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Mechanical Characterization Of Al2030 Alloy And B_4C Particulates Reinforced Composites

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ABSTRACT: *- In the present examination the Al2030 alloy composites containing 3 and 6 wt. % of* B_4C *particulates were created for the investigation. The microstructure of the composite was analyzed by scanning electron microscopy; micrographs were taken to recognize the nearness of* B_4C *particulates in the aluminum lattice. Further, mechanical behavior of as cast Al2030 alloy and Al2030 alloy-3 and 6 wt. % of* B_4C *composites were examined. Mechanical properties like hardness, UTS, yield strength and ductility were assessed according to ASTM benchmarks. Microstructural perception uncovered the uniform dissemination of particles in the Al2030 composite framework. From the investigation, it was discovered that hardness, ultimate and yield strength values of composite was expanded due to presence of* B_4C *particles in the composite. Further, from the investigation ductility of the composite abatements with the expansion of* B_4C *particulates.*

KEYWORDS: *- Al2030 Alloy,* B_4C*, Microstructure, Stir Casting, Mechanical Behavior*

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I. INTRODUCTION

A composite is a material that consists of two or more combined constituents that are combined at a macroscopic level and are not soluble in each other. One constituent is called the reinforcing phase and the one in which it is embedded is called the matrix. The reinforcing phase material may be in the form of fibers, particles, or flakes [1, 2]. The matrix phase materials are generally continuous. Examples of composite systems include concrete reinforced with steel and epoxy reinforced with graphite fibers etc.

In recent years, micro particle reinforced metal matrix composites (MMC's) have gained wide acceptance because of their attractive properties [3]. The focus of research and development in the (MMC) area has recently shifted towards low cost reinforced composites which are targeted for automotive and aerospace applications [4]. MMC are one of the important and widely known composites because of their large variety of properties offered in combining many possible materials and reinforcements which allows altering material properties to meet specific requirements [5]. Actually compared to un-reinforced materials, composites possess significantly improved properties including high specific strength, specific modulus, damping capacity, stiffness, hardness, good wear resistance, low co-efficient of thermal expansion, high thermal resistance, corrosion resistance and also high strength to weight ration, light weight, low cost, behaviors [6]. Popular reinforcement materials for these composites are silicon carbide, alumina, boron carbide, titanium carbide, and graphite particles; while, aluminium, titanium and magnesium are the most common matrix materials.

Amongst MMCs aluminium metal matrix composites (AMMCs) have received particular attention in the past three decades due to their high specific strength and stiffness and superior wear resistance [7]. There are several fabrication techniques available to produce AMC materials but there is no unique route in this. Due to the choice of material and types of reinforcements, fabrication techniques can be varying. Generally there are two types of fabrication methods available – (i) solid phase fabrication method includes diffusion bonding, extrusion, drawing, hot rolling, powdered metallurgy route. (ii) Liquid phase fabrication method includes liquid metal infiltration, squeeze casting, compo casting, and pressure casting [8]. Stir casting is generally accepted promising route because of its simplicity, flexibility, and applicability to large quantity production.

The particulate reinforced aluminium matrix composite are gaining importance because of their low cost with advantages like isotropic properties and the possibility of secondary processing facilitating fabrication of secondary components. Cast aluminium matrix particle reinforced composites have higher specific strength, specific modulus and good wear resistance as compared to unreinforced alloys.

In recent years, ceramics have widely been considered as reinforcement materials. Apart from the very popular SiC and Al_2O_3 reinforcements, researchers have also tried out mica, zircon and graphite [9, 10]. The ceramic reinforcement of the metal matrix can lead to the improvement of mechanical properties like yield strength, ultimate tensile strength and compressive strength, although there might be loss in ductility [11].

In general aluminium based MMCs offer substantial increase in elastic modulus and strength over the unreinforced alloys and often accompanied by large reduction in percent elongation. Properties of composites are affected by the reinforcement particle size, shape and volume fraction of the reinforcement, matrix material and reaction at the interface. Further, heat treatment played important role on the properties of Al based MMCs. In the present work an attempt is made to develop the Al2030-B_4C composites by using stir casting method. Further, mechanical properties like hardness, ultimate tensile strength, yield strength and ductility were evaluated as per ASTM standards.

II. EXPERIMENTAL DETAILS

Materials Involved

In the present investigation Al2030 wrought alloy has been selected as the matrix material. The chemical composition of Al2030 alloy is shown in table 1.

