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Influence of Chill Material on Micro Structure and Mechanical Properties of Al6061-B_4C Composite

Leela B N[1], Dr. N D Prasanna[2], Dr. Balasubramanya H S[3]

[1]Assistant Professor, Department of Mechanical Engineering, SSIT, Tumakuru-572105, Karnataka, India

[2]Professor and Head, Department of IEM, MSRIT, Bengaluru-560054, Karnataka, India

[3]Assistant Professor, Department of Mechanical Engineering, MSRIT, Bengaluru-560054,Karnataka, India
Email: *leelamanasvi[at]gmail.com*

Abstract: ***Aluminium matrix composites are considered to be excellent category of materials satisfying all requirements basically light weight, excellent stiffness and high strength values. They find applications in structure, aerospace and automobile industries. In the present investigation, successful attempts were made to produce aluminium matrix composites using the stir casting method with various chill materials embedded in mold. Chill materials selected were Cast Iron (CI), Stainless steel (SS) and Copper (CU). The effect of chills on microstructure, mechanical properties has been studied on Al6061 alloy reinforced with B_4C additions (reinforcement additions 4 to 10 % in steps of 2%). It is observed from the studies that, structure examination reveals fine grained structure of the composite casting with copper chill and medium to coarse grain structure is observed with the composite made using CI and SS chills. Mechanical properties assessment indicate that tensile strength and hardness values has improved with increased additions of B_4C and the composite casting using CI chills. The same increasing trend with hardness value is also observed with casting made using Copper chills. The study indicates that the thermal conductivity of the chill material influences the properties of the aluminium composite. Results are quite encouraging and will be useful for researchers and foundry men world over.***

Keywords: Al6061, B_4C, Chills, Mechanical properties, stir casting

1. Introduction

The need and development for new class of engineering materials with improved properties, processes still continues for a number of structure and automobile applications. Properties sought of such materials include high strength to weight ratio, good corrosion resistance, wear resistance properties etc., has attracted a number of scientists and researchers world over [1]. Metal matrix composites have received wide attention among all engineering materials and aluminium alloys has emerged as a promising material exhibiting light weight with improved mechanical properties. Processing methods and reinforcement nature contributing to the improvement in properties has been reported. Alloy Al6061 has excellent corrosion resistance and also offers good surface finishing characteristics has been investigated [2]. Applications include consumer durables, machinery, equipment, and components for the transportation [3]. Boron carbide reinforcements have found its way as a reinforcement material in aluminium matrix composite. It is because boron carbide is hard as SiC and harder than Al_2O_3hence has found wide applications in aluminium matrix composite [4-6]. Chills are used to promote directional solidification. The structure properties depends on the chill materials used [7-9]. Less information is available with respect to the structure and mechanical properties of aluminium alloy composite reinforced with B_4C additions.

The basic scope of this study is to investigate the effect of chill materials on the structure and mechanical properties of aluminium alloy reinforced with B_4C additions. Hence Al6061 alloy reinforced with B_4C additions (4 to 10%) were cast in three different chill materials namely copper, stainless steel and cast iron. Structure studies and mechanical properties assessment namely hardness test and tensile strength measurements have been carried out. The results indicate fine grain structure for the composite made in copper chill while medium to coarse grain structure is observed with cast iron and stainless steel chills. Increasing mechanical property trend is observed with increased additions of B_4C and higher mechanical properties are observed with casting made in copper chills.

2. Experimental Procedure

2.1 Material Selection

The matrix material selected was Al6061 alloy. Chemical composition of the matrix material is given in the table 1. The reinforcement was Boron carbide (B_4C) of particle size 105 micron. Table 2 shows the properties of boron carbide. Composite was prepared using liquid metallurgy method with different chill materials like copper, Cast iron and steel.

