

# **Fabrication and Testing of Al-Cu-B<sub>4</sub>C Composite by Mechanical Alloying**

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**ABSTRACT:** The present work focuses on the fabrication of reinforced with 12 wt. % of B<sub>4</sub>C particulates through ball milling. Ethanol (5 wt. %) has been used as a process control agent (PCA). In this work, mechanical alloying was used to synthesize aluminium matrix composite powder in a conventional ball mill under argon atmosphere with different milling time of 5, 10 and 15 hours. The ball to powder weight ratio was maintained at 10:1. Scanning electron microscopy (SEM) of the ball milled powder shows that addition of boron carbide particles accelerates the milling process, leading to a faster work hardening rate and fracture of aluminum matrix. SEM images show that distribution of boron carbide particles in aluminum matrix reaches a full homogeneity when steady state takes place. Energy-dispersive X-ray spectroscopy (EDX) is performed to check the contamination of composites during the mechanical alloying. Green densities and Hardness of each composite have been calculated. The Hardness of the composites was increased with increase in the milling time.

**KEYWORDS:** Composite, Mechanical alloying, SEM, EDX, Hardness, Green density.

## **I. INTRODUCTION**

Aluminium alloys are used in advanced applications because their combination of high strength, low density, durability, machinability, availability and cost is very attractive compared to competing materials. However, the scope of these properties can be extended by using aluminium matrix composite materials.

Metal matrix composites consist of at least two chemically and physically distinct phases suitably distributed to provide properties not attainable with either of the individual phases [1]. Metal matrix composites (MMCs) have been developed to respond the demand for lighter materials with high specific strength, stiffness and wear resistance [2, 3]. Aluminium is favoured as matrix material in MMCs because of its low density, easy fabrication and good engineering properties [4]. Metal-matrix composites (MMCs) have been developed to combine the good ductility and toughness of the metal matrix and the superior strength and stiffness of the ceramic reinforcement, and they have been used in some important engineering applications including automotive and aerospace [5].

The reinforcement of metals can have many different objectives. The reinforcement of light metals opens up the possibility of application of these materials in areas where weight reduction has first priority. The precondition here is the improvement of the component properties [6].

Aluminium-based alloys are widely used as aerospace and automotive components, because of their high specific strength, stiffness and formability. However, both pure Al and Al alloys possess poor wear resistance. On the other hand, Al alloy matrix composites are known to offer better wear resistance and bulk mechanical properties [7].

Examined that aluminium alloy-boron carbide composites were fabricated by liquid metallurgy techniques with different particulate weight fraction (2.5, 5 and 7.5%). Phase identification was carried out on boron carbide by x-ray diffraction studies. Microstructure analysis was done with SEM. Composites were characterized by hardness and compression tests. The results show an increase in the amount of the boron carbide. The density of the composites decreased whereas the hardness is increased. [8] Al-B<sub>4</sub>C composites with 0 wt. %, 5 wt. % and 10 wt. % of B<sub>4</sub>C were

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prepared by powder metallurgy and their properties were characterized successfully. Investigation of the effect of milling times (4, 8, 12, 16 hours) on microstructure, phase identification, hardness and neutron attenuation coefficient of composites has been studied. [9]

The increasing demand of light-weight materials in the emerging industrial applications, fabrication of aluminium boron carbide composites is required. In this context aluminium alloy - boron carbide composites were fabricated by liquid metallurgy techniques with different particulate weight fraction (2.5, 5 and 7.5%). [10]

The mechanical properties of Aluminium 2024 alloy reinforced with  $B_4C$ . An effort is made to enhance the mechanical properties like tensile strength and hardness of AMCs by reinforcing 2024 Al matrix with  $B_4C$  particles. By stir casting method, aluminium matrix was reinforced with boron carbide particulates of 325 mesh size. [11] Al-Rawajfeh et.al. [12] In 2009 had found in their investigation that the addition of Cu resulted in a linear increase of the hardness, and substantial reduction in the grain size, slight reduction the impact energy, substantial increase in the flow stress at 0.2 strains, and improve in the mechanical characteristics. Khakbizet. al. [13] in 2009 performed structural characterization of Al- $B_4C$  Nano-composite powders synthesized by mechanical alloying. They found the size of powder particles in the milled powder mixture was affected by the initial size and content of  $B_4C$  particle and aluminium powder.

