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Research Paper

EFFECT OF PERCENTAGE REINFORCEMENT OF B4C ON THE TENSILE PROPERTY OF ALUMINIUM MATRIX COMPOSITES

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Metal Matrix Composites (MMCs) have been developed to meet the demand for lighter materials with high specific strength, stiffness and wear resistance. Particulate reinforced Aluminium Matrix Composites (AMCs) are attractive materials due to their strength, ductility, toughness. 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. Judicious selection of the variables is important to optimize the properties of composites. The shape and size of reinforcement particles and matrix composition have to be carefully chosen. In this paper an effort is made to enhance the mechanical properties like tensile strength and hardness of AMCs by reinforcing 6061Al matrix with B_4C reinforcement. By stir casting route, aluminium matrix was reinforced with 105 μm size boron carbide particulates of 6, 8, 10, 12 wt% respectively. The microstructure and mechanical properties of the fabricated AMCs was analyzed. The optical microstructure images reveal the homogeneous dispersion of B4C particles in the matrix. The reinforcement dispersion has also been identified with X-Ray Diffraction (XRD).The tensile strength and hardness was found to increase with the increase in the wt% of reinforcement.

Keywords: MMCs, Boron carbide particulate, Reinforcement, Matrix, XRD

INTRODUCTION

The Metal Matrix Composites (MMCs), like all other composites consist of at least two chemically and physically distinct phases, suitably distributed to provide properties not obtainable with either of the individual phases.

For many researches the term MMCs is often equated with the term light metal matrix composites. Substantial progress in the development of light metal matrix composites has been achieved in recent decades, so that they could be introduced into the most important applications.

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6061Al is widely used in numerous engineering applications including transport and construction where superior mechanical properties such as tensile strength, hardness, etc., are essentially required (Mohanty *et al.*, 2008).

6061Al is quite a popular choice as a matrix material to prepare MMCs owing to its better formability characteristics. Among different kinds of the recently developed composites, particle reinforced metal matrix composites and in particular aluminium base materials have already emerged as candidates for industrial applications.

Aluminium alloys are still the subjects of intense studies, as their low density gives additional advantages in several applications. These alloys have started to replace cast iron and bronze to manufacture wear resistance parts. MMCs reinforced with particles tend to offer enhancement of properties processed by conventional routes.

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.

A limited research work has been reported on AMCs reinforced with B_4C due to higher raw material cost and poor wetting. B_4C is a robust material having excellent chemical and thermal stability, high hardness (HV = 30 GPa), and low density (2.52 g/cm^3) and it is used for manufacturing bullet proof vests, armor tank, etc. Hence, B_4C reinforced aluminum matrix composite has gained more attraction with low cost casting route (Kerti and Toptan, 2008; and Toptan *et al.*, 2010).

EXPERIMENTAL DETAILS

The following section highlights the material, its properties and methods of composite preparation and testing.

Materials Used

The matrix material for present study is Al6061. Table 1 gives the chemical composition of Al6061. The reinforcing material selected is B_4C of particle size 105 µm.

Table 1: Chemical Composition of Al6061 by Wt%

Elements	Si	Fe	Cu	Mn	Ni	Pb	Zn	Ti	Sn	Mg	Cr	Al
%	0.4	0.7	0.2	0.1	0.05	0.2	0.1	0.15	0.001	0.8	0.2	left

The liquid metallurgy route (stir casting technique) was adopted to prepare the cast composites as described below. A batch of 200 g of 6061Al was melted to 750 °C in a graphite crucible using resistance furnace. The melt was agitated with the help of stirrer to form a fine vortex. 3 g of degassing tablet (C_2Cl_6 – solid hexachloro ethane) was added to the vortex and slag was removed from the molten metal. At the temperature of 800 °C the preheated B_4C particles was added into the vortex with mechanical stirring at 300 rpm for 5 mins. Before pouring the molten metal to mould, 2 g of cover flux (NaCl 45% + KCl 45% + NaF 10%) was added to the molten metal to reduce the atmospheric contamination. The molten metal at a temperature of 850 °C was then poured into mould preheated to 300 °C and allowed to solidify. The AMCs having different wt% (6, 8, 10, and 12 %) of B_4C were fabricated by the same procedure.

Microstructure and Testing

To study the microstructure of the specimens were cut and prepared as per the standard metallographic procedure. The specimen surfaces were prepared by grinding through 600 to 1000 mesh size grit papers. Velvet cloth polishing is done for the specimen to get fine surface finish. After that the specimens were etched using Keller's reagent (HCl + HF + HNO_3). The microstructures of etched specimens were observed using optical microscope.

The hardness was measured at different locations. The micro-hardness of polished samples was measured using Zwick/Roell Vickers hardness tester at a load of 50 g for 10 s.

The tensile specimens were prepared as per ASTM E8M standard. The dimensions of the specimen are shown in Figure 1. The ultimate tensile strength was estimated using computerized uni-axial tensile testing machine.

