Processing, Microstructure and Mechanical Behaviour of Al6262-4wt. % B_4C Composites

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***Abstract*-Metal matrix composites play an important role in automobiles, aerospace, sports and marine sector. In the present investigation, an attempt has been made to investigate the mechanical properties of Boron Carbide (B_4C) particulates reinforced Al6262 alloy composites. Al6262 alloy was used as the base matrix. B_4C particulates were used as reinforcement. The composites containing 4 wt. % of B_4C particulates were fabricated by using liquid metallurgy route. The microstructures of the composites were examined by scanning electron microscopy. Further, tensile behaviour of as cast Al6262 alloy and 4 wt. % B_4C composites were studied. Mechanical properties like hardness, ultimate tensile strength, yield strength and percentage elongation were evaluated as per ASTM standards. Microstructural observation revealed the uniform distribution of particles in the Al6262 alloy matrix. Further, it was found that the hardness, ultimate tensile strength and yield strength of composites were increased due to presence of boron carbide particle in the Al6262 alloy matrix. Percentage elongation of the composites decreased with addition of 4 wt. % of B_4C particulates in soft Al alloy.**

Keywords – Al6262 Alloy, B_4C particulates, Stir Casting, Hardness, Tensile Behaviour

I. INTRODUCTION

In the past, few years the global need for low cost, high performance and good quality materials has cause the shift in research from monolithic to composite materials. Aluminium is one of the major metals used in in the preparation of the metal matrix composites [1]. Aluminium alloys are broadly classified into wrought alloys and cast alloys. Major alloying elements in aluminium alloys are magnesium, copper, manganese, zinc and silicon. Aluminium alloys are frequently chosen as matrix because of their low density, good isotropic mechanical properties, high damping capacity, excellent corrosion resistance, and reasonable cost [2-4]. The replacement of conventional materials by lighter metals such as aluminium alloy is, therefore, highly required. However, aluminium alloys are not sufficiently stiff or strong for many applications so the composition of reinforcement is very much necessary. Therefore, the introduction of a hard-ceramic material into a metal matrix yields a composite material which results in a better combination of physical and mechanical properties that cannot be achieved alone with the matrix phase. Particle reinforced metal matrix composites are attractive for automotive and aeronautical application due to their high strength and low density [5, 6]. They are also interesting for their high temperature behaviour, good creep and wear resistance, also high stiffness than the base alloy. The most commonly used aluminium alloy matrices are 7475, 6061, 6068, 7010, 5052, 2024, 2014, 2219 and 5083.

Among them AL6262 is used in our current research work, magnesium and silicon are the major alloying elements which are used in the manufacturing of hydraulic components and various aircraft structures (extrusions, forgings, sheets). Other applications like transport applications, rock climbing equipment's, marine, in line skating-frames, bicycle frames and mobile equipment [7]. These also found in high stressed parts fabrication. Micro B_4C is chosen as reinforcement phase due to its suitable properties, such as wear resistant, high strength and high stiffness. The matrix-particle interface strength is important as it manages the efficiency of load transfer affecting the strengthening as well as the ease of de-cohesion which as implication for the composites failure mechanism. The two main factors associated to reinforcement particles are the volume fraction and the size of the reinforcing particulates. With the increasing in the volume fraction the strength is improved due to larger number of dislocation barrier but at the cost of condensed ductility, as deformation is localized on a lesser volume of the plastic matrix which is less able to accommodate the deformation. On the other hand, the increase in the strength can also be achieved with decreasing particle size, due to a greater number of particles for the same volume fraction, whereas at the same time ductility is preserved because below a critical size, particles no longer rupture. Statistically larger flaws and other defects are more likely to exist because of the larger particles size and weaken the strength of composites when compared with the composites containing smaller size of the particles.