## II. MATERIALS AND METHODS OF SYNTHESIS

A conventional ball mill consists of a rotating horizontal drum half- filled with small steel balls. As the drum rotates, the balls drop on the metal powder that is being ground; the rate of grinding increases with the speed of rotation. At high speeds, however, the centrifugal force acting on the steel balls exceeds the force of gravity, and the balls are pinned to the wall of the drum. At this point the grinding action stops.



Fig. 1 Conventional Ball Mill

In this experiment, aluminium powder (200 mesh), copper powder (325 mesh) and boron carbide powder (150 mesh) are used to make Al-Cu- $B_4C$  composite. Steel balls of 1.5 cm dia. are used to mill the powder. Initially aluminium 96 % and copper 4 % by weight mixture is made. In aluminium and copper mixture boron carbide powder is mixed as 12 % by weight. Then these mixtures are mixed in Fritsch Pulverisette MM-1552 mixer so that all powders are homogeneously mixed. Mixer is rotated at a speed of 600 rpm for 30 min. Powder mixture is milled in ball mill to produce aluminium metal matrix composites. In order to minimize the extreme cold welding of aluminium particles during the process, ethanol is used as a process control agent (PCA). Ball mill was rotated at a rotation speed of 115 rpm and the milling time of 5, 10, 15 (hours) and the ball to powder weight ratio was varied as 10:1 respectively. The cylinder is filled with pure argon gas to prevent oxidation during the milling process. Synthesized samples of Al-Cu

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with 12 wt. % boron carbide and milling time of 0, 5, 10 and 15 hours are used for making pellets. During compaction, force of 69 KN was employed for aluminium composites with soaking time of 2 minutes. Zinc stearate as a lubricant was admixed 0.5 wt.% and applied to the top punch, bottom punch, and die with a view to reduce the frictional effect during compaction.



Fig. 2 Image of Compaction press

Compaction press is used for a wide range of press applications. The press has a compact, small footprint design making it ideal for bench-top and glove box laboratory applications. With a rigid steel construction, and protective safety shield as standard, this compaction press is particularly well-suited for pellet press, and thin film press applications

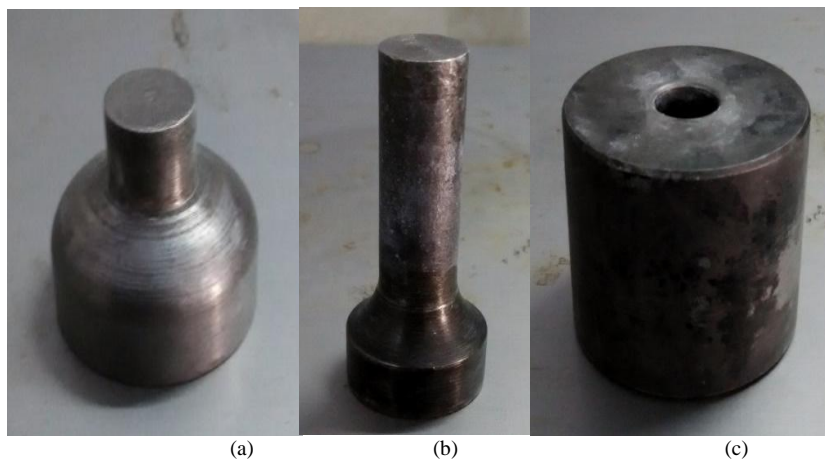


Fig. 3 Image of (a) lowerpunch (b) upper punch and (c) die

Figure (a) shows a lower punch which is inserted into the die and remains constant at their position in the whole operation, whereas figure (b) shows a upper punch which is inserted into the die gradually and pressure increases by the press to the die. After that die was filled with a known volume of powder delivered from a fill shoe. Compaction of the powder within the die with punches to form the compact. Generally, compaction pressure is applied through punches from both ends of the toolset in order to reduce the level of density gradient within the compact.



