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Mechanical Characterization of Stir Cast Al 356-B4C Composite

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***Abstract*:- The development of light weight material for industrial utilities attracted Aluminum composites as this material have superior mechanical properties over unreinforced alloy. The present investigation focused on utilization of boron carbide into Al356 alloy fabricated by stir casting. The Boron Carbide particle weight fractions of 3, 6,9, 12 % wt. of particle sizes 53-106 µm were reinforced into matrix material. The scanning electron microscopy (SEM) was done to see distribution of the B4C particles in the matrix. The evaluation of mechanical properties viz; tensile strength, compressive strength, density and hardness were carried out. It was found that the tensile strength, compressive strength and hardness of the metal matrix composite (MMC) increases as weight fractions of the B4C particles increases. Also density of composite decreases subsequently. So boron carbide has potential to fabricate strengthened metal matrix composite for diverse Al alloy applications.**

Keywords –MMC, Stir casting, B4C, Al356, SEM, Hardness.

I. INTRODUCTION

Metal matrix composites (MMCs) are the combination of metal matrix & reinforcement or filler material which gives excellent mechanical properties and they are classified according to reinforcement type or its content. MMCs have ability to achieve any combination of stiffness, strength and density. The principal matrix materials for MMCs are Aluminium and its alloys. The major advantage of aluminium matrix composites over other material such as steel are, increased specific strength and stiffness, lower thermal coefficient of expansion, wear resistance, lower density and good corrosion resistance.

Metal matrix composites (MMCs) have received substantial attention due to their excellent strength, stiffness, lighter and wear resistance for tribolgological, aerospace and marine industries. Though MMCs possess superior properties, they have not been widely applied due to the complexity of fabrication. The conventional stir casting is convenient processing method for fabrication, as it is relatively inexpensive and offers wide selection of materials and processing conditions[1]. Stir casting offers better matrix particle bonding due to stirring action of particles into molten Aluminum. Among various reinforced used, Boron Carbide particulate reinforced aluminium composites possess a unique combination of high specific strength, high elastic modulus, good wear resistance and good thermal stability than the corresponding non-reinforced matrix alloy system. Hence, composites with boron carbide as reinforcement are possible to overcome the cost barrier and weight for wide spread applications in Bullet proof tees and armor tank.

Manufacturing of aluminium composite by stir casting is one of the most economical methods of processing MMC. In this project silicon carbide and boron carbide particulate reinforced aluminum alloy matrix composites are produced by stir casting process by varying the particulate addition by weight fraction of Al (90%), Sic (5%, 6.5%, 8%) and B4C (5%, 3.5%, 2%). Micro structural changes of the cast composites are studied by using metallurgical microscope and scanning electron microscope (SEM) [1]. The paper is the result of investigations made on microstructure and mechanical behavior of 3 and 6 weight percentage of nano sized B4C particulate reinforced to Al7075 alloy composites. Al7075 matrix composite having nano boron carbide was fabricated by liquid stir casting method [2]. Metal Matrix Composites (MMCs) have been widely investigated and used in automobile and aerospace industries due to their advantages of improved strength, stiffness and increased wear resistance over the monolithic alloys. Also considering limited reports on the study of weight % influence on wear characteristics of Al-6061-Boron Carbide (B4Cp) composites. This study presents the effect of weight % of B4Cp in Al-6061 alloy matrix on wear loss during dry sliding wear in pin-on-disc tribometer at different wear parameters against oil hardened non-shrinking (OHNS) steel disk at room temperature. The composites are prepared by stir casting technique. Tribological investigations were examined according to the L9 orthogonal array of Taguchi. The influence of % of reinforcement along with load, speed and distance were examined for the wear loss of composites [3]. Boron carbide is one of the potential neutron-shielding materials and its use can be maximized for structural shielding application by dispersing it into metal matrixes such as aluminum. Dispersion of B4C and its interfacial stability is a major issue during its processing. This investigation is on the synthesis of B4C-reinforced 6061 aluminum matrix composite by liquid–metal stir-casting technique under optimized conditions after solving the issues related to the processing, and evaluation of the structural, mechanical, and interfacial characteristics. During processing of composites, pretreatment of B4C particles is necessary to improve its dispersion [4]. Aluminium matrix composites (AMCs) reinforced with Nano-sized MgO particles are widely used for high performance applications such as automotive, military, aerospace and electricity industries because of their improved physical and mechanical properties. In this research, Magnesium Oxide (MgO) Nano particles were synthesized by Solution Combustion Synthesis process. The Nano particles were characterized by Powder X-ray diffraction (PXRD). A356.1 Aluminum alloy was reinforced with 0.5, 1.0, 1.5 and 2.0 Wt.% of the Synthesized Magnesium Oxide Nano particle, via Stir casting Technique. [5]

