

The Effect of Ti Addition on the Properties of AA6061-B₄C Interface -A Microstructural Study

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ABSTRACT: In this present work, focus is on producing Al-B₄C composites by liquid metallurgical route and to overcome the wetting problem between liquid aluminium metal. The microstructure of the composites, evaluated by scanning electron microscope (SEM), shows the effect of addition of Ti added composites. EDS analysis is done to characterize the reaction layer on the prepared composites. It is observed from the scanning electron micrograph of fabricated AMCs that wetting issue was solved by the formation of very thin reaction layers of Titanium carbide (Ti-C) and Titanium di-boride (Ti-B).

KEYWORDS: AA6061, B₄C, EDS, Microstructure, SEM, Ti.

I. INTRODUCTION

Aluminium Metal matrix composites (AMMCs) belong to a range of advanced materials providing properties which are not achieved by conventional materials [1-3]. These materials range from ordinary materials (e.g., copper, cast iron, brass), which have been available for several hundred years, to the more recently developed, advanced materials (e.g., composites, modern ceramics, and high-performance steels) [4]. AMMCs compared to unreinforced materials are greater strength, improved stiffness, reduced weight, improved high temperature properties, controlled thermal expansion coefficient, thermal/heat management, enhanced and tailored electrical performance, improved abrasion and wear resistance as well as improved damping capabilities [5]. Properties of AMMCs can be tailored by varying the type, size of constituents and percentage of reinforcement. Particulate Reinforced Aluminium Metal Matrix Composites are much less expensive to fabricate than continuously reinforced composites. Consequently, performance enhancement of the matrix comes at lower additional costs in comparison to composites with aligned reinforcements [6,7]. Silicon carbide, alumina, boron carbide, and graphite are common reinforcements for aluminium matrices. Boron carbide is the third hardest material after diamond and cubic boron nitride, which possesses low density (2.51 g/cm³), high specific strength, high degree of chemical inertness, high temperature stability, excellent thermoelectric properties, high Elastic modulus, high refractoriness, higher bending strength, high shock resistance, high wear and impact resistance, high toughness, has a relatively low fracture toughness, low specific weight and low specific gravity [8].

Aluminium reinforced boron carbide composite gives interesting features such as high strength and high hardness. These characteristics have made this composite as a very potential material in engineering field. It could be an alternative to silicon carbide composites in applications where high stiffness and wear resistance are major requirements. One of the solutions is going for boron carbide-reinforced metal matrix composites that are stronger, stiffer, fracture resistant, lighter in weight, harder, possess higher fatigue strength and exhibit significant improvements over other materials. The lower density, high elastic modulus, high refractoriness and higher hardness of B₄C than SiC and Al₂O₃ make it better reinforcement for high performance MMCs [9,10].

Al-B₄C composites can be processed with low-cost casting routes. But below 1200 °C, poor wetting is observed between Al and B₄C composites, which means it is difficult to produce Al-B₄C composites by mixing particles into the

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liquid phase. In order to improve the incorporation of hard ceramic material into the molten melt and to enhance wettability of hard ceramic particles, often they are coated or heat treated. Also it is important to control interphases occurring at the interface of Al-B₄C composites, as it is reported there are nine phases in Al-B-C ternary system. Titanium is one of the highly reactive metal that can be used to increase the wettability in Al-B₄C composites [10]. In this present study Al-B₄C composites were produced through liquid metallurgical route by adding flux K₂TiF₆ which forms a reaction layer which contains Titanium carbide (Ti-C) and Titanium di-boride (Ti-B), which helps in strengthening the interface bonding and wettability.

II. EXPERIMENTAL PROCEDURE

The proposed AMCs was produced by the liquid metallurgy route Table 1, shows the nominal chemical composition of AA6061, and Table 2, shows the properties of B₄C. Boron carbide (B₄C) of particle size 220 mesh size is chosen as reinforcement material.

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.

Table 2 Properties of B₄C

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

To improve wettability between B₄C with Al matrix K₂TiF₆ 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 B₄C 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 B₄C surface. K₂TiF₆ incorporate B₄C particulates in the melt. Also magnesium present in AA6061 (Aluminium Alloy 6061) alloy is also found to increase the wettability of the particulates by reducing the surface tension of the melt.

2.1 Preparation of cast composites

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 (C₂Cl₆-Solid hexachloro ethane) was added to the vortex and slag was removed from the molten metal. Degasser remove all the absorbed gases in the melt. Once the temperature reaches 810 °C the preheated mixture of B₄C (200 °C for 1 hour) with an equivalent amount of K₂TiF₆ halide salt (with 0.05 Ti/ B₄C ratio) were added at a constant feed rate of 0.5-1.0 g/s into the vortex with mechanical stirring at 300 rpm 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 CI 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% wt% of B₄C were fabricated by the same procedure.