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.Fig. 3(d)Image of Pellet

After the compaction of powder using lower and upper punch into the die the material formed is of Al-Cu-B<sub>4</sub>C composite and is shown in the above figure.

### III. EXPERIMENTAL RESULTS

#### Scanning electron microscopy (SEM)

The milled samples were characterized for their microstructure and distribution of B<sub>4</sub>C particles in the Al matrix, using scanning electron microscopy (SEM). The micrograph thus obtain are used in characterizing the various samples of powder. JOEL-JSM 6510 LV SEM has been used in this work.

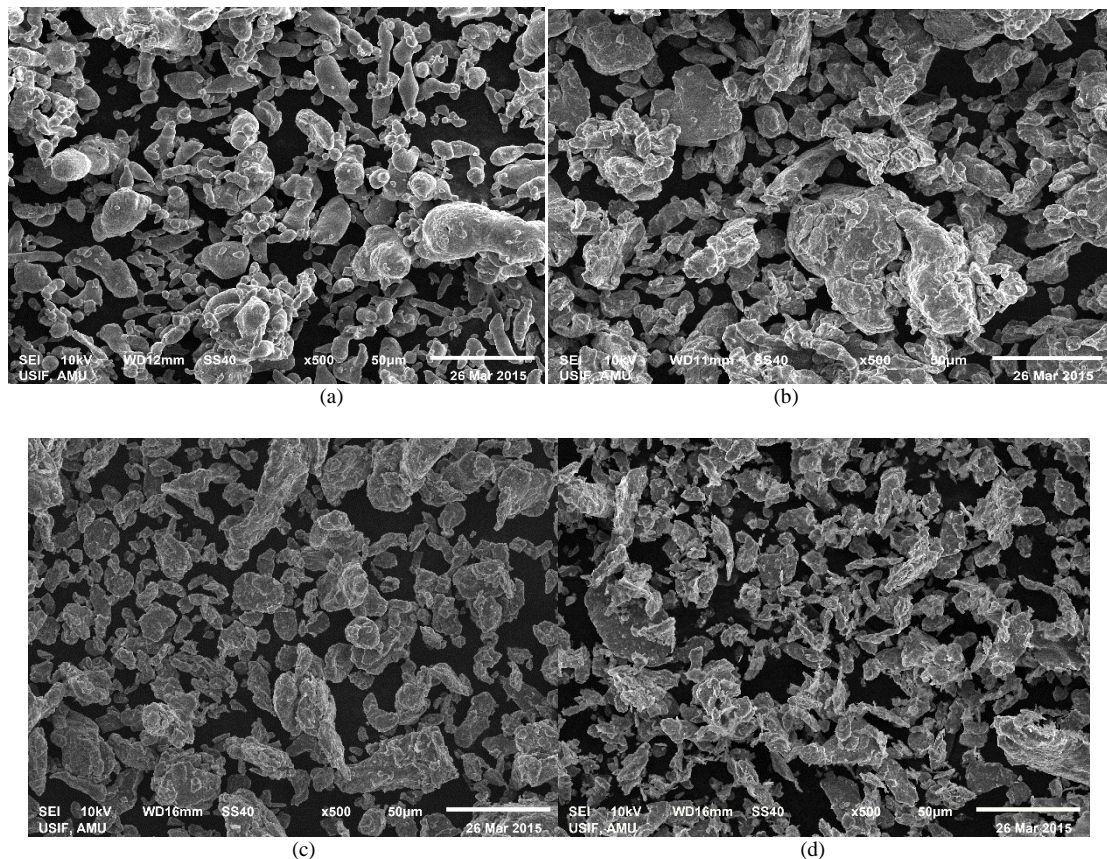


Fig. 4 SEM micrographs of Aluminium composites for different milling time: (a) 0 h, (b) 5 h, (c) 10 h and (d) 15 h

