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FABRICATION AND CHARACTERISATION OF 6061ALUMINIUM ALLOY WITH BORON CARBIDE PARTICULATE

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***Abstract*—The present study deals with the optimization of process parameters of aluminium alloy (Al6061) – boron carbide (B_4C) composites fabricated by stir casting. Nowadays, aluminium alloy is used as structural material in several applications due to its high formability, high strength to weight ratio. But it has low tensile strength, impact strength, hardness and corrosion resistance. So to increase the above mentioned properties, boron carbide is added to the aluminium alloy. The sample specimens of four were made by varying the percentage of reinforcements with respect to aluminium alloy alone with various stirring time. The evaluation of mechanical properties indicates the variations in tensile strength, hardness and impact energy for different composite combinations. The tensile strength and hardness was found to increase with the increase in the particle size and also with the increase in weight % of the reinforcement**

Keywords— ***Aluminium, boron carbide, stir casting, metal matrix composite, stirring time.***

I. INTRODUCTION

In the last three decades manufacturing of engineering materials which are light and durable yet strong has been one of the most interesting topics in both academic and industry. There has been a abundant interest in aluminium reinforced ceramic composites due to their low density and excellent wear resistance. Since in early 1960, there is a demand for new and improved engineering materials with progression of modern technology interest in the areas of aerospace, automotive industries had forced a rapid development of metal matrix composites [1].

The aluminium matrix is getting strengthened when it is mixed with the hard ceramic particles like B_4C. Aluminium alloys have low density which gives additional advantages in several applications. These alloys have started to swap cast iron and bronze to manufacture wear resistance parts.

MMCs reinforced with particles incline to offer enhancement of properties processed by conventional methods. Al6061 is widely used in numerous engineering applications including transport and construction where superior mechanical properties such as tensile strength, hardness etc., are essentially required [2]. Al 6061 is quite a popular choice as a matrix material to prepare MMCs owing to its improved formability characteristics. Among different kinds of the recently developed composites, particle reinforced metal matrix composites and in particular aluminium base materials have already appeared as candidates for industrial applications. Boron Carbide particulate reinforced aluminium composites possess a exclusive mixture of high specific strength, high elastic modulus, good wear resistance and good thermal stability than the corresponding non-reinforced matrix alloy system.

In this experimental study two major parameters are considered. First is weight composition and other is stirring time. Tensile strength and hardness of the composite increased with increasing of particle size and also with the weight % of the B_4C. Hardness is greatly influenced by the stirring time.

II. METHODOLOGY

This experimental study begins with the selection of matrix and reinforcement material. This is followed by design of experiments. Design of experiments is done using design experts. After parameters are selected fabrication process is done. Materials are fabricated by stir casting method. After fabricating, materials are undertaken with different mechanical testing to determine its physical properties. Finally the results are tabulated and comparative study is made.

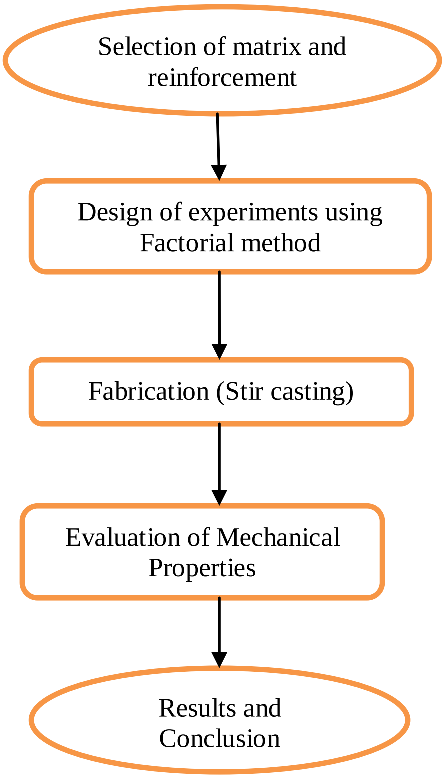

Figure 1 Flow chart representation of process

III. EXPERIMENTATION

1. Selection of materials

1) matrix

The matrix material which is used in this study was aluminium of grade 6061 which contains iron, silicon and chromium as its major alloying elements as indicated in Table 1. It has good mechanical properties and exhibits good weldability, good formability and high corrosion resistance [3].