Shisheng and co-authors [8] studied the mechanical behaviour of in situ carbon nano tube and silicon carbide reinforced Al6061 aluminium matrix composites. Results show that significant improvement in tensile properties with the SiC size to be 7 microns, which has ductility of 8.5% and Young's modulus of 98 GPa, and tensile strength of 428 MPa. Ibrahim et al. [9] investigated the impact toughness of Al-15 vol. % B_4C composites produced using powder injection method. Aluminium based composites exhibited better toughness. The composite impact toughness was controlled by the precipitation and coarsening of hardened phase particles. Xin Gao et al. [10] reported the mechanical properties of graphene reinforced aluminium framework composites. Graphene strengthened aluminium lattice composites were set up by powder metallurgy course. The outcomes demonstrate that with expanding the graphene substance, a definitive elasticity of the composites at first increments and later reductions. In any case, the extension to crack of the composite steadily diminishes. From the writing overview, it can be presumed that the vast majority of the studies are given to miniaturized scale measure particulates. However, the utilization of nano estimated clay particulates is moderately restricted.

So, the present work aims to develop high strength and low density composites for structural and transport applications by usage of micro sized B_4C particles. With the development of new processing techniques stir casting process has evidenced to be comparatively economical and easy to use. The preparation of the composites focuses on B_4C ceramic particulates that are reinforced in steps of two into the vortex formed in molten metal Al6262 alloy by liquid metallurgy stir casting.

II. MATERIALS USED AND EXPERIMENTAL DETAILS

A. *Matrix material*

In the present experimental investigation, Aluminium Alloy 6262 is used as the matrix material and its chemical composition is shown in Table 1. Al6262 alloy is one of the wrought aluminium alloy containing magnesium as the major element and it is combined with silicon and copper. The density of Al6262 is 2.70 g/cm^3 and the melting point is considered as 660 ˚C.

TABLE I Chemical Composition of Al6262 alloy

Zn	Mg	Si	Fe	Cu	Ti	Mn	Cr	Al
0.25	1	0.6	0.5	0.25	0.15	0.15	0.1	Balance

B. *Reinforcement material*

The main benefit of introducing the reinforcement material to the matrix is to enhance both mechanical and tribological properties. In the current research, micro B_4C particulates is been used because the micro-particles of B_4C are water dispersion is having high hardness and good dimensional, phase stability and it also is used to improve fatigue resistance, smoothness, fracture toughness, and creep resistance. The density of B_4C is 2.52 g/cm^3, is less than that of base alloy. So, the reinforcement material is added in steps of two during the preparation of the composites to have proper mixing with the base matrix and to avoid the difficulty of agglomeration.

C. *Fabrication Procedure*

In the present research, the composites of micro B_4C and Al6262 is mostly arranged by two phase fluid metallurgy mix throwing process and an endeavour has done to examine the tractable properties of Al6262 amalgam and Al6262 – 4 wt. % micro B_4C composites. Firstly, the micro B_4C particulates were preheated for 400˚C to make their surface oxidized and enhance the wettability, then the required measure of Al6262 is kept in a graphite pot which was set in electric furnace at a working temperature of 750˚C.The furnace temperature was raised up completely to soften the bolster stock totally. Once the Al6262 is totally liquefied then the degassing tablet i.e. Solid Hexa Chloroethene (C_2Cl_6) was acquainted with the liquid dissolve and blended for 4 to 8 minutes, which helps in the expulsion of undesirable adsorbed gases from the soften [11]. Next the pre-warmed particles are likewise brought into the liquid liquefy of Al6262 amalgam novelty which incorporates two phase expansion of the fortification into the framework. The two-phase options incorporate isolating the 4wt. % of micro B_4C particles in two equivalent weights and after that individual weights of particles are included two phases rather including at the same time. Fig. 1a and b shows the stir casting set up and the prepared composites with the cast iron die which used in the present study.