Figure 1: Tensile Specimen of Al6061-B_4C Composite

All Dimensions are in mm

(a) Tensile Test Specimen

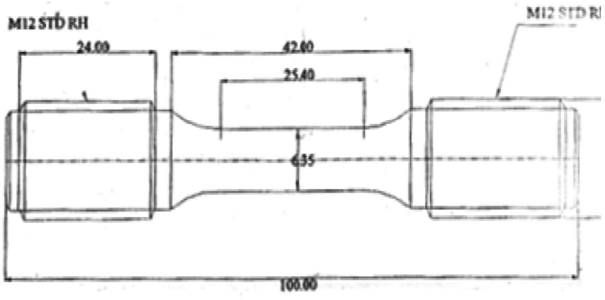
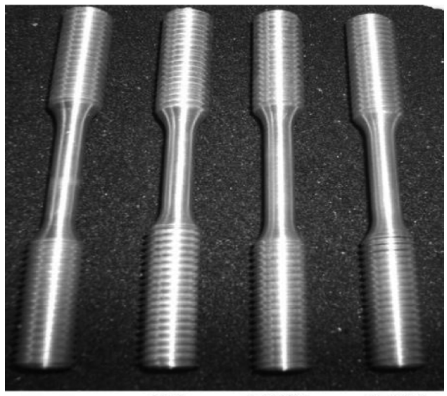


Figure 1 (Cont.)

(b) Tensile Specimen Before Test



6 % 8% 10% 12%

(c) Tensile Specimen After Test

6% 8% 10% 12%

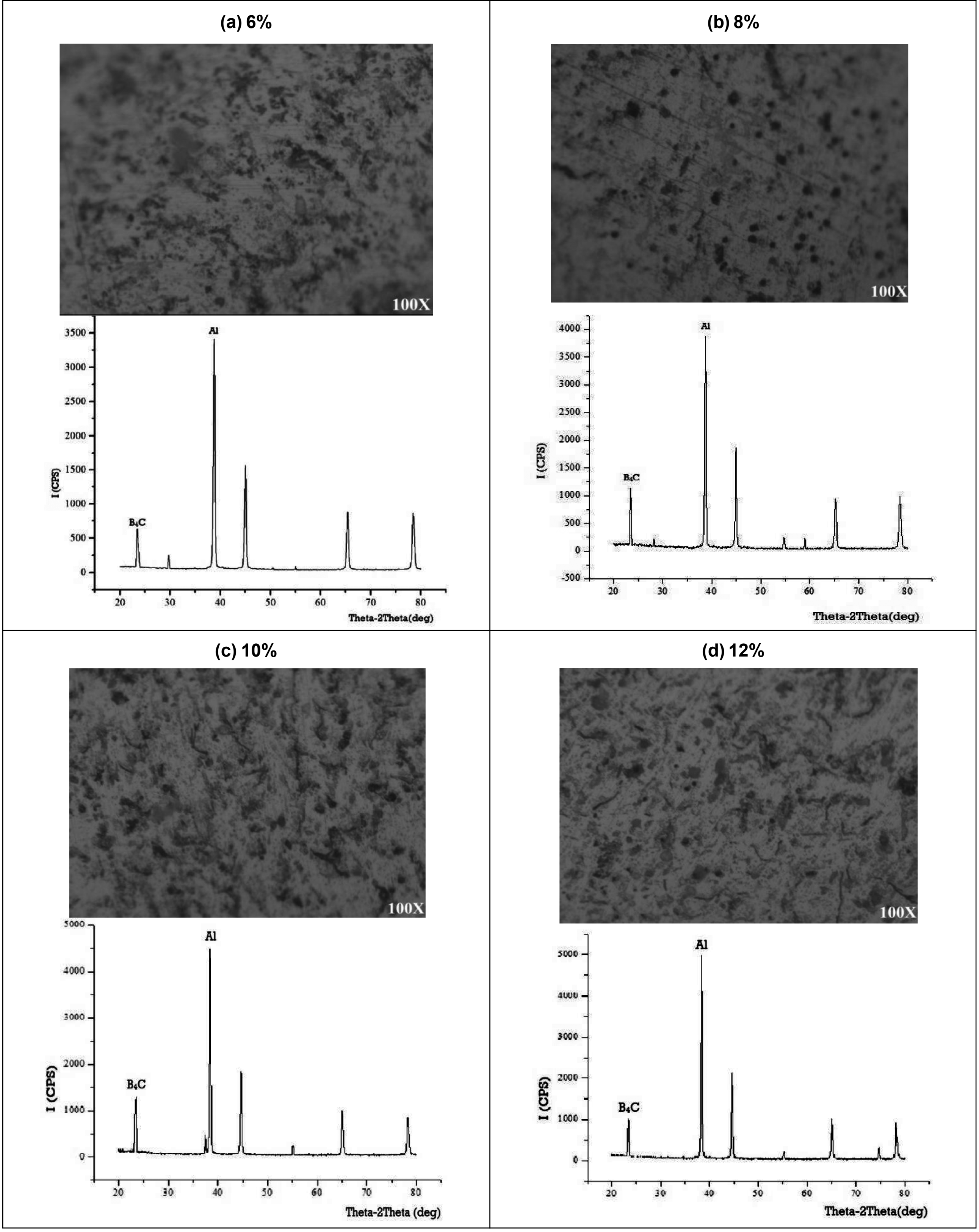
RESULTS AND DISCUSSION

Evaluation of Microstructure

Aluminium reinforced with B_4C particulate composites are successfully fabricated by stir casting process.