Table 1: Chemical composition of Al2030 alloy

Elements	Si	Fe	Cu	Mn	Mg	Zn	Pb	Al
Wt. %	0.8	0.7	4.5	0.8	1.1	0.3	1.2	Bal

Table 2: Physical Properties of Boron Carbide

Physical Property	Specification
Crystallography	Rhombo-hedral
Color	Black
Specific Gravity	2.52
Knoop100 Hardness	2800
Shape	Blocky – Angular
Melting Point	2350° C

Boron Carbide is one of the hardest man-made materials available in commercial quantities. Boron carbide ceramics have excellent physical and mechanical properties, such as a high melting point, hardness, good abrasion resistance, high impact resistance and excellent resistance towards corrosion. As an outstanding in borne mechanical property, the boron carbide as a ceramic material have attracted attention over wide variety of applications that comprises light-weight armour plating, blasting nozzles, mechanical seal faces, grinding tools, cutting tools and neutron absorption materials. The physical and mechanical properties of Boron Carbide are shown in Tables 2 and 3 respectively.

Table 3: Mechanical Properties of Boron Carbide

Density (gm /cm^3)	2.52
Melting Point (°C)	2445
Young's Modulus (GPa)	450 – 470
Thermal Conductivity (at 25°C - W/m-K)	30 – 42
Hardness (Knoop 100g) (kg/mm^2)	2900 – 3580

Composites Fabrication

The manufacture of Al2030 -B_4C composites were prepared by liquid stir casting method. Boron carbide particles were preheated to 400ºC for 45 minutes to ensure their surfaces are completely oxidized. 2030 Al alloy ingots are cut in to small pieces and calculated quantity of it is taken in a graphite crucible and placed in the electric melting furnace. The furnace is heated to the required temperature where melting of the ingots starts to happen and the solid ingots completely melt and liquidifies with period of time.

The preheated 3 weight percentage of boron carbide particulates were added and mixed with stirrer at rated speed. The heating is continued for longer periods to maintain the slurry in the molten state. The uniform distribution of the particles in the slurry is ensured by mechanical mixing through a stirrer at an average mixing speed of 300 rpm for about 15 minutes. Complete melting of the alloy takes place at a temperature of around 750ºC. The melt embedded with B_4C reinforcement is shifted using graphite crucible in to the specially prepared die that possess pockets of diameter15mm and length 120mm. The composites in the molten state were allowed to solidify to obtain the desired die castings. The entire process is repeated for 6 weight percentages of B_4C reinforced composites.

