International Journal of Engineering Applied Sciences and Teclogy, 2021
Vol. 6, Issue 7, ISSN No. 2455-2143, Pages 322-332
Published Online November 2021 in IJEAST (http://www.ijeast.com)

IMPACT OF VARIATION IN SIZES OF BORON CARBIDE ON PROPERTIES OF NOVEL COMPOSITE OF ALUMINIUM ALLOY 6063-T6 AND BORON CARBIDE

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***Abstract*-Composites are continuously evolving as the most demanding materials among various industries because of their reinforced mechanical properties and lesser weight. The present work aimed to fabricate a novel aluminium matrix composite using Aluminium Alloy 6063 T6 as base metal and ceramic boron carbide particles with three different micro sizes viz.104µm, 74µm, and 53µm as reinforcement. For composite fabrication, stir casting technique has been utilized. Micro-structure and mechanical behavior of base alloy and prepared composites has been analyzed in this work. Observing through optical microscopy reveal a uniform and proper distribution of B_4C particle in Al matrix, along with cluster formation at few sites. The results also exhibit that hardness of reinforced composite has been found to be more than that of base alloy by 81.35 %, in which composite with particle size 53µm has shown maximum hardness of 75.77HV. The trend in tensile strength indicates that the ultimate tensile strength of composite with boron carbide of mesh size 53µm is more than the base alloy by 20.79% and is also highest among the rest of composites with a value of 219.196MPa.**

***Keywords*-Aluminium alloy 6063 T6, Boron Carbide (B_4C), Aluminium Metal Composite (AMC), Micro-structure, Micro-Hardness, Ultimate Tensile Strength**

I. INTRODUCTION

In current scenario, composites are emerging as materials replacing the monolithic materials and occupying the place of most demanding materials in various industrial sectors listing from automation & aerospace to electronics and healthcare [1]. Encompassing the properties like high specific strength, good stiffness, low thermal expansion, excellent corrosion and wear resistance along with lighter weight helps it to satisfy the global need at various level [2]. Among various composites, metal matrix composites are ones attracting the eyeballs of researchers most. Basically, metal matrix composites are made from two components- one is matrix which is continuous in nature and perform functions such as it helps to hold the reinforcement fibers together and protects it from environment and abrasion. The other component is reinforcement which is discontinuous in nature, stronger, harder and helps in bearing the load that is applied over the composite and transfers the required strength to the matrix [3]. Metal matrix composites can be basically categorized based on the type of reinforcement induced like particulate, laminar or fibre & on type of matrix like metal, ceramic etc. Centering on particulate metal matrix composites, here the reinforcement is dispersed over the entire volume of base matrix in the form of particles. Being isotropic in nature, the strength-to-weight ratios of the metal matrix composite is generally higher than most of the base alloys.

This investigation aims to prepare composites having aluminium alloy of grade 6063 T6 as base matrix since aluminium is one of the lightest metals with properties like good corrosion resistance, high reflectivity and strength that can some time smatch up with construction steel. Boron carbide (B_4C) is used as reinforcement which is extremely hard ceramic and covalent in nature, find its utilization in tank defensive layer, impenetrable vests, motor damage powders and in various other mechanical applications[2]. It is accepted as one of the hardest materials in present times, behind cubic boron nitride and precious stone diamond. Though various techniques are available to manufacture the composites, stir casting is chosen as its highly economical method requiring only one-third of cost to prepare composites as compared to other methods available[4].In recent times, double stircasting or two- step mixing process is gaining more popularity. This process involves melting base metal above its liquidus temperature and then dropping the temperature to a value lying in between liquidus and solidus so that when cools, it forms a semi-solidstate. Assoonasmelt reaches at semi solid state, preheated reinforcement particles are added to it. After that, composite slurry is again heated to higher temperature to gain the liquid state. This process is able to break the layer of gases which form around the surface of the particles hindering the wettability of the reinforcement particle with molten metal matrix. Majorly, there are three factors which influence the output of the stir casting process-speed of mixing/stirring, time length of mixing/stirring and mixing temperature [3]. Stirring can enhance the uniformity and homogeneity in the microstructure of composite achieved.