III. MICROSTRUCTURE AND TESTING

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 were finished through 400, 600 to 1000 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 were recorded using scanning electron microscope (SME). Energy dispersive spectroscopy (EDS) analysis was also used for identifying the presence of B₄C particles and to study the interface characteristics.

IV. RESULTS & DISCUSSIONS

4.1 Evaluation of microstructure

The main objective of incorporating Ti into the molten metal is to form a reaction layer on the interface that contains Titanium carbide (Ti-C) and Titanium di-boride (Ti-B), 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. Potassium (K) and fluoride (F) helps in removing the oxide film from molten Al surface. K_2TiF_6 incorporate B_4C particulates in the melt and improves wettability of B_4C particle with molten aluminium. This reaction is exothermic in nature and heat evolved in the vicinity of B_4C particle-melt interface. The local increase in temperature enhance the incorporation of particles in to the melt and bonding with the matrix. Also magnesium present in AA6061 alloy is also found to increase the wettability of the particulates by reducing the surface tension of the melt.

Figure. 1, 2, 3 & 4 shows the SEM micrographs of 4%, 3%, 2%, 1% B_4C particulate reinforced AA6061 composite, where formation of reaction layer can be seen on Ti element.



Fig. 1 SEM image of 4 % B_4C particulate reinforced AA6061 composite.

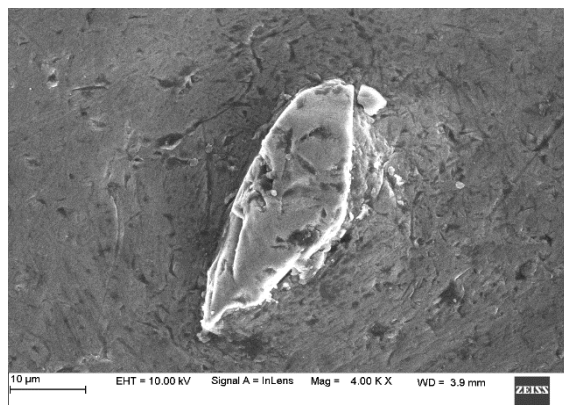


Fig. 2 SEM image of 3 % B_4C particulate reinforced AA6061 composite.

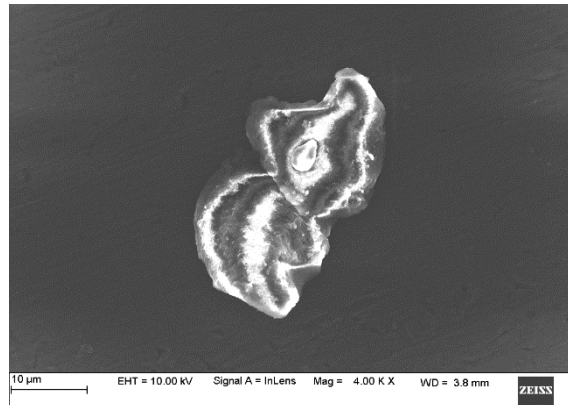


Fig. 3 SEM image of 2 % B₄C particulate reinforced AA6061 composite.

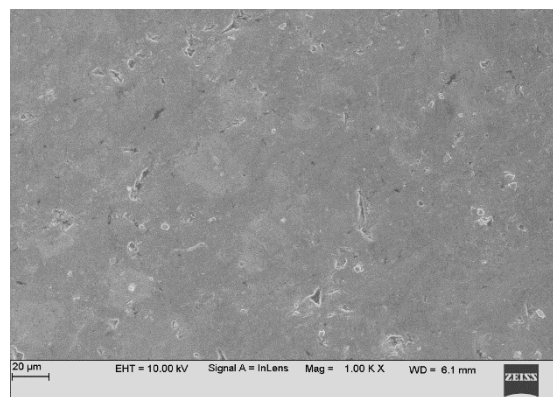


Fig. 4 SEM image of 1 % B₄C particulate reinforced AA6061 composite.

The SEM images reveal that around B₄C particle there is the presence of white layer of Ti compound. However in some region the weak Ti compound layer is observed. The presence of weak Ti compound is also evident from the analysis and is depicted respectively. During solidification of composites the aluminium dendrites solidify first and the particles are rejected by the solid-liquid interface.

The layer consists of titanium carbide and titanium boride having spherical shape, square shape, and pyramid shaped morphology is uniformly distributed and grow over B₄C particle. The reaction layer also acts as a reaction barrier on the surface of the B₄C particulates and limits the interfacial reaction between the hard ceramic particle and molten aluminium, which in turn prevents the interphases. This layer gives excellent wettability and interfacial bonding between matrix and reinforcement. It is observed from the Fig. 2, 3 and 4 that Ti compound layer around the B₄C particles which tends to react as a reaction barrier and prevents the interfacial reactions between aluminium matrix and B₄C.