Table 1: Aluminium 6061 chemical composition

Elements	Mg	Cu	Si	Fe	Mn	Zinc	Ti	Cr	Al
wt. by %	0.83	0.16	0.52	0.26	0.03	0.01	0.10	0.15	Remaining

Table 2: Boron Carbide Properties

Density (gm/cc)	Hardness (BHN)	Size (µm)	Young's Modulus (Gpa)	Melting Point (^oC)
2.52	350	105	450-470	2445

2.2 Composite Preparation

Low thermal conductivity ACC brick was used to prepare mold with chill on one side. [Chill end extracts the overall heat of the mold] Chills of varying thermal conductivity namely cast iron, stainless steel and copper were used. The arrangement of mold with chill end is as shown in figure 1 (a &b) (Mold cavity dimension 50mm x80mm x 180mm). Al6061 and boron carbide of particle size 105 microns is used as matrix and reinforcement materials. Resistance furnace is as shown in figure 1(c) was used to melt matrix material and boron carbide (powder form) was preheated to 250°c. After degassing and removing the slag, the melt was constantly agitated to create a fine vortex. The preheated B_4C particles (4, 6, 8 & 10 percent) were then introduced into the vortex, and mechanical stirring at 150 rpm was then applied for 15 minutes. To minimize atmospheric contamination, flux was added to the molten metal before pouring it into the mould figure 1 (d). The cast MMC composites were machined using CNC to carry out the different tests namely microstructure examination, hardness and tensile strength measurement.

(A) (B)

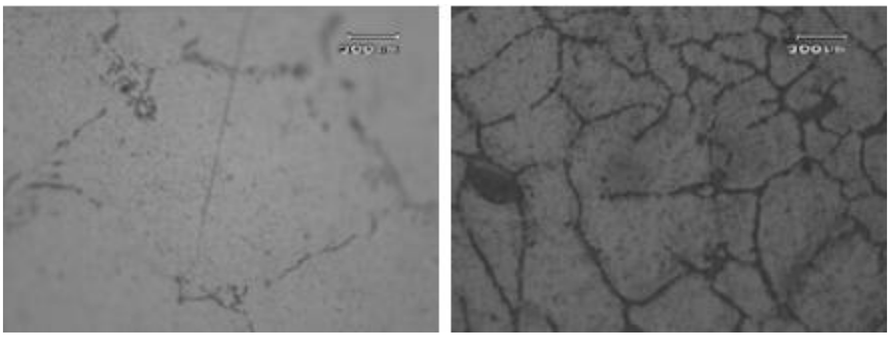
(C) (D)

Figure 1: (a) Mold with chill plate, (b)side view of mold, (c) Resistance furnace, (d) pouring of the melt (molten composite)

3. Results and Discussions

3.1. Microstructure Examination

Microstructure examination of the composites was carried out using optical microscope. This was carried out to study the dispersion and distribution of B_4C in Al matrix. Standard procedure was employed to carry out microstructure examination. Figures 2 -5 shows optical micrographs of AMCs with varying B_4C percentage (4 to 10%) cast in different chill materials. Faster cooling rate of copper chill has resulted in finer grain structure and improved mechanical properties whereas Stainless Steel chill results in coarse grain size. In case of cast iron chill, grains of moderate size were observed. This may be attributed to the thermal conductivity of Copper which leads to high cooling rate of casting near its vicinity. High cooling rate leads to fine grain structure. Whereas the thermal conductivity of SS and CI has slower cooling rate thus leading to coarse and medium grain structure.