The primary contributions of this research are as follows-(1) Manufacturing of composite has been done through convention alstircasting technique(2)Novelty of the research lies in the combination of base matrix and reinforcement chosen i.e. aluminium alloy of series 6063 T6 and reinforcement boron carbide ,as till now properties of a composite with this particular combination hasn't been explored or touched upon.3)For the first time, these three mesh sizes(MS) of boron carbide particle -150,200 and 270 are imparted with same weight of 6% (4) Micro structural observations, tensile strength and micro hardness measurements have been carried out on the surface of the composite samples and base alloy.

II. EXPERIMENTAL METHODS ANDMATERIALS

Materials

Aluminium alloy 6063 T6 is put to use as a base metal matrix which comprises of magnesium and silicon as main alloying elements. Here T6 stands for solution that is heat-treated and artificially aged. This alloy of aluminium portrays properties like good surface completion, high corrosion resistance, and can go easy with welding operation. Reinforcement of aluminium has been done by imparting boron carbide powder, ceramic by nature and one of the hardest elements known. In this experiment, three novel and different sizes of B_4C has been incorporated- viz.104μm, 74μm, 53μm with a weight of6%.

Table 1 Chemical distribution of Al alloy 6063

Elements	**Percentage**
%Mg	0.45-.090
%Si	0.20-0.60
%Fe	0.0-0.35
%Cu	0.0-0.10
%Mn	0.0-0.10
%Cr	0.0-0.10
%Zn	0.0-0.10
%Ti	0.0-0.10
%Others	0.0-0.15
%Al	Balance

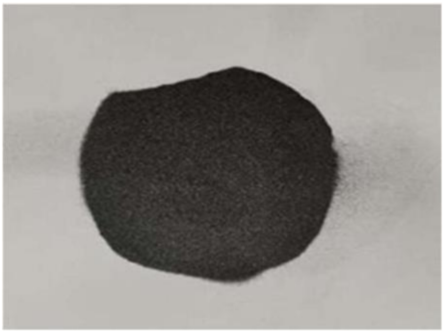

Figure 1 Boron Carbide Powder

Table 2 Particle size of B4C powder used in the experiment

Mesh size	Microns(µm)
150	104
200	74
270	53

Though many techniques are available in the market to prepare the composite like stir casting, infiltration, squeeze casting but stir casting is one that dominates among all as it is economical, facilitates the fabrication of large size product and can handle huge volumes of production [4].

Fabrication process

Aluminium6063–T6alloyisusedasthebasematrixand boron carbide (B_4C) of mesh size 150 (104µm), 200 (74µm) and 270 (53µm) at 6 % wt. are used as reinforcement in the manufacturing.

For the fabrication purpose, stir casting method is employed which involves various steps from melting of metal alloy to the preparation of final composites. Elaborating these steps as follows [5,6]-

Step1-A cylindrical graphite crucible of required dimension and having a maximum working temperature of 2700℃ is kept inside a 220V, three phase electrical resistance furnace (maximum operating temperature 1500℃) for base alloy melting and to prepare the slurry. It is equipped with thermocouple (K type) having a maximum range of 1200℃ and speed regulated motorized stirring system.

Step 2- Using muffle furnace, the boron carbide powder is heated to 350°C for 45 min before being mixed with the molten alloy. In order to oxidize particles surface, to eliminate moisture and improving the wettability in matrix content, preheating of ceramic particle is done.

Step 3-In order to achieve proper mixing of ceramic particles, vortex is being developed on the surface of the molten alloy using a stirrer running at a speed of 400 rpm. After this, boron carbide particulates are added slowly into the vortex of molten alloy using funnel and rod. Speed of the stirrer is increased slowly and continuously for up to 10 minutes. The stirrer bladesare positioned from the surface atadepthofone third of the molten slurry, to enable propermixing.

Step4-Aftermixingthereinforcementforabout15min with the help of stirrer, stirrer is taken out and composite slurry is allowed to cool down and solidify. After this, casted composite is removed out of the graphite crucible.