III. RESULTS AND DISCUSSION

Microstructural Analysis

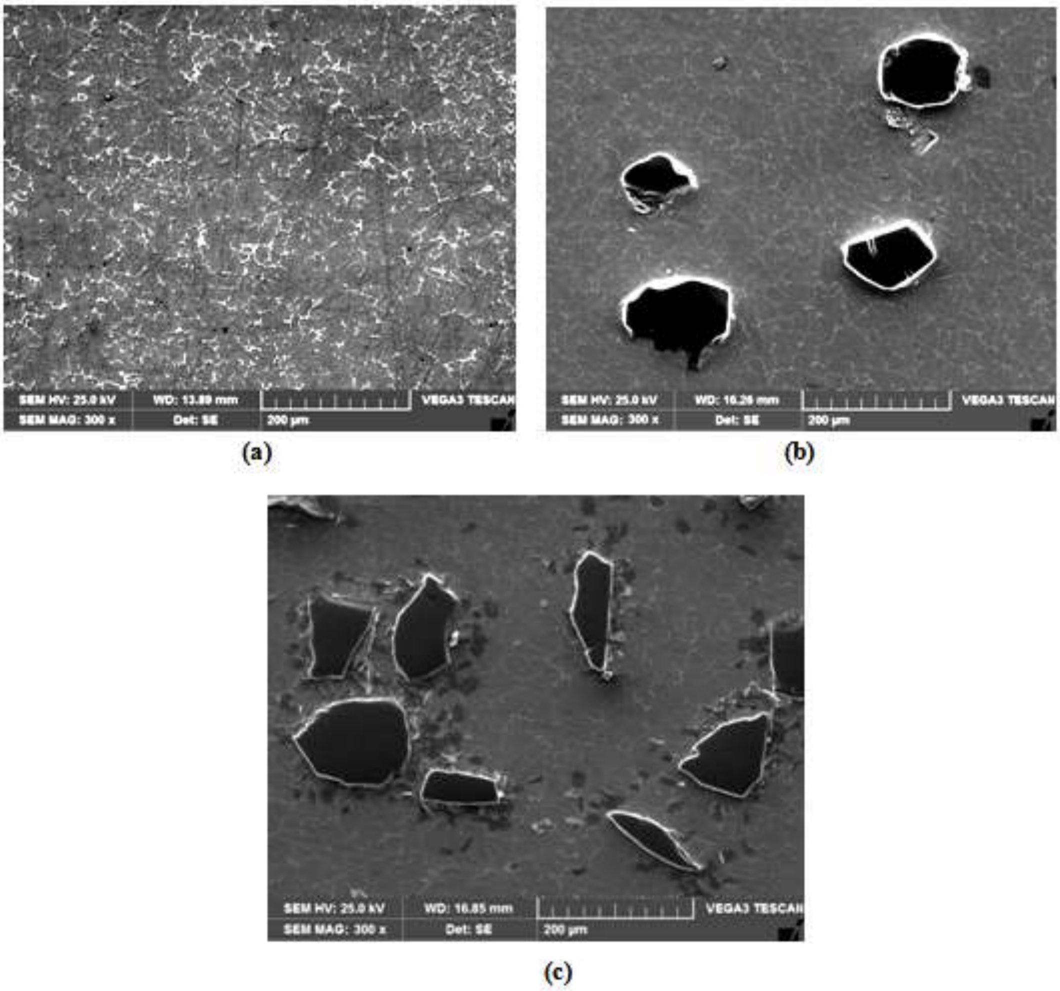

Figure 1: Scanning Electron Microphotographs of (a) as cast Al2030 alloy (b) Al2030-3% B_4C (c) Al2030-6% B_4C composites

Figure 1 (a-c) shows the SEM microphotographs of Al2030 alloy as cast and Al2030 with 3 and 6 wt. % of B_4C particulate composites. This reveals the uniform distribution of B_4C particles and very low agglomeration and segregation of particles, and porosity.

Fig. 1 b-c clearly show and even distribution of B_4C particles in the Al2030 alloy matrix. In other words, no clustering of B_4C particle is evident. There is no evidence of casting defects such as porosity, shrinkages, slag inclusion and cracks which is indicative of sound castings. In this, wetting effect between particles and molten

Al2030 alloy matrix also retards the movement of the B_4C particles, thus, the particles can remain suspended for a long time in the melt leading to uniform distribution.

Hardness

Table 4: Hardness of Al2030-B_4C particulate composites

Sl. No.	Material	Hardness (BHN)
1	Al2030 Alloy	65.5
2	Al2030-3 wt.% B_4C	75.6
3	Al2030-6 wt.% B_4C	87.3

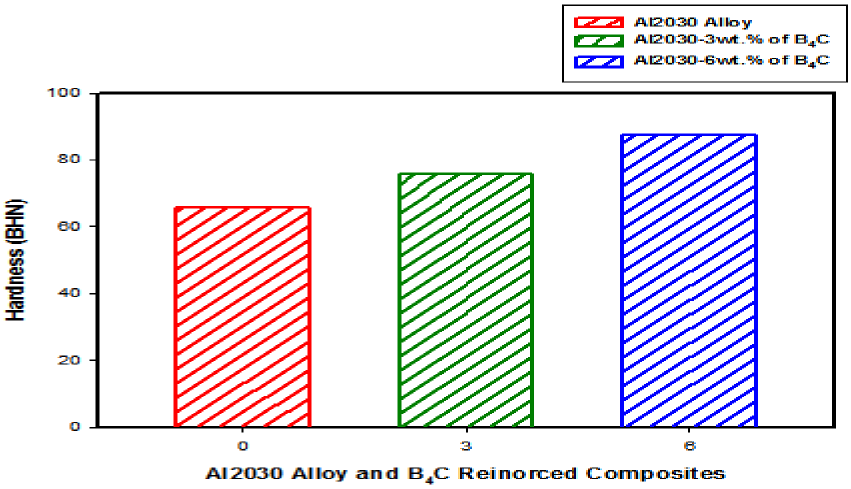

Figure 2: Hardness of Al2030 alloy and its B_4C composites

Brinell hardness test was conducted on the specimens of Al2030 alloy, 3 and 6 wt.% of B_4C composites, with ball diameter 5mm, load 250kg and the values obtained are in the range 65.5 to 87.3 BHN evident from the graph 2 and table 4. The values indicate that there is gradual increase in the hardness because of the hard boron carbide inclusion. As the percentage of particulates increased the hardness also increased parallel.

In the hardness test, severe plastic flow has been concentrated in the localized region directly below the indentation, outside of which material still behaves elastically. Directly below the indentation the density of the particles increased locally, compared to regions away from the depression. Although plastic deformation itself has not been responsible for volume change, the existence of very large hydrostatic pressure under the indentation can contribute to volumetric contraction of the metal matrix. As the indenter moves downward during the test, the pressure has been accompanied by non uniform matrix flow along with localized increase in particle concentration, which tends to increase the resistance to deformation [12, 13].

