119
³⁴⁵Department of Mechanical Engineering, St. Joseph’s College of Engineering, Chennai -119

¹E-mail: ashwin.prabhu1990@gmail.com

Abstract: Now a days composite materials plays a vital role in various aspects of engineering such as in the development of light weight and high strength components. The composite material’s strength depends upon the type and the reinforcement. In composite analysis, the influence of B₄C particles on the mechanical behaviour and tribological behaviour of Al-359 with Al₂O₃ composites has been studied. The manufacturers of automobiles have been showing an interest and focusing on the wear resistance and other properties for improvement. There are various characteristics of aluminium such as high thermal conductivity, low wear rate, high specific heat capacity and low density when compared to conventional cast iron. Here composites with aluminium oxide (Al₂O₃) and boron carbide (B₄C) are used as reinforcement.

Keywords: Aluminium, light weight, strength, reinforcement, cost reduction, resistance

1. Introduction

Today most of the research has been done in the improvement of the material and its standard. Everyone in the society who has been doing their research has been analyzing using different compositions. A composite material plays a vital role in the field of engineering. A composite material is the combination of two or more materials which provides a different property such as its physical and chemical properties are different when combined. Depending upon the composition the characteristics differ accordingly. The classification of composite are done on the basis of the material matrix such as Metal Matrix Composites (MMC), Ceramic Matrix Composites (CMC) and Polymer Matrix Composites (PMC). The application of composite materials has seen a significant increase in the recent years. Improvements have been in the sector of manufacturing so as to achieve the best outcome and reduction in the cost of the product. Composite material is needed widely for the production of light materials and shock absorbent materials. The raw materials used in the work are: -

1. Al-359
2. Boron Carbide (B₄C)
3. Aluminium Oxide (Al₂O₃)
1.1 Al-359

Aluminium is the type of chemical element which is produced from bauxite. It has a wide range of applications because of low density and the ability of resistance to corrosion. The composition of Al-359 is aluminium (90.42%), silicon (9.04%) and magnesium (0.64%). The number “359” represents the grade of the aluminium. Among various cast aluminum alloys, Al-359 composition has comparatively high amounts of silicon in it. The characteristics of silicon are used for the improvement of casting fluidity and lower melting temperature. Silicon also has the effect of strengthening.

1.2 Boron Carbide (B₄C)

Boron carbide is one of the significant components utilized in the composites. Boron carbide has been used in various things such as in tank armor, bulletproof vests and in the various industrial applications. The Vickers hardness of boron carbide is greater than 30GPa. After cubic boron nitride and diamond, boron carbide is the hardest material known among other materials. The person named Henri Moissan synthesized boron carbide and the process involved in the synthesis is by the reduction of boron trioxide either with the carbon or magnesium in the presence of carbon in electric arc furnace. When carbon is present the reaction occurs above the melting point of B₄C where a large amount of carbon monoxide is liberated. The reaction of the process is 2B₂O₃ + 7 C → B₄C + 6 CO.

1.3 Aluminium Oxide (Al₂O₃)

Aluminium oxide is the chemical formulation of aluminium and oxygen. Al₂O₃ is one of the components used in the aluminium metal in the form of abrasive to improve the hardness of the material and is also used as a refractory material for high melting point. It is also amphoteric in nature. There are various applications of aluminium oxide such as in composite fibres, abrasives, glass etc.

2. Literature Survey

In composite materials, Metal matrix composites (MMC) is becoming a large leading material. Because of their highly excelling engineering properties particle reinforced aluminium MMCs have received considerable attention. Because of their hardness and abrasive nature of reinforcement elements like silicon carbide (SiC) particles these materials are difficult to machine. For experimental investigation of tool wear and surface roughness, homogenised 5% SiC-p aluminium MMC material is used in this study. [1].

By Vortex method, three 2024 Aluminium alloy metal matrix composites (MMCs) of varying sizes are reinforced and weight fractions till 30% of the weight of Al2O3 particles were fabricated. From the results, it was inferred that the hardness and the tensile strength of the composites increased with decrease in size and increase in weight fraction of particles [2].

Al2O3-ZrO2 with a high level of hardness and toughness is known as ceramic steel. Due to its unique properties it can be used as a reinforcement in fabrication of metal matrix composites. In this study, nanoparticles of Al2O3-10% ZrO2 with an average size of 80 nm were used to
fabricate Al matrix composites containing 0.5, 1, 1.5 and 2 wt.% of the reinforcement. The results revealed that with increasing the reinforcement content, density decreased while yield, ultimate tensile strength and compressive strength increased [3].

One of the most conventional types of metal matrix composites is aluminum matrix composite. This paper deals with the effect of production parameters on wear resistance of Al–Al2O3 composites. Alumina powder with a particle size of 12, 3 and 48 l and pure aluminum powder with particle size of 301 were used [4].