Step 5-Proper turning and finishing is done over the composite's outer surface through conventional lathe machine using carbide tip cutting tool. After finishing, required specimen are being cut along the transverse section using wire electro discharge machine which is a thermal non-contact machining technique.

Step 6-Two specimens are being cut from each prepared AMC's, one for tensile test and other common for microstructure and micro hardness.

Step 7-Hardness test is performed on Vickers micro hardness machine with model name FISCHERSCOPE HM2000 S having test load range-0.1-2000 mN, F=300,000 mN/20sec and Creep-5.0 sec.

Step 8-To analyze the microstructure, specimens are cut and prepared as the per standard metallographic procedure performed in sequential order-Sectioning, Mounting, Sample surface. polishing, Grinding, Course polishing, Etching.

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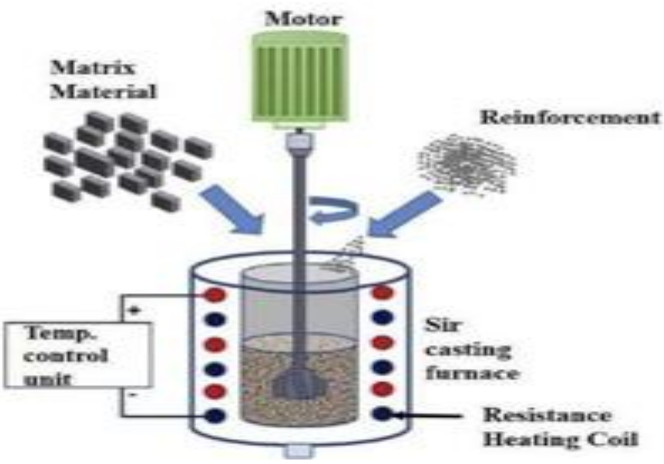


Figure 2 Stir Casting Techniques [2]

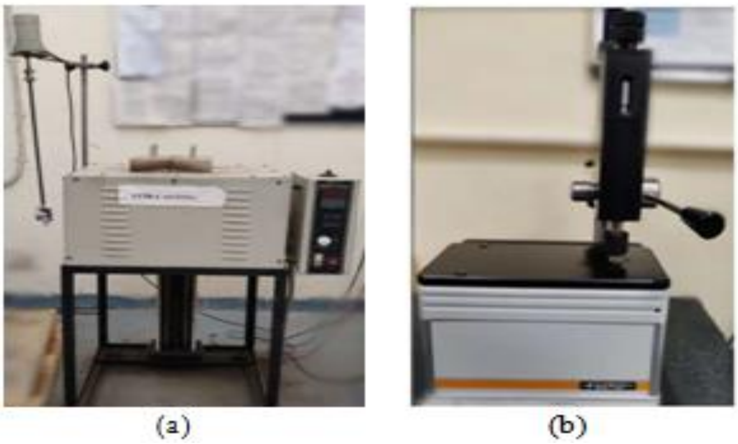


Figure 3 (a) Conventional Stir Casting setup (b) Vickers's micro hardness equipment