ACC CI chill

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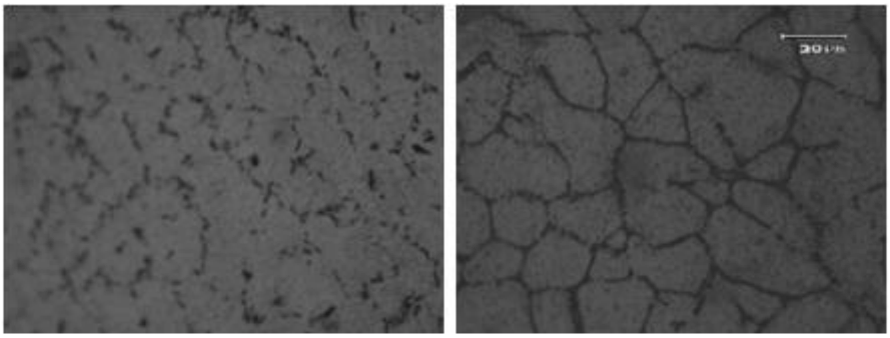
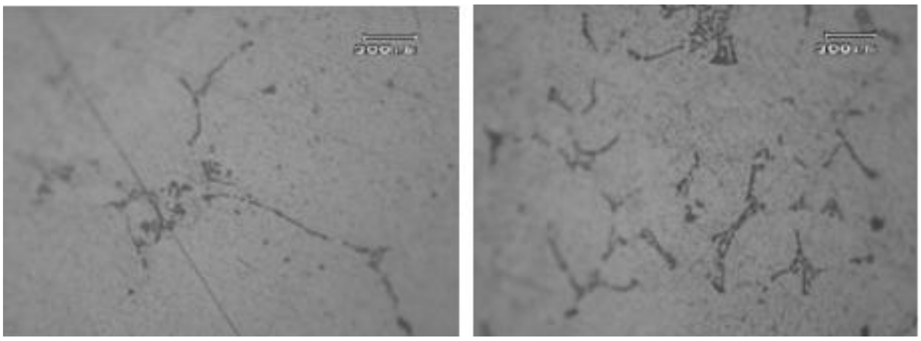
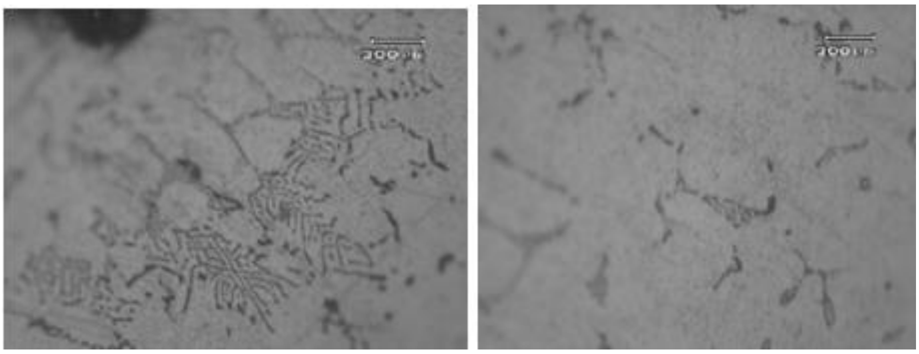