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Fig.4 (a) shows that the period of 0 hours of milling,  $B_4C$  found scattered among the aluminum matrix. The increase in the milling time causes a more uniform distribution of  $B_4C$  powders in aluminum matrix. Fig. 4 (b) shows the uniform distribution of  $B_4C$  powders. In the early milling process,  $B_4C$  is stick among aluminum particles. The increase in the milling time will cause cracks in the particles and the aluminum particles broke down and form a new surface with  $B_4C$  particles attached to it. Fig. 4 (c) shows the  $B_4C$  particles spread located between the aluminum matrixes. An increasing in milling to 15 hours Fig. 4 (d) showed that there was a more even uniform distribution. This could be due to the occurrence of cracks and broken during the milling process causes the aluminum and  $B_4C$  particle more distribution uniform. There was also observed that the changes in the size of the  $B_4C$  particles occur due to particle fracture and breakdown during the milling process.

Thus, from all the SEM micrographs it is observed that as amount of boron carbide is increased fracturing rate of particles increased and particle size distribution becomes more homogeneous.

## Energy Dispersive X-ray Spectroscopy (EDX)

Elemental analysis was carried out in an EDX system attached to scanning electron microscope to investigate the chemical composition of final powder products after 5, 10, 15 hours of ball milling with 12 weight percentages of boron carbide reinforcement. The EDX diffractograms for the same are shown in fig.5 all the EDX graphs are taken after performing ball milling. From the images it is clear that all the elements which are added in the mixture are present, as their peaks are clearly visible.

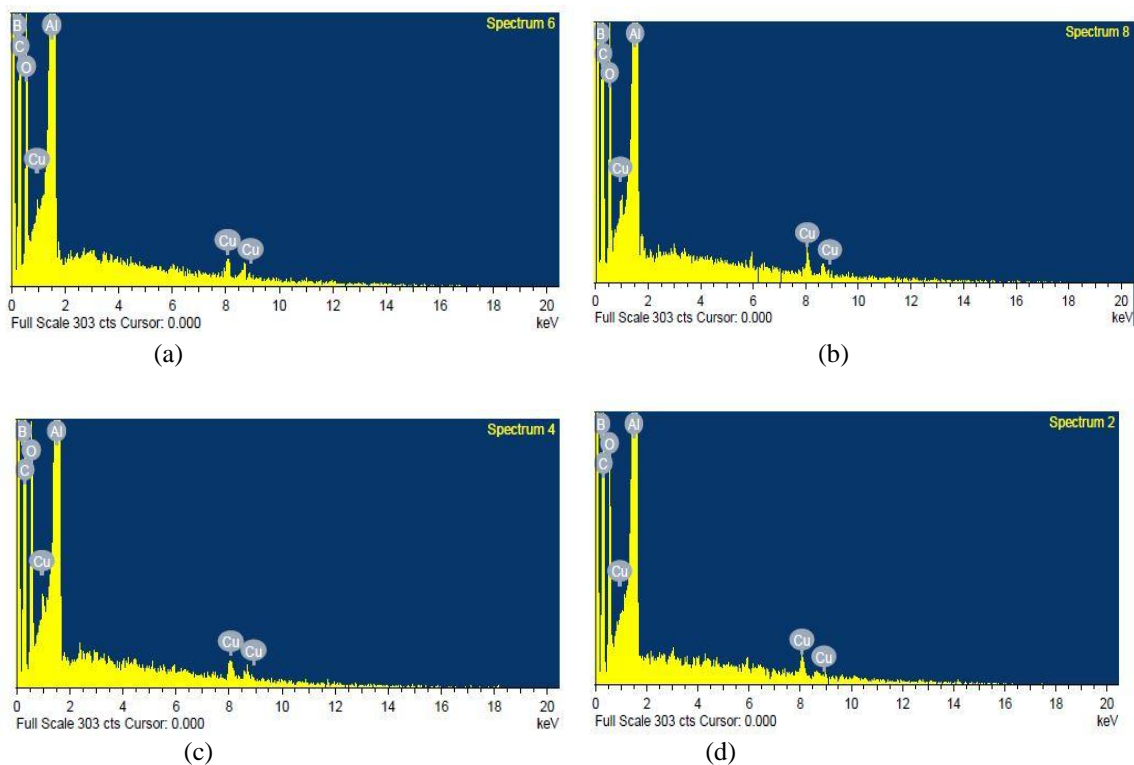


Fig. 5 EDX diffractograms of milled Aluminium composites for different milling time: (a) 0 h, (b) 5 h, (c) 10 h and (d) 15 h