(a)

(b)

Fig.1. Showing (a) Stir casting set up (b) castings obtained

D. Characterization and Testing of Composites

The investigation of microstructure is the key part of the examination. These microstructures will help in describing the arrangement of the structure furthermore the properties of materials. For inspecting the microstructure, the cast compound Al6262 and its composites strengthened with 4 wt. % of B_4C were cut by hack saw blade for the required measurement around 5mm by settling to the hand savvy. Once the sample is separated, then the surfaces of the specimens were cleaned by utilizing distinctive review water verification emery papers like 400, 800, 1000 and 1200 grit sizes by utilizing precious stone glue on mescaline texture [12]. Encourage, the cleaned examples were completed for drawing process by utilizing Keller's reagent to uncover the grain structure. In the wake of drawing tests were washed and dried altogether, these specimens were analysed by utilizing scanning electron microscope to know the uniform dispersion of B_4C particulates in Al6262 grid.

When uncovering the uniform appropriation of particulates in base grid, then the composites and the base amalgam Al6262 tests were set up according to the ASTM E8 standard with the gage measurement of 9mm, gage length of 45mm and general length of 104mm for the tensile test as appeared in figure 2, which were tried at room temperature by utilizing modernized universal testing machine with the cross head speed set at 0.280 mm/min. Ultimate and yield stress values were plotted to know the impact of B_4C particulates on elastic conduct of Al6262 amalgam composites. The best results were taken as normal by directing different various test and distinctive a few tractable properties like extreme elasticity, yield quality and rate extension were assessed for as cast Al6262 compound furthermore for Al6262-4 wt. % B_4C.

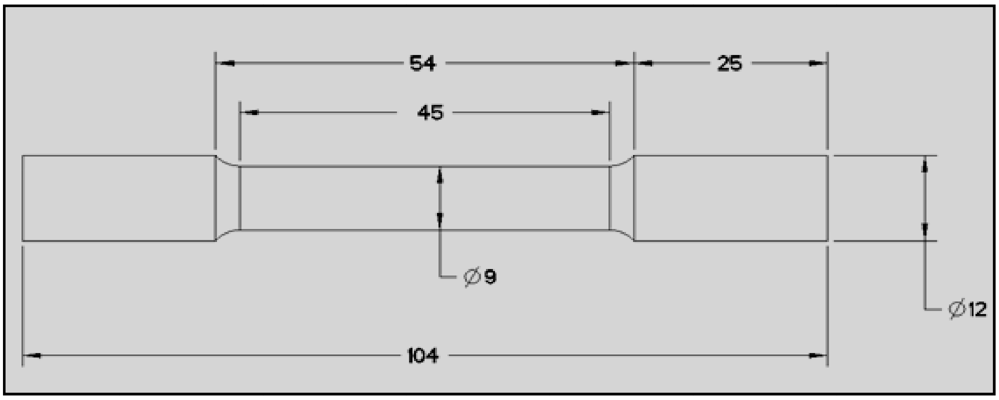
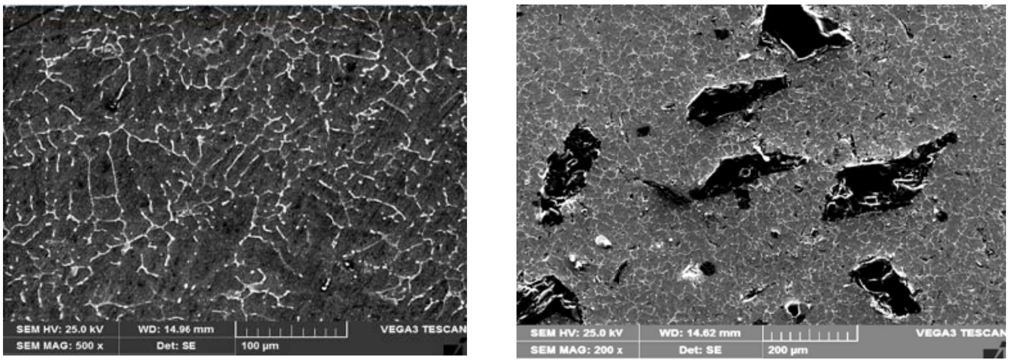


Fig.2.Schematic diagram of tensile test specimen

III. RESULTS AND DISCUSSION

A. Microstructural Study



(a) (b)

Fig.3. Showing scanning electron micro photographs of (a) as cast Al6262 alloy (b) Al6262-4wt. % B_4C composites

Fig. 3a and b shows the SEM micrographs of as cast alloy Al6262 and the composite of 4 wt. % of micro B_4C reinforced with Al6262. These two examined samples were chosen from the middle segment from the cylindrical specimens. The microstructure of as cast Al6262 alloy comprises of fine grains of aluminium solid solution with a sufficient dispersion of inter-metallic precipitates.