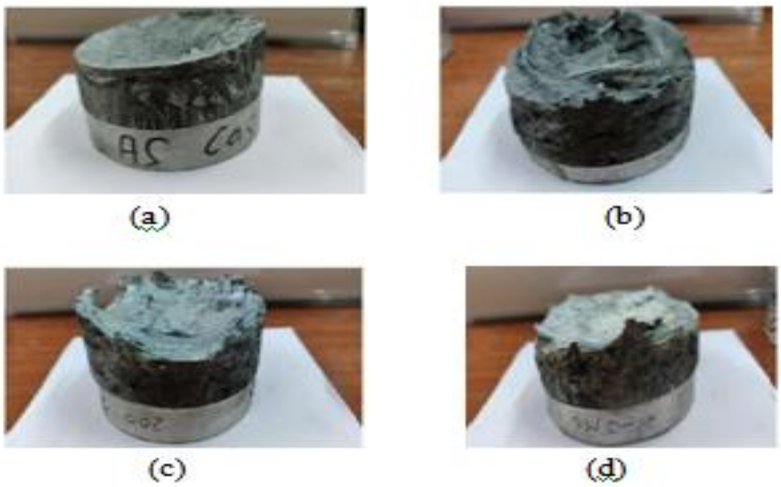


Figure 4 Casting of (a) Base alloy (b) AMC MS-150

(c) AMC MS-200 (d) AMC MS-270

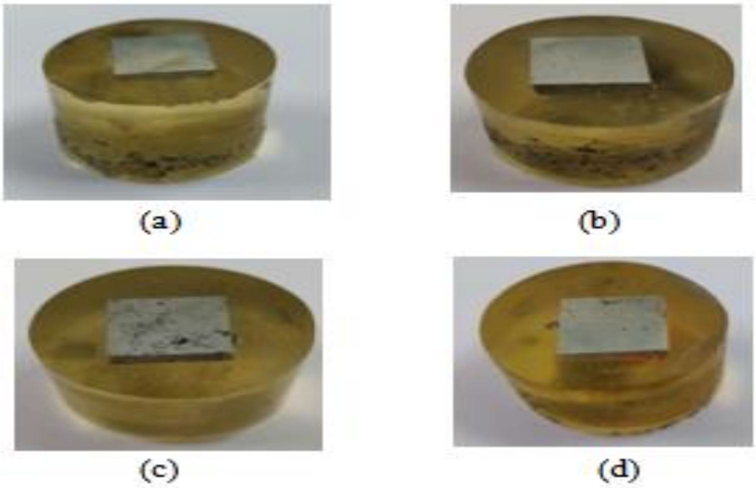


Figure 5 Specimens for microstructure and micro hardness analysis (a)Base alloy (b) AMC MS-150 (c) AMC MS-200 (d) AMC MS-270

III. RESULT AND DISCUSSIONS

Micro-Hardness

Hardness is the measure of the resistance of a material to indentation or damage on the surface [7]. In this experiment,hardnessofalloyandthreecompositeshas been calculated using Vickers's Micro Hardness test at four different locations on the prepared transverse section of composite and calculating its mean value in terms ofHV.

Table 3 Hardness value for various specimens

Specimens	**Hardness (HV)**
As casted Al-6063	41.78
AMC (MS-150)	49.94
AMC (MS-200)	60.02
AMC (MS-270)	75.77

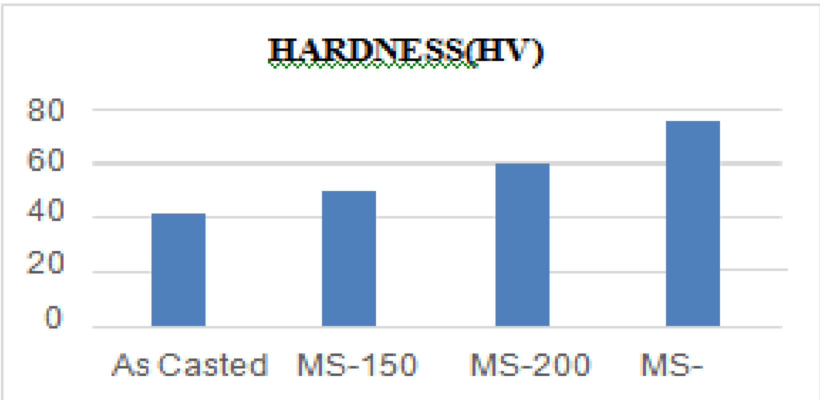


Figure 6 Bar graph representing Hardness value

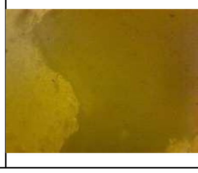
From above graph, it is revealed that hardness of reinforced composite specimen is more than that of basemetalAl-6063[8],[7,9].Thiscanbeexplainedon the basis of two facts that, firstly B4C is entitled as one of the hardest known materials and secondly the presence of reinforcement particles come with a large amount of dislocation density during the solidification. Hence, presence of its particle on the surface of the prepared composite increases resistance towards indentation or plastic deformation, resulting in increase of composite hardness[10].

