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# Processing and Mechanical Characterization of AA6061-$B_4C$ Composite

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***Abstract :*** *Aluminium Boron Carbide Metal Matrix Composites have revolutionized aeronautical and automobile industries, in the recent times due to their exceptional mechanical and physical properties. Their ability to be produced by conventional methods adds to the advantage. The aluminium matrix can be strengthened by reinforcing with hard ceramic particles like SiC, $Al_2O_3$ and $B_4C$, etc. In the present work, attempt has been made to enhance the mechanical properties like hardness and tensile strength of AMCs by reinforcing AA6061 matrix with $B_4C$ particulates of 220 mesh size with varying weight percentage of 1%, 2%, 3%, 4% by liquid metallurgical route. To enhance better wettability of $B_4C$ particles in the matrix halide salt $K_2TiF_6$ flux is added in to the melt. The mechanical properties and microstructure of the fabricated AMCs are analysed. The scanning electron microscope (SEM) images reveal the homogeneous dispersion of $B_4C$ particles in the matrix. The reinforcement dispersion has also been identified with X-ray diffraction (XRD). The hardness and tensile strength was found to increase with the increase in wt% of $B_4C$ particles to AA6061 matrix.*

***Keywords:*** *AA6061, $B_4C$, Micro Hardness, Microstructure, Tensile*

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## I. Introduction

Nowadays with the modern development need of development of advanced engineering materials for various engineering application goes on increasing. To meets such demands composite material is one of the reliable solutions.Composite material is made by combining two or more materials to give a unique combination of properties. The metal matrix composites (MMCs) consists of at least two physically and chemically distinct phases, suitably distributed to obtain properties not obtainable with either of the individual phases.

Aluminium metal matrix composites (AMCs) have captured the attention of material community to a large extent. AMCs possess greater strength, improved stiffness, reduced weight, improved high temperature properties, controlled thermal expansion coefficient, heat management, improved abrasion and wear resistance, excellent fatigue properties, high formability. Properties of AMCs can be tailored by varying the type, size of constituents and percentage of reinforcemt. AMCs has become major focus in marine, automotive and aircraft industries due to their excellent properties.

AA6061 is one of the most versatile and widely used alloys in numerous engineering application including construction and transportation where superior mechanical properties such as hardness, tensile strength etc., are essential required [1]. A6061 has excellent corrosion resistance to atmospheric condition and good corrosion resistance to sea water [2, 3]. This alloy also offers good finishing characteristics and responds well to anodizing. Application range from machinery and transportation components to recreational products and consumer durables.

Boron carbide is a robust material having excelling chemical and thermal stability, and is the third hardest material after diamond and cubic boron nitride, which possesses low density (2.51 g/cm$^3$), high hardness (HV = 30 GPa), very high stiffness (445 GPa), high specific strength, high Elastic modulus, high refractoriness and toughness, higher bending strength, high shock resistance, high wear and impact resistance and is used for manufacturing armour tanks, bullet proof vests etc. [2-5].

The high hardness of $B_4C$ is attributed to the presence of B and C which forms covalently bonded solids. A limited research work has been reported on AMCs reinforced with $B_4C$ due to poor wetting and high raw material cost [6]. Boron carbide ($B_4C$) particulate reinforced aluminium composites possess a unique combination of good wear resistance, high specific strength, high elastic modulus, and good thermal stability than the corresponding un-reinforced alloy. Hence $B_4C$ reinforced aluminium matrix composite has gained more attention with low cost casting route [7-10]. This paper, fabrication, characterization and evaluation of mechanical properties of produced AMCs reinforced with $B_4C$ are detailed.

## II. Experimental Details

In the present work matrix used is AA6061, Table 1. gives the chemical composition.

**Table 1.** Chemical composition of AA6061

| Elements | Mg | Si | Fe | Cu | Mn | Cr | Zn | Ti | Al |
|---|---|---|---|---|---|---|---|---|---|
| **Wt. %** | 0.95 | 0.54 | 0.22 | 0.17 | 0.13 | 0.09 | 0.08 | 0.01 | Bal. |

Boron carbide ($B_4C$) of particle size 220 mesh has chosen as reinforcement, Table 2. gives the properties.