4.2 EDS analysis of AMCs

Energy dispersive spectroscopy (EDS) analysis as seen in Fig. 5, 6, 7, 8 confirms the presence of B₄C reinforcement within the matrix and the reaction layer confirmed the TiB₂ and TiC.

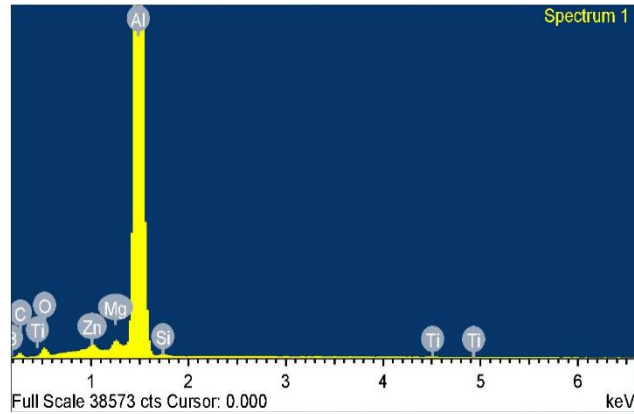


Fig. 5 EDS analysis of AA6061-4%B4C particulate.

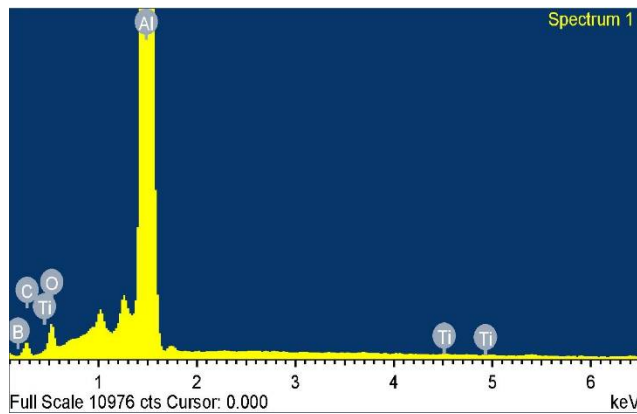


Fig. 6 EDS analysis of AA6061-3%B4C particulate.

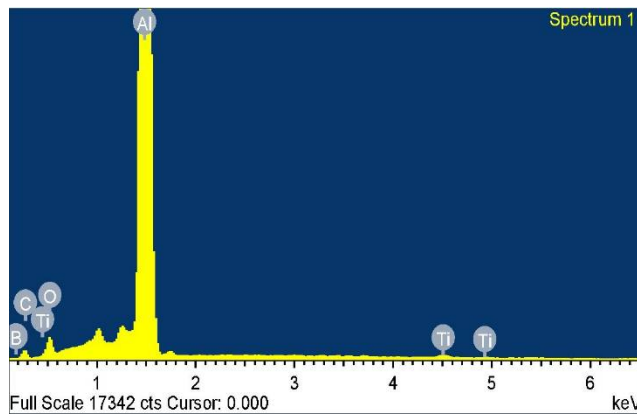


Fig. 7 EDS analysis of AA6061-2%B4C particulate.

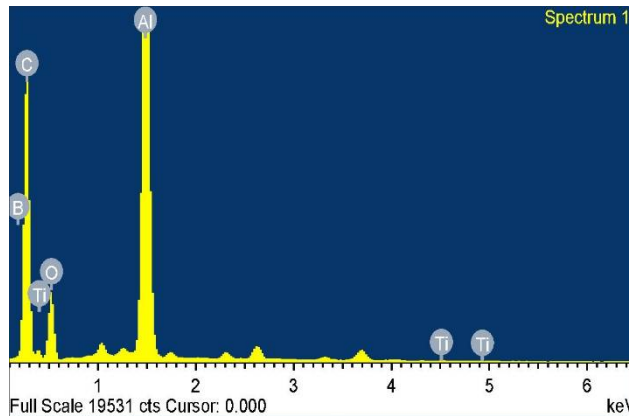


Fig. 8 EDS analysis of AA6061-1%B₄C particulate.

IV. CONCLUSIONS

The Al-B₄C composites were produced by liquid metallurgical route, by incorporating K₂TiF₆ flux. The K₂TiF₆ flux has improved the wettability of B₄C particle with molten aluminium. The incorporation of B₄C particle in the Al matrix is facilitated by the flux and bonding with the matrix. Poor wetting was effectively solved by the addition of K₂TiF₆ resulting in the formation of very thin Titanium carbide (Ti-C) and Titanium di-boride (Ti-B) reaction layers.

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