Among the AMC's, the hardness is found maximum for the composite with B_4Cmeshsize270whichis81.35% more than base alloy and gradually goes on decreasing for composite with B_4C mesh size 200 and 150 accordingly. As the size of there in forcement decreases, it results in more uniform mixing with themetal matrix and shorter inter-particle distances within the matrixas compared to larger size reinforcement. As a result, composite start behaving as more monolithic with less spatial dependent material variations. Hence results in increase in hardness.[11]

Microstructure

To investigate the microstructure, proper sectioning and mounting has been done one achaluminium matrix composite carrying different size of B_4C. Samples are observed through transverse section under the optical microscope at magnification level i.e., 10X,20X,50X& 100Xintwostages-firstbeforeetchingandsecondafter etching.

Table 4 Micrographs of various specimens

Specimen	Magnifications				
	Etching	**10X**	**20X**	**50X**	**100X**
As casted Al alloy 6063	**Before**				
	After				
AMC(MS-150)	**Before**				
	After				
AMC(MS-200)	**Before**				

	After				
AMC(MS-270)	**Before**				
	After				

Figure 7 Optical micrograph of a composite

From micrographs, it is observed that the boroncarbide powder with different sizes has fairly uniform distribution in maximum portion within the core of molten matrix of Al-6063 and only some areas encounter a cluster formation [11]. This is because of proper stirring action and the usage of appropriate process parameters like preheating temperature, stirring speed, stirring temperature, stirring time, [12]. Clustering may have occurred due to inappropriate wetting behavior of boron carbide particles in molten aluminium alloy [12]. Some porosity also occurred in the microstructure of the composite due to entrapment of air bubbles while mixing of reinforcement in the molten alloy.[12].

Tensile Strength

On performing tensiletest on five samples of base alloy and composites each on TINIUS OLSEN H50K-S UTM, following mean values of tensile strength are obtained along with respective standard deviation.

Table 5 Tensile strength & Standard deviation values for various specimens from five tests.

Specimens	Tensile strength Mean value (MPa)	Standard Deviation
As casted Al-6063	181.486	0.439064