**Table 2.** Properties of $B_4C$

| Density | Hardness | Young's Modulus | Stiffness | Melting Point |
|---|---|---|---|---|
| 2.52 g/cm$^3$ | 30 GPa | 540 GPa | 445 GPa | 2880 °C |

### 2.1 Fabrication Process

The proposed AMCs was produced by the liquid metallurgy route. To improve wettability between $B_4C$ with Al matrix $K_2TiF_6$ halide salt (Potassium titanium fluoride) is added as a flux to the melt. At an appropriate Ti level, the titanium rich reaction layer covers the $B_4C$ particulates and thus these particles are wetted by Al melt. The titanium rich layer consists of particle clusters of titanium carbide and titanium di-boride formed on the $B_4C$ surface. $K_2TiF_6$ incorporate $B_4C$ particulates in the melt. Also magnesium present in AA606 alloy is also found to increase the wettability of the particulates by reducing the surface tension of the melt. The process parameters employed are given in the Table 3.

**Table 3.** Process parameters of casting

| Parameters | Value | Units |
|---|---|---|
| Stirring time | 5 | min |
| Stirring speed | 300 | RPM |
| Temperature of melt | 760 | °C |
| Preheated temperature of $B_4C$ particles | 200 | °C |
| Preheating time of $B_4C$ particles | 1 | hr. |
| Preheated temperature of Mould | 300 | °C |
| Powder feed rate | 0.5 - 1.0 | g/s |
| Pouring temperature | 860 | °C |

A batch of 250g of AA6061 was melted at 760 °C in a graphite crucible using an electric resistance furnace. The melt was agitated with the help of a zirconia coated steel rod to form a fine vortex. 3g of degassing tablet ($C_2Cl_6$-solid hexachloro ethane) was added to the vortex and slag was removed from the molten metal. De-gasser removes all the absorbed gases in the melt. Once the temperature reaches 810 °C the preheated mixture of $B_4C$ (200 °C for 1 hour) with an equivalent amount of $K_2TiF_6$ halide salt (with 0.05 Ti/ $B_4C$ ratio) were added at a constant feed rate of 0.5-1.0 g/s into the vortex with mechanical stirring at 300rpm for 5 min. Before pouring the molten metal to the mould, 2g of cover flux (45% NaCl + 45% KCl + 10% NaF) was added to the molten melt to reduce atmospheric contamination. Cover flux helps in decreased contact angle and surface tension forces. The molten metal at a temperature of 860 °C was then poured into the permanent graphite mould preheated to 300 °C after holding the melt for an interval of 1-2 minutes and allowed to solidify. The AMCs having particle size of 220 mesh with varying weight percentage of 0%, 1%, 2%, 3%, 4% of $B_4C$ were fabricated by the same procedure.

### 2.2 Microstructure

Microstructure characterization of the prepared composites was carried out using scanning electron microscope (SEM). The specimens were cut and prepared as per standard metallographic procedure. The specimen was prepared through 400, 600 to 1000 mesh emery papers. Polishing is done for the specimen to get fine surface finish. Etching was done using Keller's reagent. The microstructure of etched specimens was recorded using scanning electron microscope (SME). X-ray diffractions (XRD) was also used for identifying the presence of $B_4C$ particles and to study the interface characteristics. The microhardness of polished specimens' (10 mm length and 12mm diameter) was measured using micro-vicker hardness tester at a load of 200 g for 10 sec. The hardness measurement was carried out at 20 different locations & average of readings were recorded. The macrohardness was measured using Brinell hardness tester at a load of 500 kg for a period of 15 sec. The tensile specimens were prepared as per ASTM- E8 standard.

## III. Results & Discussions

### 3.1 Microstructure

The aluminium reinforced with $B_4C$ particulate composites are successfully fabricated by casting techniques. The Scanning electron micrograph (SEM) of fabricated AMCs with varying weight percentage of $B_4C$ are shown in Fig.1. The SEM images reveal that the homogeneous distribution of $B_4C$ particles in the aluminium matrix for all Wt. %. This can be attributed to effective stirring action and use of appropriate process parameters during casting and also due to the equal value of density of matrix and reinforcement material causing the particle neither float nor descent in the mixture.

XRD analysis as seen in Fig.2 confirms the presence of $B_4C$ reinforcement within the matrix. It is observed from the Fig.2 that Ti compound layer around the $B_4C$ particles which tends to react as a reaction barrier and prevents the interfacial reactions between aluminum matrix and $B_4C$.