CU chill SS chill

Figure 2: Microstructure of 4% B_4C with various chill material

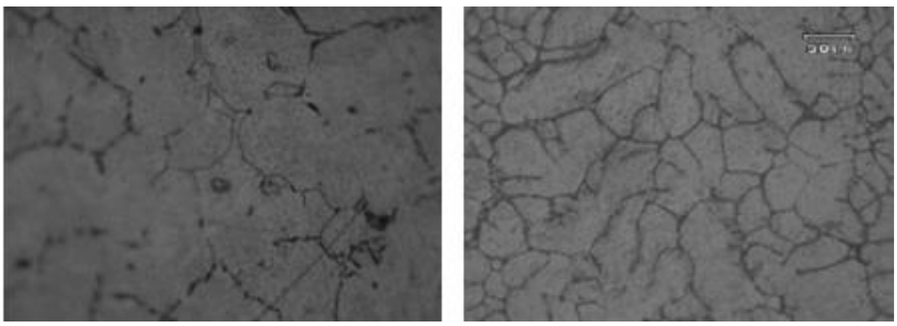


ACC CI chill

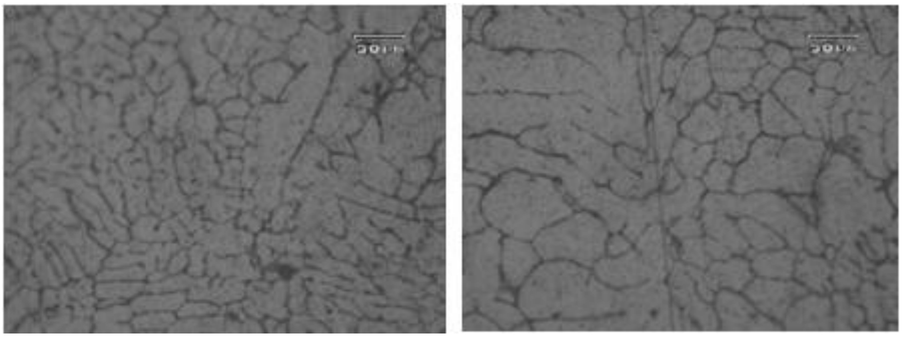


CU chill SS chill

Figure 3: Microstructure of 6% B_4C with various chill material

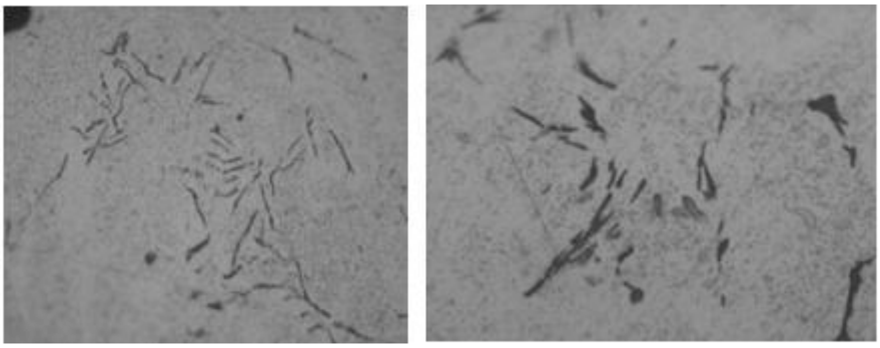


ACC CI chill

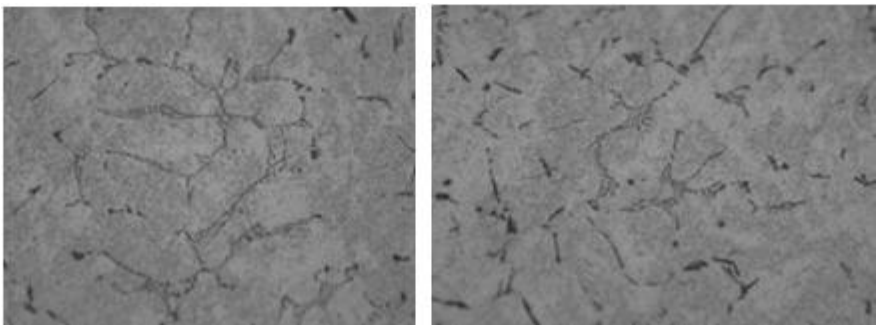


CU chill SS chill

Figure 4: Microstructure of 8% B_4C with various chill material



ACC CI chill



CU chill SS chill

Figure 5: Microstructures of 10% B_4C with various chill material

3.2 Ultimate Tensile Strength (UTS)

The tensile strength properties of the composites were assessed using a UTM[ASTM E08 standard was employed]. Figure 6shows dimensional detail of tensile test specimen.