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## Density of Aluminium composite

Fig. 6 shows that increase in milling time will cause the density of the Al-Cu-B<sub>4</sub>C composite to decrease slightly. Milling process causes microstructure to experience changes which in turn affects the density of the material. Increasing milling times introduce more porosity into the material which turn reduces its density. Aluminium has higher density which is 2.70 g/cm<sup>3</sup> compared to boron carbide which is 2.51 g/cm<sup>3</sup>. Combination of these two materials will produce a composite with lower density. Mohanty et al. [14]

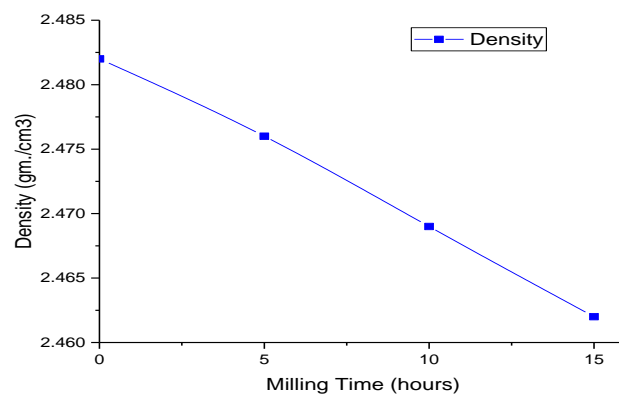


Fig. 6 Density of aluminium composite.

## Hardness of Aluminium composite

The hardness of the Al-Cu-B<sub>4</sub>C composites was evaluated using Rockwell hardness testing with 100 kg load and 0.5 mm diameter steel ball indenter. The indentation time for hardness measurement was 15 seconds.

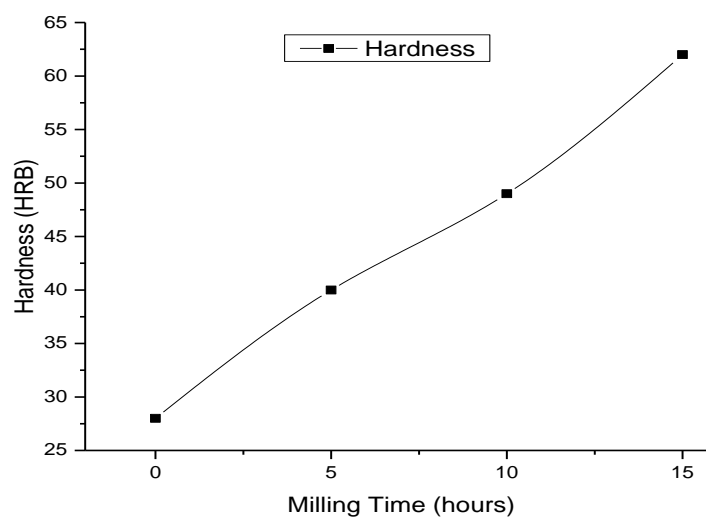


Fig 7 Hardness of aluminium composite

Fig. 7 shows the effect of milling times on hardness of Al-Cu-B<sub>4</sub>C composites. It is clearly shown that the hardness increased slowly with milling times between 0 hours to 15 hours. Slow increment of hardness with milling time might

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be due to increase in particles agglomeration. Grain boundary is one of defects that lead to increase in the value of free energy of materials. Thus, in order to reduce free energy in materials, particle size should be large enough to shrink the grain boundaries.

## IV. CONCLUSION

In the present experimental work we have successfully synthesized Al-Cu-B<sub>4</sub>C composites at different milling time by mechanical alloying process. In addition to this following conclusions are drawn from the analysis.

1. SEM is showing that as the milling time increases more homogeneous composites are obtained.
2. EDX analysis shows that there is no contamination in the composites during mechanical alloying.
3. The green density of the composites are decreasing as the milling time increases.
4. The hardness of the composites are increasing as the milling time increases.

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