In the second microstructure, the small size of the composite get dense and shut than that of the framework combination in light of the fact that micro molecule go about as nucleation site. It additionally demonstrates the great holding between the framework and the fortification alongside the uniform homogenous circulation of micro estimated B_4C particulates with no agglomeration and bunching in the composites [13]. This is essentially because of the viable mixing activity accomplished all through the expansion of the fortification by two phases. The micro particles everywhere throughout the grain limit of the lattice obstruct the grain improvement and oppose the separation development of grains amid stacking.

B. Ultimate Tensile and Yield Strength

Tensile test of specimens with ASTM standards were carried out using universal testing machine (UTM), the test was conducted for 3 specimens and the average is taken for each composition. The ultimate strength and yield strength is investigated. The results are tabulated and shown in table 2 and fig. 4 and 5.

TABLE II Showing tensile properties of Al6262 and its B4Ccomposites

Tensile properties		
Composition	**Ultimate Tensile Strength (MPa)**	**Yield Strength (MPa)**
Al6262 Alloy	142.6	121.2
Al6262 + 4% B_4C	168.7	146.3

Fig. 4 demonstrates the variety of ultimate tensile strength (UTS) of base combination and 4 wt. % of B_4C particulates. A definitive rigidity of Al6262 combination with 4 wt. % B_4C particulates expanded when contrasted with as cast base Al6262 compound. The microstructure and properties of hard earthenware B_4C particulates controls the disfigurement of the composites. Because of the solid interface holding, stack from the lattice exchanges to the fortification bringing about expanded extreme elasticity [14]. Fig. 4 demonstrates the 18 % change in a definitive elasticity of Al6262 compound in the wake of including 4 wt. % of B_4C particulates.