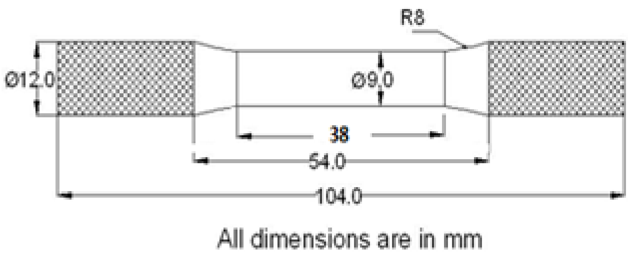


Figure 6: Dimensional detail of tensile test specimen

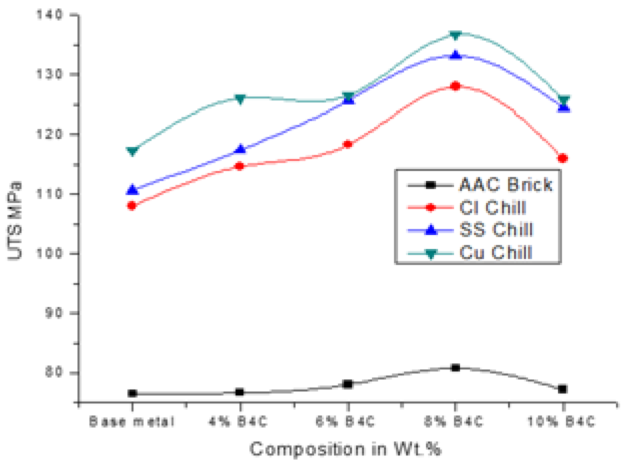


Figure 7: Tensile strength of Al-B_4C composite with various chill

Figure 7 shows the variation of UTS with varying percentages of B_4C made in various chill materials. It can be observed that the composite cast using ACC brick exhibits the least tensile strength values. Specimen made in the copper chill material exhibits the highest UTS value compared with the ones made with other chill material namely SS and CI. The increasing the tensile strength value may be attributed due to the higher thermal conductivity of copper (higher heat extraction which was lead to the formation of fine grain structure).

3.3 Hardness Studies

Micro-hardness studies of the composites were assessed using Vickers micro hardness tester (ZWICK Tester).Figure 8shows the variation of hardness values with different amounts of B_4C additions of the composite made using different chill materials. Here also it can be observed that the specimen made in ACC brick exhibits the least hardness values compared with the specimen made using different chill materials. Specimens cast using copper chill materials has exhibited higher hardness values compared with the ones made using other chill materials.

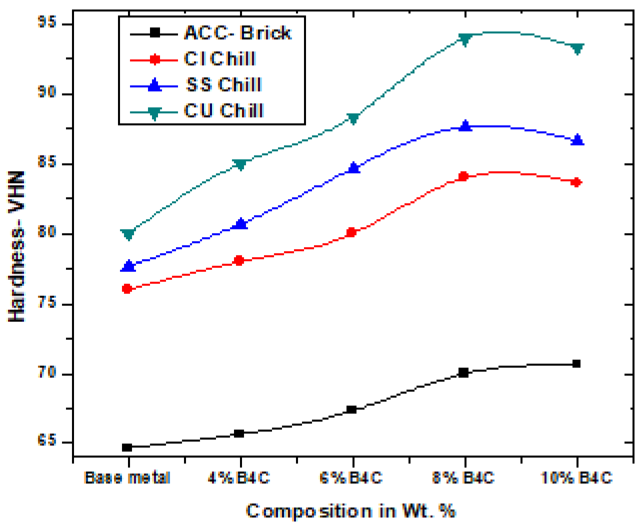


Figure 8: Hardness of Al-B_4C composite with various chill

4. Conclusion

From the studies carried out on Al6061 alloy subjected to B_4C additions cast in different chill materials indicate the following:

- Uniform dispersion of B_4C is observed in the matrix. Fine structure is observed in the specimen made in copper chills, coarse structure is observed in the specimen made in SS and CI chills.
- Higher tensile strength values are observed for the specimen made in copper chills.
- Higher hardness values are observed for the specimens made in copper chills.

Hence from this investigation it is observed that cooling rate has an influence in imparting higher strength values and hardness value to the composite.

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