Table 1 Composition of Al 6061

Constituents	**Percentage**
Manganese(Mn)	0.108%
Iron (Fe)	0.125%
Copper (Cu)	0.392%
Magnesium(Mg)	0.970%
Silicon (Si)	0.620%
Chromium (Cr)	0.079%
Others (Total)	0.04%
Aluminium (Al)	97.7%

Figure 2 Aluminium6061

2) Reinforcement

The material selected to be reinforced into the metallic matrix was Boron Carbide having particle size of 105 µm. Boron carbide is an industrial ceramic which is the third hardest material next to diamond and cubic boron nitride [4]. It is reinforced in the Al6061 matrix to increase strength, hardness, stiffness, wear resistance and impact strength. Its attractive properties like

- Extreme hardness
- Good chemical resistance
- Low density
- Good nuclear properties

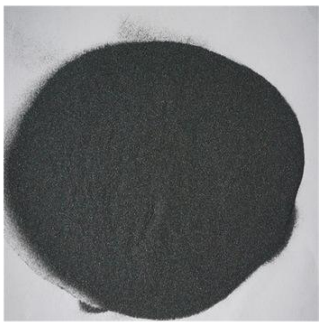

Figure 3 Boron carbide of size 105 µm.

2. Design of experiments

Based on the research gap obtained from various literature review design of experiments is done. It is done by using Design Experts 10.0 version.

3. Fabrication Process

Following parameters were considered for fabrication of aluminium boron carbide. Mainly two different operating parameters with two different level were selected.

Table 2 Operating parameters and levels

Operating Parameters	Level 1	Level 2
Stirring time (sec)	20	40
Weight %	5	10

Aluminium based composites are usually produced by stir casting which is one of the popular method. Fabrication process begins with preheating of the furnace. When the furnace reached the required temperature, crucible was placed inside the furnace, on reaching the heat hot condition Al6061 was placed inside the crucible. The aluminium billets were charged into the furnace and heated to a temperature of 750 ± 30°C (i.e) above the liquidus temperature of the alloy to ensure that the alloy melts completely. Now boron carbide was added between 5-15% of aluminium matrix. With the help of electrical stirrer, the molten matrix along with reinforcement is stirred at a constant speed of 450 rpm to create vortex. As mentioned 2 different stirring time is maintained. Then the molten matrix and reinforced particles are poured into the preheated mould with the temperature around 700ºC. After solidification, the composite was cut according to the requirement.

Table 3 Compositions of Composite Specimens

Sl.no	Aluminium (g)	Boron carbide (g)	Time (s)
1	285	15	20
2	270	30	20
3	285	15	40
4	270	30	40

This table describes the complete proportions of aluminium with which the particles of boron carbide of size 105 µm are added.

Figure 4 Fabricated materials

The above figure describes the fabricated material of aluminium boron carbide with stir casting process.

IV. TESTS CONDUCTED

The specimens fabricated by Stir casting is cut and machined into test samples of required shape and dimensions for the conduction of various tests.

1. Tensile Test

Tension means pulling force. The tensile test is done in a Universal Testing Machine as shown in fig. 5. to determine the tensile strength of the specimen.

Figure 5 Universal Testing Machine

The specimen to be tested is fastened to the two end-jaws of the UTM and the load is applied gradually on the specimen by means of pulling the movable crosshead, till the specimen fractures. Results are tabulates and using the given formula ultimate tensile strength is calculated.

$$\textbf{Ultimate Tensile strength} = \frac{\textbf{Maximum load}}{\textbf{Area of cross section}}$$

Table 4 Tensile Strength of specimens

Specimen	**σ_U (MPa)**
I	78.97
II	65.54
III	75.65
IV	64.83

From the calculated results of tensile test following graph is been plotted which indicates the effects of operational parameters in the fabricated material.

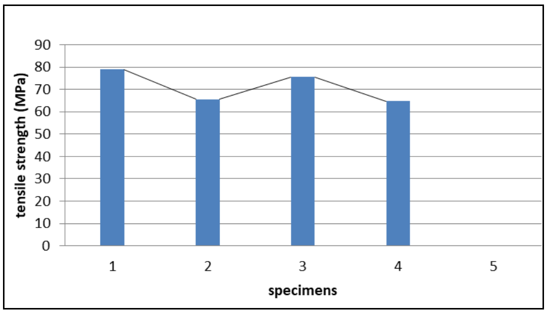

Figure 6 Results of Tensile test

It is inferred that when ceramics were added to a matrix its strength gets reduced. Specimen 2 and 3 has more amounts of ceramics compared with other two specimens. Similarly, even though stirring time increases it has little influence on the materials.

2. Brinell Hardness Test

Hardness is the ability of the material to resist wear, scratching, abrasion and indentation. Brinell hardness test is done in the hardness testing machine to determine its hardness value.