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II. EXPERIMENTATION

A. *Specimen Preparation*

B4C reinforced Aluminum alloy (Al356) composites, processed by stir casting route was used in this work. The three types of stir cast composites had a reinforcement particle size of 53-106 μm each. The required quantities of Boron carbide (3, 6, 9 and 12 Wt. %) were taken in powder containers. Then the Boron carbide was heated to 450^0 C and maintained at that temperature for about 20 min. then weighed quantity of Al 356 alloy was melted in a crucible at 800^0 C which is more than 100^0 C above liquidus temperature of the matrix alloy. The molten metal was stirred for 10 minutes to create a vortex and the weighed quantity of preheated Boron carbide particles were slowly added to the molten alloy. A small amount of Mg (1 wt. %) was added to ensure good wettability of Boron carbide particles with molten metal. After mixing the composite melt was poured into mould for the preparation of specimen.

Table 1 shows the chemical composition of the Al 356, Table 2 shows its mechanical properties and Table 3 shows the major chemical composition of the Boron carbide.

Fig. 1 shows stir casting set up and specimen.

Fig. 1 Stir casting set up and specimen

TABLE 1 CHEMICAL COMPOSITION OF THE Al 356

Composition	Si	Fe	Cu	Mn	Zn	Mg	Ti	Al
Wt.%	7.24	0.26	0.17	0.24	0.10	0.43	0.05	Bal

TABLE 2 MECHANICAL PROPERTIES OF AL356

Tensile strength (N/mm^2)	Elongation %	Hardness (BHN)	UTS (N/mm^2)
151.27	2.2	93	151.27

TABLE 3 PROPERTIES OF BORON CARBIDE

Molecular Formula	B_4C
Molar mass	55.255 g/mol
Density	2.52 g/cm_3, solid.
Melting point	2,763 °C (5,005 °F; 3,036 K)
Boiling point	3,500 °C (6,330 °F; 3,770 K)
Acidity (pK_a) 6–7 (20 °C)	6–7 (20 °C)
Appearance	Dark Gray or Black Powder, odourless
Solubility in water	Insoluble

B. *Mechanical Testing of Composites*

Microstructural analysis done by XRD & SEM with standard metallographic process to check uniform distribution of reinforcement of B4C into Aluminium. The tensile tests were conducted on MMC samples according to BS1490 at room temperature, using a universal testing machine. The specimens used were of diameter 13 mm and Gauge length 62 mm, machined from the cast composites with the gauge length of the specimen parallel to the longitudinal axis of the castings. The wear tests were conducted as per ASTM-G99 using pin-on-disc set up. The specimens used were of diameter 10 mm, and length 100 mm machined from cast composites. The Brinell hardness tests were conducted in accordance with the ASTM E10. Density measured as per BS EN1706:1998/BS 1490:1988 in laboratory

III. RESULT AND DISCUSSION

A. *Microstructure Analysis*

As the microstructure plays an important role in the overall performance of a composite and the physical properties depend on the microstructure, reinforcement particle size, shape and distribution in the matrix alloy. Prepared samples were examined using a Scanning Electron Microscope (SEM) to study the distribution pattern of Boron carbide in the matrix.