Al 6061 alloys are used broadly in many engineering applications in the fields of construction and transportation where mechanical properties like hardness and tensile strength are essential. The addition of TiB2 to the metal matrix increases the matrix phase strength [5].

3. Methodology

4. Composition of the Sample

| Table 1. Composition of Sample |
|-------------------------------|
| Sample 1 | Al-359 + 5% B4C |
| Sample 2 | Al-359 + 5% B4C + 2.5% Al2O3 |
| Sample 3 | Al-359 + 5% B4C + 5% Al2O3 |
5. Processing of the composites

In the experiment performed, Al-359 is used as the matrix phase. Using an electric furnace Al-359 is melted at a temperature of 1000°C in a graphite crucible of 2kg capacity. Initially boron carbide and aluminium oxide are preheated to 400°C in a crucible before mixing with molten Al-359. A mild steel stirrer coated with zirconium is used to avoid contamination of melt. The composite is formed due to the uniform distribution of B₄C and Al₂O₃, the reinforcement phase in the Al-359 alloy, the matrix phase by stirring at a speed of 300 to 400rpm. The formation of slag takes place during the chemical reaction taking place in the Al-359 alloy.

6. Tests performed on the specimen

There are various tests performed on the specimen. They are Compressive strength test, hardness test and corrosion test.

6.1 Compressive Strength Test

Compressive strength is the one where capacity of the materials can be analyzed so that how much load the component can withstand against the tensile strength which can be able to withstand loads which tends to elongate. Various things can be analyzed according to the composition and the compression strength differs according to the material used.

6.2 Hardness Test

Hardness test is the type of mechanical test for analyzing material properties. It is generally used in the engineering design, structure analysis and in the materials development. The main purpose of the test is for the determination of suitability of material for the particular application to be performed. The various types of hardness tests are: Macro Hardness test (>1kg) (Rockwell, Brinell and Vickers testing), Micro Hardness Test (<1kg).

6.3 Corrosion test

The test in which salt spray is the standardized method for the corrosion test method. This is used to check the corrosion resistance of materials. The appearance of the material corrosiveness is determined by after a period of time that is after a stipulated time for the material.

7. Results and Discussions

7.1 Compression Test

7.1.1 Sample 1

The composition of sample 1

Al-359 + 5% B₄C
The compression value is 151.96 kN

Figure 2. Sample 1

7.1.2 Sample 2

The composition of sample 2

Al-359 + 5% B₄C + 2.5% Al₂O₃

The compression value is 172.45 kN
7.1.3 Sample 3

Test Report

Test Details
Name of Organisation & Address: OMEGA LAB, Guindy
Material Name: Aluminum Sample
Serial No: C2
Batch No: 1% Al -359 + 5% B4C + 2.5% Al2O3

TOCR No: 19-7649

Test Method: ASTM D695

Input Data
Mode of Test: Compression
Sample Type: Flat
Thickness: 13.66 mm
Width: 50.45 mm
Area: 689.15 mm²
Gage Length: 50.00 mm
Final Gage Length: 0.000 mm
Final Gage Length: 0.000 mm

Results
Fmax: 172.45 KN

Figure 3. Sample 2

The composition of sample 3
Al-359 + 5% B4C + 5% Al2O3

The compression value is 223.6
Table 2. Compression Test of Al-359, Boron carbide (B$_4$C) and Aluminium Oxide (Al$_2$O$_3$)

| Sample Number | Sample Composition                         | Compression Load (KN) |
|---------------|-------------------------------------------|------------------------|
| 1             | Al-359 + 5% B$_4$C                        | 151.96                 |
| 2             | Al-359 + 5% B$_4$C + 2.5% Al$_2$O$_3$      | 172.45                 |
| 3             | Al-359 + 5% B$_4$C + 5% Al$_2$O$_3$        | 223.68                 |
Table 3. Hardness Test (using Vickers Hardness machine)

| Sample Number | Sample Composition                  | Hardness Value (HV) |
|---------------|-------------------------------------|---------------------|
| 1             | Al-359 + 5% B4C                     | 99,94,97            |
| 2             | Al-359 + 5% B4C + 2.5% Al2O3        | 103,103,104         |
| 3             | Al-359 + 5% B4C + 5% Al2O3          | 112,115,104         |

Figure 5. Hardness Test Comparison

8. Conclusion

After the thorough analysis of the specimens final observations and conclusions have been arrived upon various aspects.

1. In the compression test, when compared with the three-sample produced, the third sample is good when compared to other two samples and the compressive strength is best for the particular composition respectively, that is sample 3 is good.

2. In the hardness test conducted by using Vickers hardness method, the hardness is good compared to other two samples that is sample 3 is good than the others.

Therefore sample 3, having the composition Al-359 + 5% B4C + 5% Al2O3 is the best sample when compared to other two samples.

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