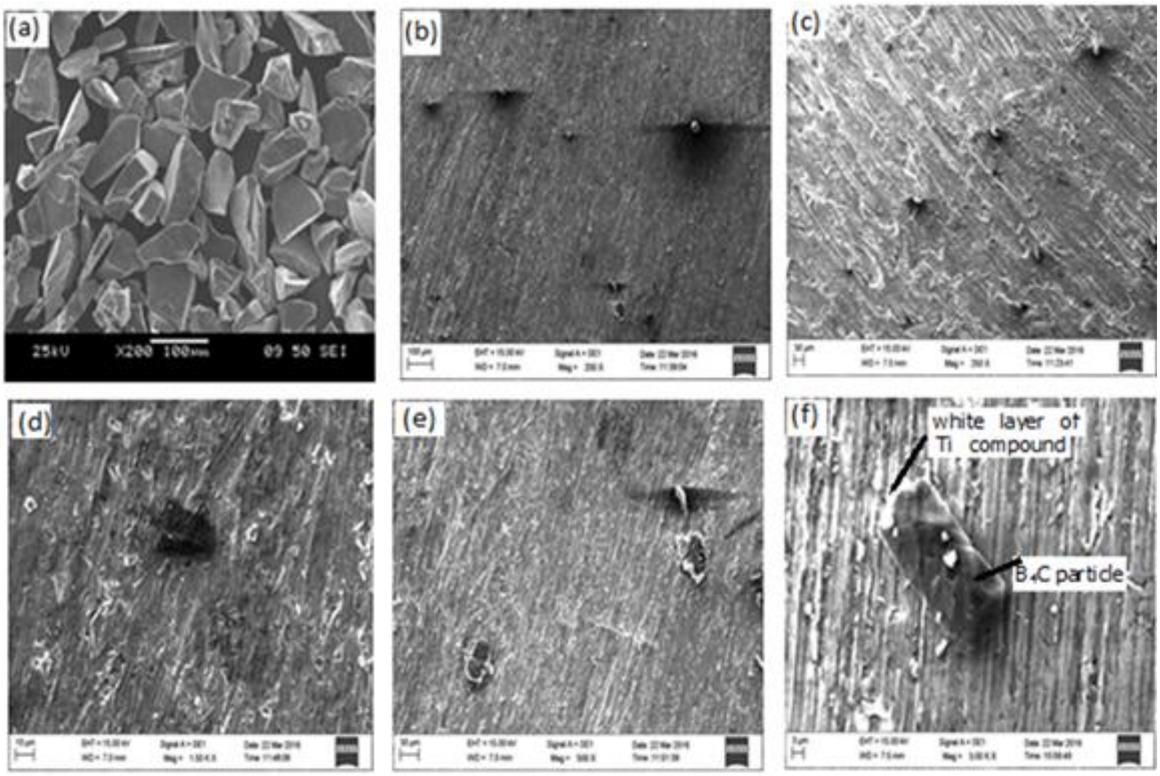


**Figure 1. (a)** SEM micrograph of $B_4C$ particles, AMC$^s$ of AA6061(b) As Cast (c)with 1% $B_4C$ (d)with 2% $B_4C$ (e)with 3% $B_4C$ (f)with 4% $B_4C$ particle

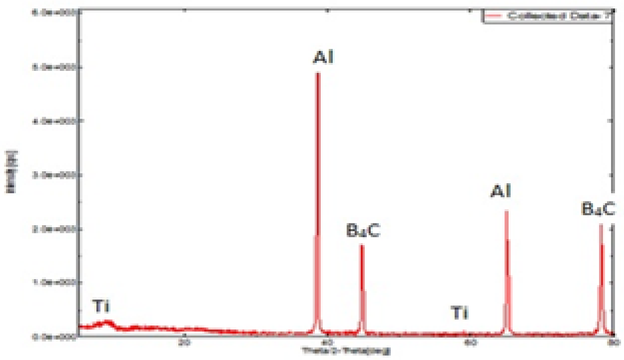


**Figure 2**. XRD pattern of AA6061- $B_4C$

### 3.2 Mechanical Properties

**3.2.1** Micro Hardness

It is observed from the Fig.3. the micro hardness of the AMCs is increased with increasing the Wt. % of $B_4C$ reinforcement. The micro Vickers hardness of the AMCs was found to maximum (100 VHN) for 4% and increased in hardness value compare to the as-cast. The presence of such hard surface area of particles offer more resistance to plastic deformation which leads to increase in the hardness of composites.