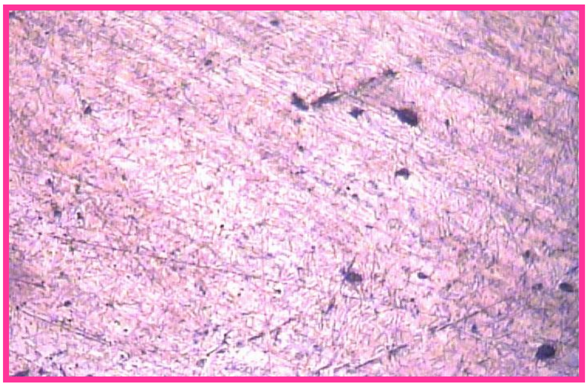

Fig. 2 Microscopic views of 3% Boron Carbide reinforced in Al356 at 100 X

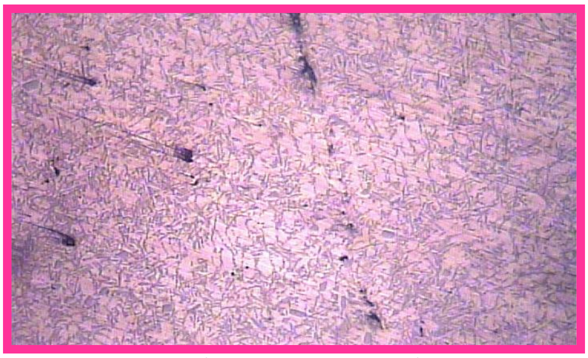

Fig. 3 Microscopic views of 6% Boron Carbide reinforced in Al356 at 100X

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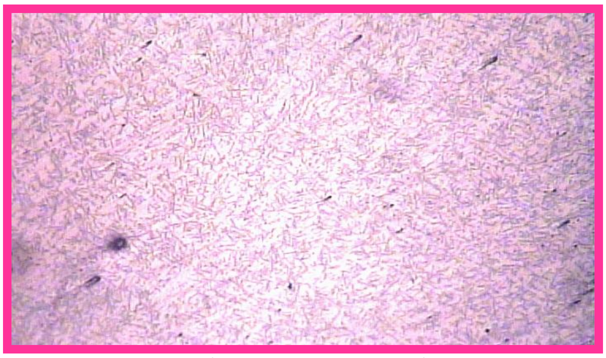

Fig. 4 Microscopic views of 9% Boron Carbide reinforced in Al356 at 100 X

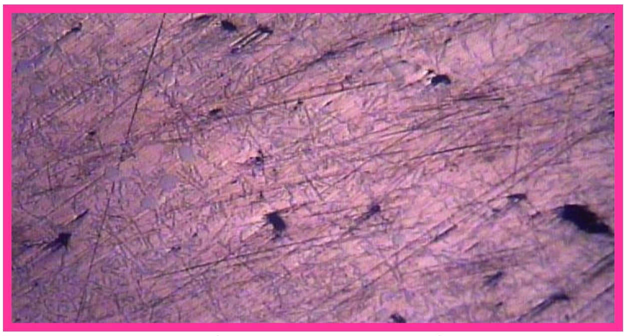

Fig. 5 Microscopic views of 12% Boron Carbide reinforced in Al356 at 100 X

The microstructure of MMCs clearly shows a uniform distribution of Boron Carbide in the matrix (Fig 2, 3, 4 and 5) with no void and discontinuities observed. There was good interfacial bonding between the Boron carbide particles and matrix material. However, in few composites the particle clustering occurred in some places, and also some places were identified without Boron Carbide inclusion. During fabrication, the particles were added into the molten alloys was observed to be floating on the surface.

B. Density

Density values of the Boron Carbide composites decreases linearly with addition of Boron Carbide particles. The decrease in density of composites can be endorsed to lower density of Boron Carbide particles (1.9 g/cc) than that of the unreinforced Al alloy (2.76 g/cc). The level of density increases with Boron Carbide wt% as shown in Fig. 6

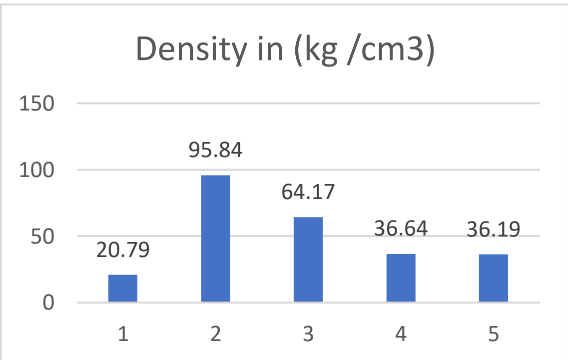

Fig. 6 Variation of Density with wt fraaction of Boron Carbide

C. Ultimate Tensile Strength

The tensile testing of the composite was done, on Universal testing machine to evaluate tensile properties.