Figure 7 Brinell hardness testing

In the brinell test, a steel indenter, having diameter of 10 mm is forced in the surface of the composite. Standard load of 500 kgf is supplied and maintained constant for 10 seconds and then removed. Brinell hardness number is calculated from the impression of the indentation.

$$\textbf{Brinell Hardness number} = \frac{2P}{\pi D\,[D - \sqrt{(D^2 - d^2)}]}$$

where,

P = load applied on indenter (500 kgf)

D = diameter of steel ball indenter (10 mm)

d = diameter of ball impression in mm

Table 5 Brinell hardness number of each specimen

Specimen	**Hardness Value (BHN)**
I	41
II	44
III	42
IV	45

From the obtained BHN following graph is been plotted which indicates the effects of operational parameters in the fabricated material.

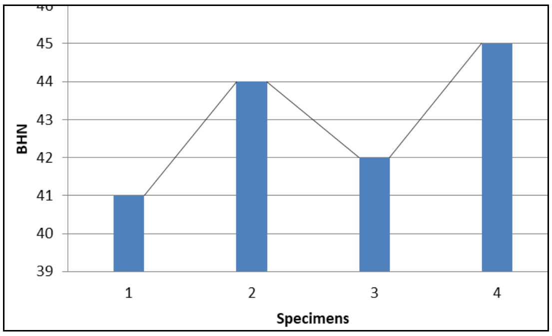

Figure 8 Results of BHN

From the above test it was inferred that on adding boron carbide to the matrix aluminum its hardness gets increased and stirring time also has significant influence.Therefore specimen 2 and 4 has greater hardness than specimen 1and 3.

3. Charpy Impact Test

Impact strength is the capacity of a material to withstand blows without fracture

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Figure 9 Charpy impact testing machine

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In Charpy test of impact strength, the test sample is fixed horizontally to the machine base just as a simply supported beam and the striking hammer is blown to hit the specimen behind the v-notch.

Table 6 Charpy impact strength of each specimen

Specimen	Charpy Impact Test (N/m)
I	6
II	8
III	7
IV	9

From the above obtained reading from charpy impact test following graph has been plotted which indicates the influence of operational parameters in the fabricated material in which specimens or samples on x axis and impact strength (N/m) on y axis.

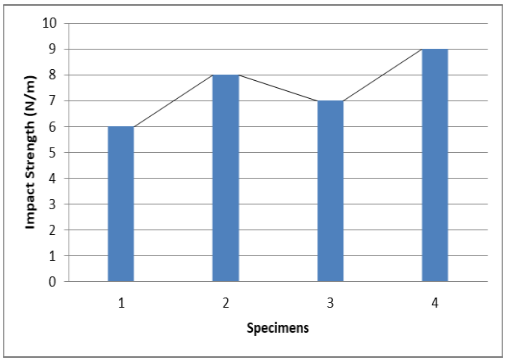

Figure 10 Results of Charpy impact test

From the above test it was inferred that on adding boron carbide to the matrix aluminium and improved stirring time makes impact strength gets increased. Therefore specimen 2 and 4 has greater impact strength than specimen 1and 3.

4. Double Axial Shear Test

Double axial shear test is similar to tensile test but instead of expansion process, compression is done on the workpiece.

Initially the piece is machined and reduced to 55mm long with16mm diameter. Then it is placed in the machine and its corresponding compression activity happens.

Table 7 Double axial shear of each specimen

Specimen	Double axial shear (N/mm^2)
I	107.25
II	79.1
III	86.70
IV	54.71

From the obtained results of double axial shear test following graph is been plotted which indicates the effects of operational parameters in the fabricated material which specimens or samples on x axis and double axial shear (N/mm^2) on y axis.

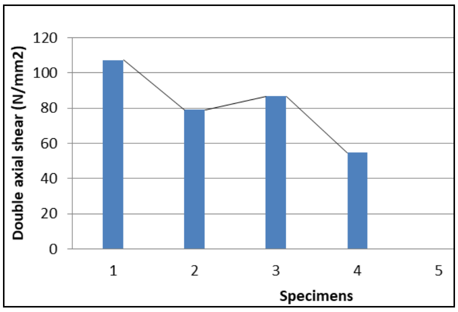

Figure 11 Results of Double axial shear test

It is inferred that when ceramics were added to a matrix its strength gets reduced. Specimen 2 and 3 has more amounts of ceramics compared with other two specimens. Similarly, even though stirring time increases it has little influence on the materials.

V. RESULTS AND CONCLUSION

From the above mechanical properties test it can be said that weight % of boron carbide play an important role compared with stirring time. On increasing the weight % of reinforcement gradual variations can be seen. Thus from the above tests and results, it was concluded that

- Addition of 5% weight of boron carbide will increase the tensile strength compared to 10% weight composition.
- Particle size has greater influence in improvement of tensile strength
- Addition of reinforcement will increase the hardness of the MMC
- Impact strength is greatly influenced by increase in boron carbide particle.

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