

# Analysis and Investigation on A2024 Metal Matrix Composites with B4C and Graphite

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**ABSTRACT:** The aim involved in designing aluminium based metal matrix composite by combining different percentage of particulates in the combination. Current study is concentrated on the fabrication of 2024 aluminium based metal matrix composites reinforced with boron carbide, graphite by stir casting technique to determine Hardness, Tensile strength and microstructure of the metal matrix was performed on the samples obtained by stir casting technique. These types of alloys are widely used in the following industries like automobile, Ship-yard and aerospace applications due to their great mechanical behaviors, low density, low factor of thermal expansion, corrosion resistance is better and increased wear rate as compared with conventional metals and alloys. The production cost will be reduced and an improved mechanical property of composites makes them very useful for various applications in many areas from technological point of view.

**KEYWORDS:** Metal Matrix Composite, Aluminium, B4C, Graphite, Stir casting.

## 1. INTRODUCTION

A composite may be defined as any multiphase materials that exhibit significant proportions of properties of both the constituents' materials. Judicious combination of two or more distinct materials can provide better combination of properties. Scientist and Engineers have ingeniously designed various composite materials by the combination of metals, ceramics and polymers to produce new generation of extra-ordinary materials having combination of superior mechanical characteristics such as toughness, stiffness and high temperature strength. A composite, in the present context, is an artificially prepared multi-phase material in which the chemically dissimilar phases of separated by the distinct interphase carbide and graphite in the form of particles.

Our modern technologies many a times, demand materials with unusual and extra-ordinary combination of properties that can't be provided by the conventional metal alloys, ceramics, and polymeric materials. This is particularly to for materials required for aerospace, underwater and transportation applications. For instances, aircraft engineers are in search of structural materials having low density, stiffness, high strength, abrasion-resistance, impact resistance and corrosion resistance. Such a combinations of properties are rather difficult to achieve in conventional materials because usually associated with high density materials and also increasing strength and stiffness usually results in decreasing impact strength. They ever increasing demand for special materials having unusual combination of properties for use in our modern technologies are responsible for the development of composite materials.

### 1.1 Role of Metal Matrix

The choice of a matrix alloy for an MMC is dictated by several considerations. Of particular importance is whether the composite is to be continuously or discontinuously reinforced. The use of continuous fibers as reinforcements may result in transfer of most of the load to the reinforcing filaments and hence composite strength will be governed primarily by the fiber strength. The primary roles of the matrix alloy then are to provide efficient transfer of load to the fibers and to blunt cracks in the event that fiber failure occurs and so the matrix alloy for a continuously reinforced MMC may be chosen more for toughness than for strength.

On this basis, lower strength, more ductile, and tougher matrix alloys may be utilized in continuously reinforced MMCs. For discontinuously reinforced MMCs, the matrix may govern composite strength. Then, the choice of matrix will be influenced by consideration of the required composite strength and higher strength matrix alloys may be

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required. Additional considerations in the choice of the matrix include potential reinforcement/matrix reactions, either during processing or in service that might result in degraded composite performance; thermal stresses due to thermal expansion mismatch between the reinforcements and the matrix.

In MMCs intended for use at elevated temperatures, an additional consideration is the difference in melting temperatures between the matrix and the reinforcements. A large melting temperature difference may result in matrix creep while the reinforcements remain elastic, even at temperatures approaching the matrix melting point. However, creep in both the matrix and reinforcement must be considered when there is a small melting point difference in the composite.

## II. MATERIAL PROPERTIES

### 2.1 Aluminium 2024 Alloy

The aluminium 2024 is heavily utilized in aircraft applications because it has good machining characteristics and higher strength than either 2014 or 2017. Though cold formability is considered fair, it is one of the most popular alloys for cold heading and thread rolling applications as a result of the superior grain structure that can be obtained. Corrosion resistance and anodizeability are only fair. Again; this is because of its high strength and good machinability, which are essential for precision fittings and parts.