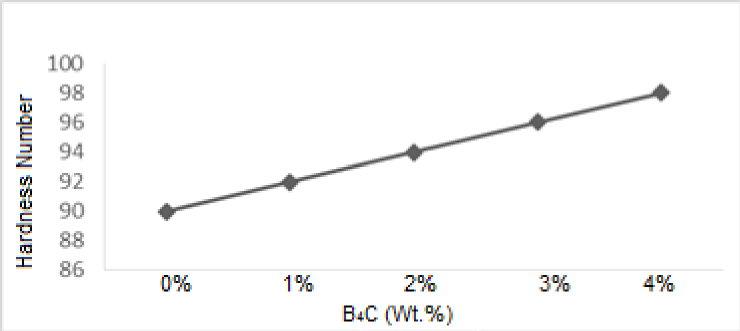


**Figure 3.** Effect of wt% $B_4C$ particulates on the Hardness

### 3.2.2 Tensile Strength

The tensile strength of the AMCs was tested using computerized universal testing machine. The tensile specimens were prepared as per ASTM E8 standard. The Fig.4. shows that tensile strength is increased with increasing the Wt. % $B_4C$ reinforcement. The ultimate tensile strength of the AMCs was found to maximum for 4%. This may be attributed to increase in the grain boundary area due to grain reinforcement, at the interface and effective transfer of applied tensile load to the uniformly distributed well bonded reinforcement. The addition of $B_4C$ particles in the matrix induces much strength to matrix alloy by offering more resistance to tensile stresses. Increase in the strength is due to the increase in hardness of composite.

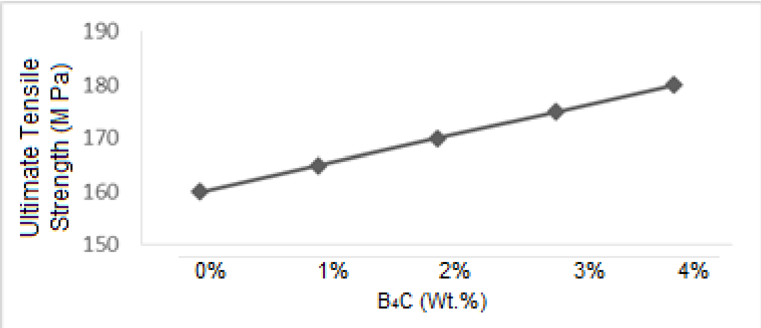


**Figure 3**. Effect of wt% $B_4C$ particulates on the Tensile strength

## IV. Conclusions

The A6061-$B_4C$ composites were produced by the liquid metallurgy route in an induction heating furnace with different Wt. % (0, 1, 2, 3, and 4) of reinforcement and the microstructure, mechanical properties are evaluated. The following conclusions are derived from the study.

1. Scanning electron micrographic study and XRD analysis revealed the presence of $B_4C$ particles in the composites with homogeneous dispersion.
2. The Micro Vickers hardness of the AMCs was found to maximum (100 VHN) for 4 wt% and increased in hardness value compare to the as-cast.
3. The ultimate tensile strength is increased with the increase of $B_4C$ content and was found maximum for 4 wt%.

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## References

[1] R. Shivanath, P. K. Sengupta, and T. S. Eyre, Wear of aluminium-silicon alloys, Br.Foundrymen, 79, 1977, 349-356.
[2] N. Saheb, T. Laoui, A. R. Daud, M. Harun, S. Radiman and R. Yahaya, Influence of Ti addition on wear properties of Al-Si eutectic alloys, Wear, 249, 2001, 656-662.
[3] J. E. Gruzleski and B. M Closset, The treatment to Liquid aluminium silicon alloys, AFS, Illinois, 1990, 1-254.
[4] S. A. Kori, Studies on the grain refinement and modification of some hypoeutectic and eutectic Al-Si alloys, IIT Kharagpur, 2000.

[5] F.H.Stott, High temperature sliding wear of metals, Tribology International, 35, 2002, 489-495.
[6] T. Sritharan, H. Li, Influence of Titanium to Boron ratio on the ability to grain refine Al-Si alloys, J. Mater. Proce. Tech., 63, 1997, 585-589.
[7] A.D.Sarkar and J.Clarke, Friction and wear of Aluminium-silicon alloys, wear, 61, 1980, 157-167.
[8] I. G. Davies, J. M. Dennis & A. Hellawell, The nucleation of aluminium grains in alloys of Al with titanium & boron, Metall. Trans, 1, 1970, 275-280.
[9] A. J. Cornish, Influence of boron on the mechanism of grain refinement in dilute aluminium-titanium alloys, Material Science., 9, 1975 477-482.
[10] Jonas Fjellstedt, Anders E. W. Jarfors and Lena Svendsen, Experimental analysis of the intermediary phases $AlB_2$, $AlB_{12}$ and $TiB_2$ in the Al-B and Al-Ti-B system, Journal of Alloys and Compounds, 283, 1999, 192-197.

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