The optical microscope views of the fabricated AMCs are shown in Figure 2. It is observed from the figure that B_4C particles are dispersed uniformly in the aluminium matrix for all wt% of reinforcement. This can be attributed to the effective stirring action and the use of appropriate process parameters. XRD

Figure 2: Optical Photomicrographs and XRD Patterns of the Cast Al6061-B_4C AMCs



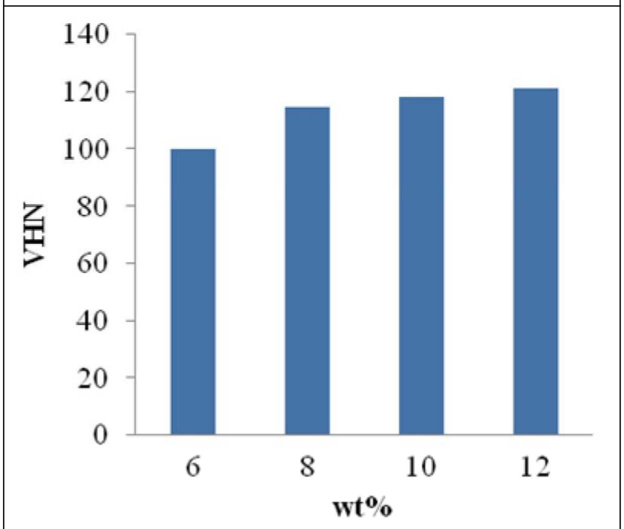
analysis confirms the presence of B_4C reinforcement within the matrix.

Evaluation of Mechanical Properties

Hardness Test Results

It was observed from Figure 3 that, the micro-hardness of AMCs was increased with increase in particle size. Addition of reinforcement particles in the melt provides additional substrate for the solidification to trigger there by increasing the nucleation rate and decreasing the grain size. The graph indicates that the hardness of the composite increases with increase in particle size as shown in Figure 3. The micro vicker's hardness of AMCs was found to be maximum for the wt% of 12%. The presence of such hard surface area of particles offers more resistance to plastic deformation which leads to increase in the hardness of composites.

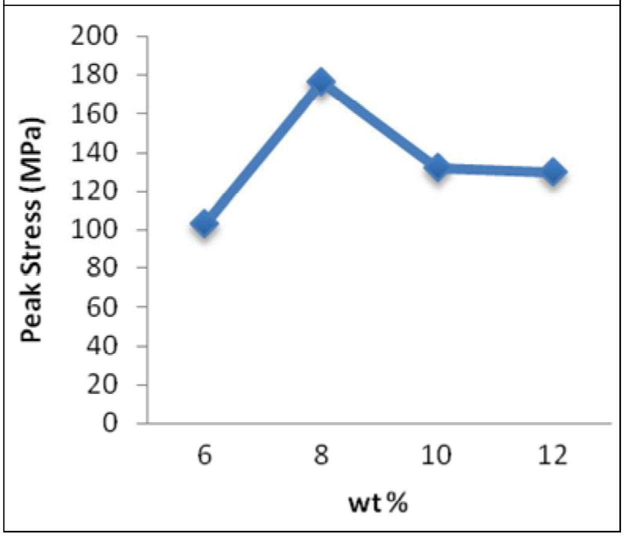
Figure 3: The Effect of the Particle Size of B_4C Particulates on the Hardness of Stir Cast AMCs



Tensile Test Results

The mechanical properties of matrix alloy Al6061 has improved on B_4C incorporation. Figure 4 shows the relation between tensile strength of the fabricated composites and B_4C wt%. It can be inferred that B_4C particles are very effective in improving the tensile strength of the composite. The tensile strength of AMCs increases with increase in particle size. The tensile strength of AMCs was found to be maximum for the wt% of 8%, and decreasing in the strength gradually with the increase in wt% of the reinforcement. The addition of B_4C particles in the matrix induces more strength to matrix alloy by offering more resistance to tensile stresses. Increase in the strength is due to the increase in hardness of the composite.

Figure 4: The Effect of the Particle Size of B_4C Particulates on the Peak Stress of Stir Cast AMCs



CONCLUSION

The Al-B_4C composites were produced by stir cast route with different wt% (viz., 6, 8, 10, 12 wt%) of reinforcement and the microstructure, mechanical properties are evaluated. From the study, the following conclusions are derived.

- Production of Al-B_4C composites was completed successfully.

- The optical micrographic study and XRD analysis revealed the presence of B_4C particles in the composite with homogeneous dispersion.
- The micro vicker's hardness of AMCs was found to be maximum (121.31 VHN) for the wt% of 12%.
- The tensile strength of AMCs was found to be maximum (176.37 MPa) for the wt% of 8 wt%.

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