### 2.3 Aluminium 2024 Properties

The important Properties of Aluminium 2024 alloys are tabulated below:

Table: 1 - Properties of Aluminium 2024 Alloy

Density ( $\rho$ )	2.77 g/cm <sup>3</sup>
Young Modulus (E)	73 GPa
Shear Strength (Mpa)	285 MPa
Strength Weight Ratio (KN-m/Kg)	177 KN-m/Kg
Ultimate Tensile Strength (MPa)	490 MPa
Yield Tensile Strength (MPa)	350 MPa
Thermal Conductivity (K)	120 W/m-K
Hardness ( Brinell)	120

### 2.4 Alloy Composition

The Various Composition of aluminium is tabulated below in percentage:

Table : 2 – 2024 Aluminium Alloy Composition

Aluminum	90.8 to 94.7 %
Magnesium	3.8 to 4.9 %
Manganese	1.2 to 1.8 %
Iron	0.3 to 0.9 %
Silicon	0 to 0.5 %
Zinc	0 to 0.25 %
Zirconium	0 to 0.2 %
Titanium	0 to 0.15 %
Chromium	0 to 0.1 %

### 2.5 Boron Carbide

Boron Carbide is one of the hardest materials known, ranking third behind diamond and cubic boron nitride. It is the hardest material produced in tonnage quantities. Hot-pressed boron carbide is one of the hardest materials available in commercial shapes, and gives outstanding resistance to abrasive wear.

### 2.6 Structure

Boron Carbide is produced by following methods:

- Boron carbide is produced from boric acid or B<sub>2</sub>O<sub>3</sub> and carbon containing materials in electric arc furnaces.
- Another method is to produce submicron boron carbide powders.

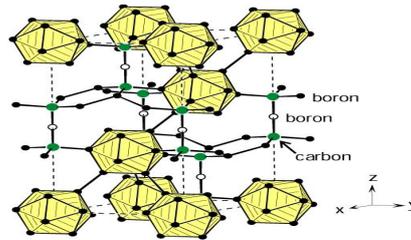


Fig 1 – Structure of Boron Carbide

The Properties of Boron Carbide at 250C are tabulated below:

Table 3 – Properties of Boron Carbide

Density ( $\rho$ )	2.52 g.cm <sup>-2</sup>
Melting Point	2445 °C
Hardness	2900-3580 kg.mm <sup>-2</sup>
Fracture Toughness	2.9-3.7 MPa.m <sup>-1/2</sup>
Young modulus (E)	450-470 GPa
Electrical Conductivity	140 S
Thermal Conductivity (K)	30-42 W/mK
Thermal Expansion	5 °C

### 2.7 Graphite

Graphite is an excellent conductor of heat and electricity and has the highest natural strength and stiffness of any material. It maintains its strength and stability to temperatures in excess of 3,600°C and is very resistant to chemical attack. At the same time it is one of the lightest of all reinforcing agents and has high natural lubricity.

### 2.8 Structure of Graphite

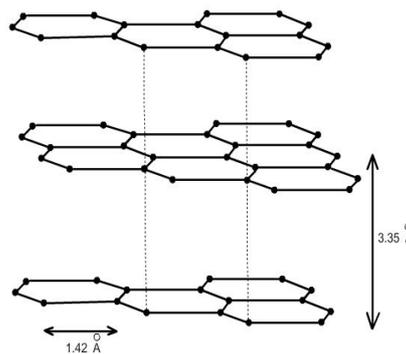


Fig:-2 Structure of Graphite

## 2. Fabrication of Samples

### Step 1

Pre heat and melting the Aluminium 2024 alloy upto its melting point 6600C in the crucible furnace. Coal is used as a fuel for heating up the furnace.

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Fig: 3 - Melting of Aluminium in Crucible

## Step 2

Reinforcements such as Graphite and Boron Carbide were preheated at a specified temperature 30 min in order to remove moisture or any other gases present within reinforcement. The preheating of also promotes the wettability of reinforcement with matrix. Reinforcements are added as 5% and 10% composition with Aluminium 2024. The Preheating of Reinforcements in furnace is shown below



Fig: 4- Preheating of Reinforcements

## Step 3

Pre heated materials are added and mixed up with the molten Aluminium manually and heating up for proper distribution with the Aluminium Matrix. The melting of the aluminium and boron carbide powder is carried out in the crucible into the coal-fired furnace Pouring of preheated reinforcements at the semisolid stage of the matrix enhance the wettability of the reinforcement, reduces the particle settling at the bottom of the crucible. Reinforcements are poured manually with the help of conical hopper.