AMC (MS 150)	194.770	2.003
AMC (MS-200)	211.498	1.249696
AMC (MS-270)	219.196	1.152464

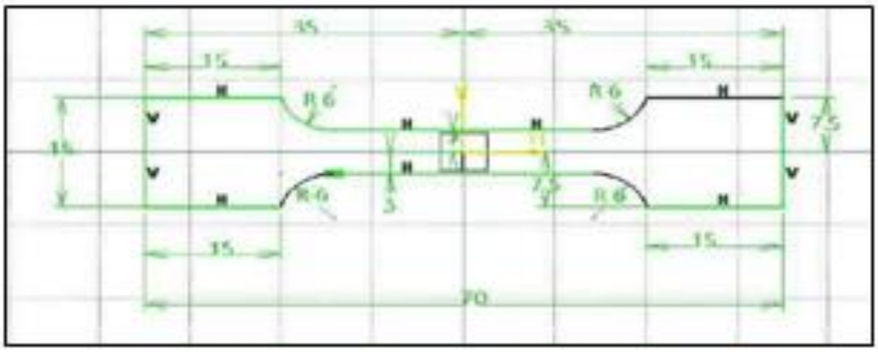


Figure 8 Schematic of standard tensile test specimen

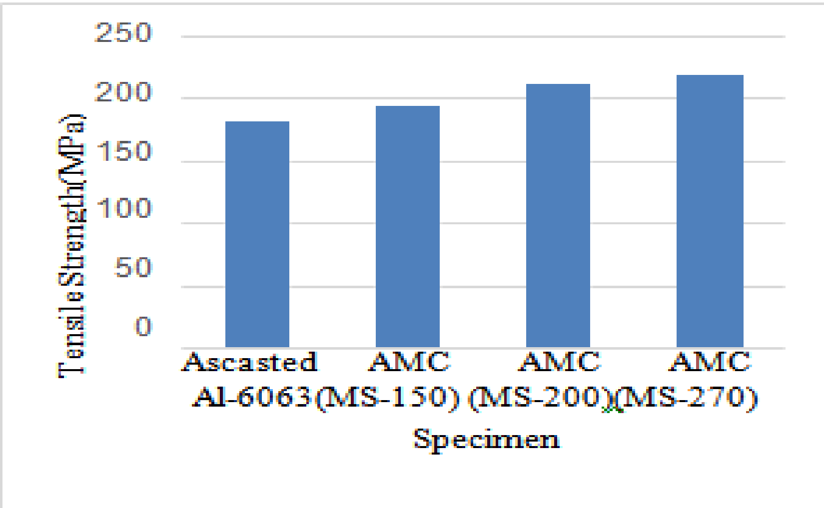
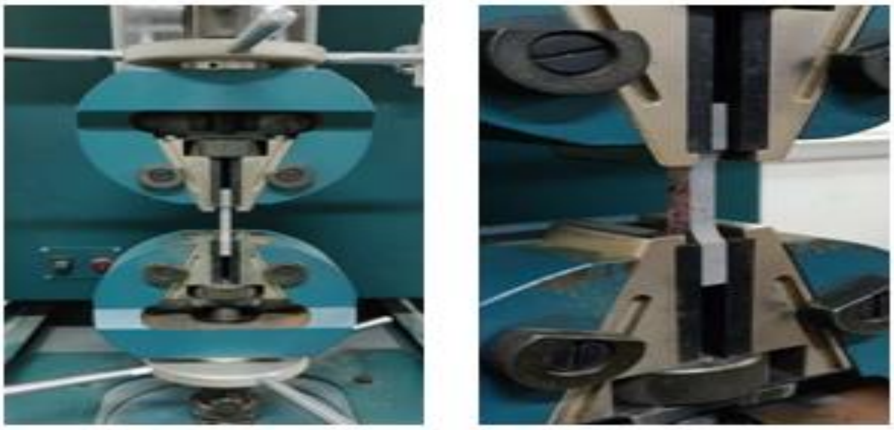


Figure 9 Bar graph between Tensile strength & various specimens



(a) (b)

Figure 10 Specimen subjected to tensile loading at UTM

From above, it is found that tensile strength of base alloy aluminium 6063 is less than the fabricated composites by 20.79 %. [9], [13] Among the composites, AMC's with B_4C mesh size 270 has highest tensile strength as compared to composite with B_4C of mesh size of 200 and 150.

This enhancement in the tensilestrength of the fabricated composite is a result of two strengthening effects which are independent but work simultaneously to produce a combine effect. One is direct effect in which the load is shifted from soft aluminium matrix to the hard boron carbide particles via matrix-particle interface. The other effect is indirect in which the presence of reinforcement increases the dislocation density in the metal matrix[1].

Figure 11 Base alloy specimens-Before and after tensile test

Figure 12 AMC MS-150 specimens-Before andafter tensiletest

Figure 13 AMC MS-200 specimens-Before andafter tensiletest

Figure 14 AMC MS-270 specimen-Before andafter tensile test

IV. CONCLUSIONS

The following significant conclusions are derived from the above investigation:

(1) Aluminum Metal Matrix composites has been preparedsuccessfullyusingaluminium6063T6asbase matrix and boron carbide powder with three different mesh sizes (viz 150,200,270) by stir castingtechnique.

(2) Optical microscopy study reveals a uniform distribution of B_4C powder in maximum region of aluminum core along with agglomerations at few sites. By developing composites through stir casting, it isobserved that clustering of reinforcement particles and their wettability with metal matrix are major concern that has be taken care for future studies.

(3) The hardness of the reinforced composites is found more than that of un-reinforced aluminium alloy. Maximum hardness is found for the composite with B_4C mesh size 270 (53µm) and shows a decreasing trend as size increases from 200 (74µm) to 150 (104µm).

(4) Ultimate tensile strength of base alloy aluminium 6063 has been found less than the prepared AMC's. AmongAMC's,thecompositewithB_4Cmeshsize270 has maximum tensile strength as compared to one with mesh size of 200 and 150respectively.

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