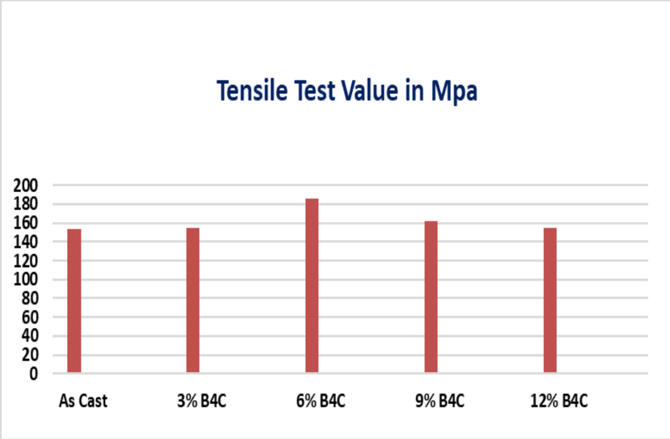

Fig. 7 Variation of UTS with wt fraaction of Boron Carbide

The tensile strength increased with an increase in the weight percentage of Boron Carbide. Therefore the Boron Carbide particles act as barriers to the dislocations when taking up the load applied .Good bonding of smaller size Boron Carbide particles with the matrix is the reason for this behaviour. The tensile strength improves from 154.27 to 186.65 Mpa, which is almost 20% improvement. The decrease in the tensile strength of the samples with Boron Carbide weight fraction beyond 5 % is due to the poor wettability of the reinforcement with the matrix and due to clustering of the reinforcement particles the composite.

D. Wear Strength

Samples are prepared with (L/D) ratio as 10.0, so length of specimen is 100 mm and diameter is 10 mm and 6mm. Further samples are polished to achieve flat surfaces with emery paper.

Table 4. Variation of Initial wt. and Final wt.

Sr. No.	**Sample Name**	**Initial Wt. (gm)**	**Final Wt. (gm)**	**Wt. difference (gm)**
1.	As cast	18.432	18.420	0.012
2.	B4C-3%	18.485	18.470	0.015
3.	B4C-6%	17.327	17.320	0.007
4.	B4C-9%	17.684	17.670	0.014
5.	B4C-12%	17.088	17.080	0.008

Wear test determines load applied 20N and 250 RPM of time limit 10 minutes . The observe the initial weight of pin sample before use of test. For wear test for removing material and final weight observe shown in Fig 7.

Wear strength increases with increasing percentage of Boron Carbide particulates. However the Wear strength of the composites begins to drop when the Boron Carbide content increased. Beyond 9 wt%, the Boron Carbide particles interact with each other of compare to base metal matrix composite .

E. Hardness

Samples are tested as per as per STD BS EN1706:1998/BS 1490:1988. For Brinell hardness test surface being tested generally requires metallographic surface finish

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and it was done with help of 100, 220, 400, 600 and 1000 grit size emery papers.

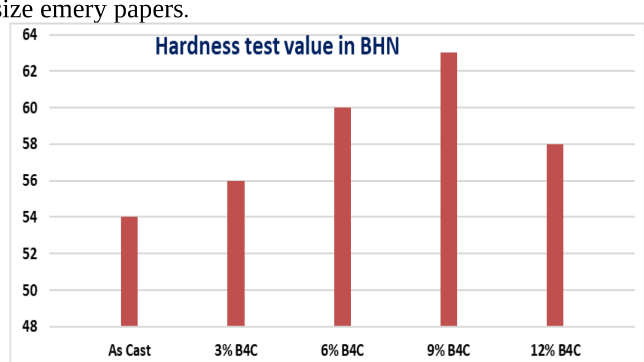

Fig. 9 Variation of BHN with wt fraction of Boron Carbide

The results of the hardness test (Fig 9) show increase in hardness with the weight fraction of Boron Carbide. It shows that hardness increases by almost 11% in 16% Boron Carbide composite as compared with Al alloy.

IV. CONCLUSIONS

1. Addition of boron carbide increases mechanical properties of composites..
2. Hardness of composite increases with increase in boron carbide percentage.
3. Tensile properties of Al-B4C composite increases with increase in boron carbide.
4. The mechanical properties viz; tensile, hardness etc increase due to hard boron carbide particle.
5. Wear resistance of Al-B4C composite increases due to presence of hard boron carbide particle.
6. Due to stirring, grain refinement helps to increase mechanical properties.
7. From microstructure study, uniform dispersion of B4C particle enhances mechanical strength of composites.

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