## Step 4

Stirring up the molten aluminium with reinforcements at a constant rate which enhances the uniform distribution throughout the matrix phase which is necessary to adjoining the reinforcements with matrix material.

## Step 5

While pouring the slurry in the Mould the flow of the slurry is kept uniform to avoid trapping of gas. Then it is quick quenched with the help of air to reduce the settling time of the particles in the matrix. After stirring molten slurry is poured into the desired Mould with preferred dimensions which would be facilitated for conduct various tests on it.

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Fig: 5-Pouring of molten metal into the Mould



Fig: 6- Casted Products

### III. RESULTS AND DISCUSSIONS

In this work Aluminium based metal matrix composite were produced in the laboratory by using stir casting method. Aluminium 2024 was selected as matrix material Reinforcement materials were Graphite and Boron Carbide. The specimen pieces were casted for 5% and 10% following tests were conducted,

- Tensile Test
- Hardness Test
- Microstructure Test

**a. Hardness Test**

For the pieces we done the following hardness follows,

Ball Intender Size: 1/16” ball

Load: 100 N

Scale: F Scale

Table 4 – Rockwell Hardness Test

1. Test : Rockwell Hardness Testing  
 Test method : ASTM A370-12a, HRF  
 Ambient temperature : 25°C

Trial No	5% of Boron carbide	Average	10% of Boron carbide	Average
1	74	74	67	68
2	71		66	
3	71		69	
4	78		67	
5	76		70	

**b. Tensile Test**

2. Test : Tensile Testing  
 Test method : ASTM A370-12a

Test Result:

Description	Result	
Identification	5%of Boron carbide	10%of Boron carbide
Diameter	15.17mm	15.24mm
Area	183.2mm <sup>2</sup>	182.4mm <sup>2</sup>
Maximum Force	16230N	21090N
Tensile strength	88.5 N/mm <sup>2</sup>	115.5 N/mm <sup>2</sup>
Elongation	1.1%	0.30%

**c. Microstructure Test**

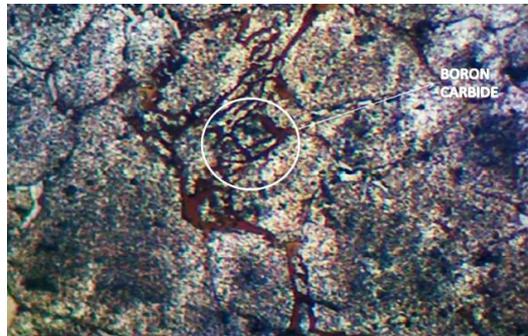


Fig: 6- Microscopic image of Al-B4C-Graphite (100 x)

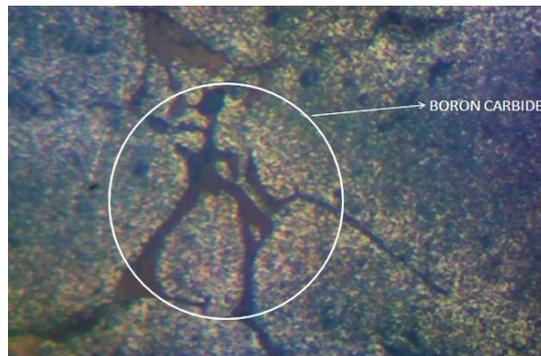


Fig: 6 - Microscopic image of Al-B4C-Graphite (200 x)



Fig: 7 - Microscopic image of Al-B4C-Graphite (400 x)

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## IV. CONCLUSION

In this work the experiment and analysis on the fabricated composite material has been done successfully. The results of the composite material which is fabricated by using stir casting technique to determine Hardness, Tensile strength and microstructure of the metal matrix was performed on the samples obtained by stir casting technique and also the SEM analysis test has been taken to find out the microstructure of the reinforcement particles like boron carbide and silicon carbide. This will increase the strength of the aluminium 2024. It is observed that the investigational results meet the confidence limits.

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