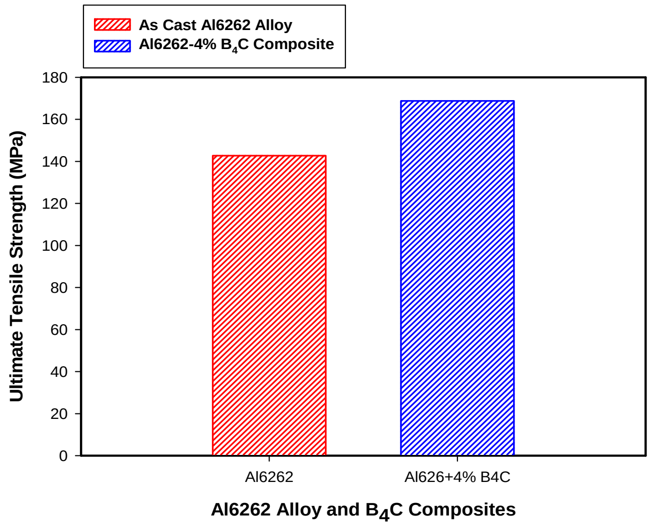


Fig.4. Ultimate tensile strength of Al6262 alloy and B_4C composites

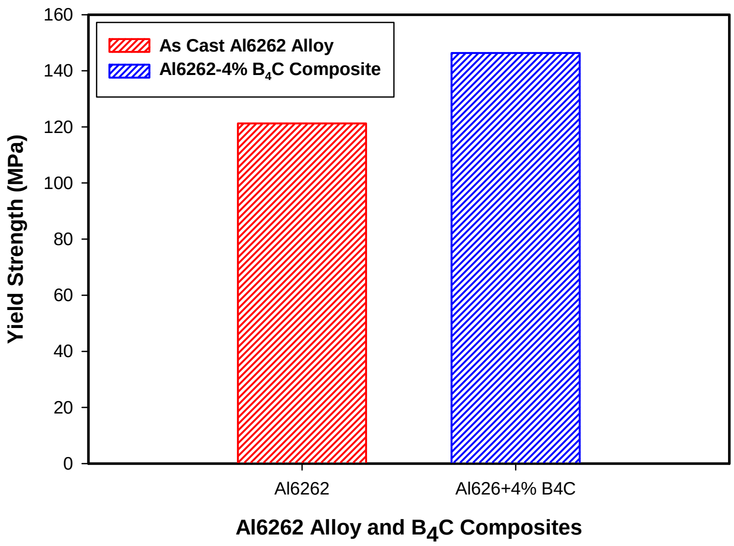


Fig.5. Yield strength of Al6262alloy and B_4C composites

Fig. 5 shows variation of yield strength (YS) of Al6262 alloy matrix with 4 wt. % of B_4C particulate reinforced composites. It can be seen that by adding 4wt. % of B_4C particulates yield strength of the Al6262 alloy increased from 121 MPa to 146 MPa. This increase in yield strength is in agreement with the results obtained by several researchers, who reported that the strength of the particle reinforced composites is more strongly dependent on the weight fraction of the reinforcement [15].

C. Percentage Elongation

Fig. 6 demonstrating the impact of B_4C content on the elongation (ductility) of the composites. It can be seen from the chart that the flexibility of the composites diminishes essentially with the 4 wt. % B_4C fortified composites. This diminishing in rate prolongation in correlation with the base amalgam is a most usually happening detriment in particulate fortified metal lattice composites. The lessened pliability in composites can be ascribed to the nearness of B_4C particulates which may get broke and have sharp corners that make the composites inclined to restricted split start and proliferation. The fragile impact that happens because of the nearness of the hard-artistic particles bringing on expanded neighbourhood stretch focus locales may likewise be the reason.

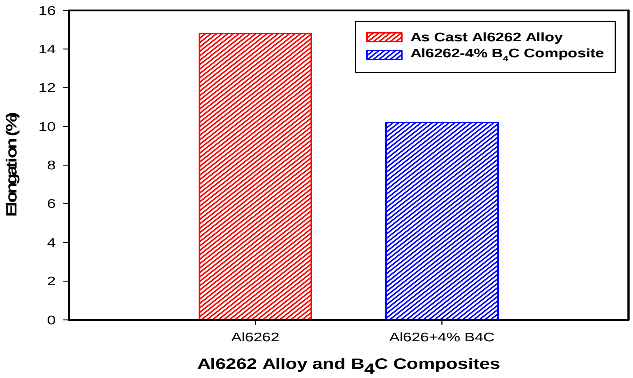


Fig.6. Percentage elongation of Al6262 alloy – B_4C composites

IV. Conclusions

The present work on synthesis and characterization of Al6262 alloy-micro B_4C composites has led to the following conclusions:

1. Al6262 alloy composites with 4 wt. % were successfully fabricated via melt stirring method involving two step additions.

2. Two stage addition methods are adopted for introducing B_4C particulates into Al6262 matrix during melt stirring has resulted in homogeneous distribution of B_4C particulates with no clustering or agglomeration as evident from SEM microphotographs.

3. Improvements in ultimate tensile strength of the Al6262 matrix were obtained with the addition of B_4C particulates. The extent of improvement obtained in Al6262 alloy after addition 4 wt. % of B_4C particulates were 33%.

4. Improvements in yield strength of the Al6262 matrix were obtained with the addition of B_4C particulates. The yield strength of Al6262 alloy increased from 121.2 MPa to 146.3 MPa after adding 4 wt. % of B_4C particulates.

5. Al6262 alloy-4 wt. % of B_4C composites shown less percentage elongation as compared to base matrix Al6262 alloy.

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