Ultimate Tensile and Yield Strength

Table 5: Ultimate and yield strength of Al2030-B_4C particulate composites

Sl. No.	Material	Ultimate Tensile Strength (MPa)	Yield Strength (MPa)	Elongation (%)
1	Al2030 Alloy	206.0	161.4	13.4
2	Al2030-3 wt.% B_4C	218.3	175.3	12.5
3	Al2030-6 wt.% B_4C	244.9	197.7	11.3

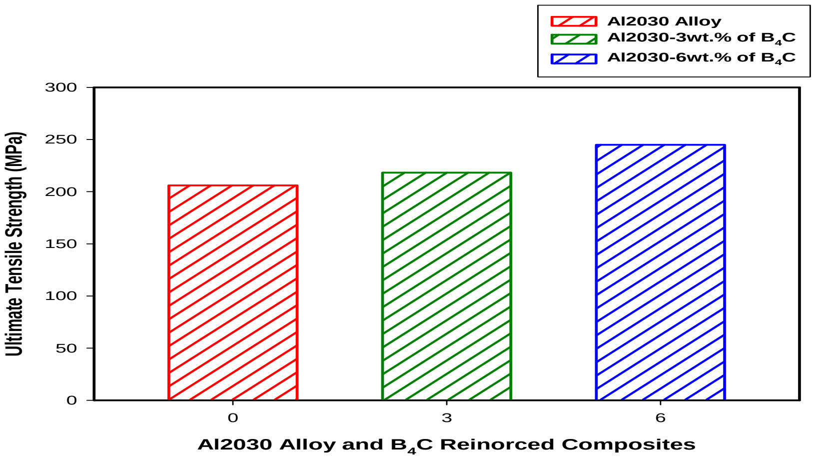

Figure 3: Ultimate tensile strength of Al2030 alloy and its B_4C composites

Figure 3 and table 5 shows there is gradual increase in the UTS with 3 and 6 % wt. addition of B_4C due to the fact that the properties of B_4C particulates control the mechanical properties of the composite showing the intense tensile strength. The variation in the UTS is may be because of matrix fortifying with increase in reinforcement size.

Figure 3 shows variation of ultimate tensile strength (UTS) with 3 & 6 wt. % of B_4C particulates. The ultimate tensile strength of Al2030- 6 wt. % B_4C composite material increases by an amount of 18.8% as compared to as cast Al2030 alloy matrix. The microstructure and properties of hard ceramic B_4C particulates control the mechanical properties of the composites. Due to the strong interface bonding load from the matrix transfers to the reinforcement exhibiting increased ultimate tensile strength. This increase in UTS mainly is due to B_4C particles acting as barrier to dislocations in the microstructure. The improvement in UTS may be due to the matrix strengthening following a reduction in Al2030-B_4C grain size, and the generation of a high dislocation density in the Al2030 alloy matrix a result of the difference in the thermal expansion between the metal matrix and the B_4C reinforcement [14, 15].

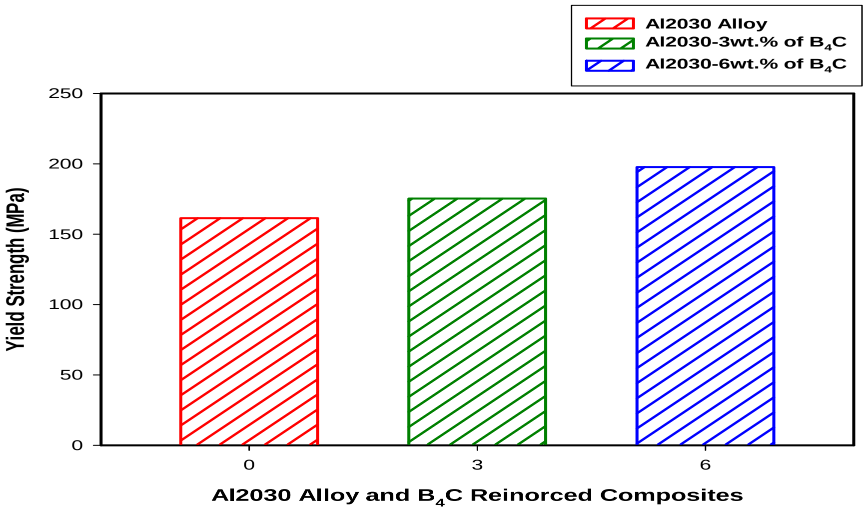

Figure 4: Yield strength of Al2030 alloy and its B_4C composites

Figure 4 and table 5 indicates yield strength improved from 161.4 MPa to 197.7 MPa with addition of B_4C from 3% to 6wt.%. The enhancement in the yield strength is due to the close packing of B_4C particles providing molecule strength with the aluminum lattice in turn composite [16]. This increase in yield strength is in agreement with the results obtained by several researchers [17, 18], who reported that the strength of the particle reinforced composites is more strongly dependent on the volume fraction of the reinforcement. The increase in YS of the composite is obviously due to presence of hard B_4C particles which impart strength to the soft aluminium matrix resulting in greater resistance of the composite against the tensile stress. In the case of particle reinforced composites, there is a restriction to the plastic flow due to the dispersion of the hard particles in the matrix, thereby providing enhanced strength to the composite.

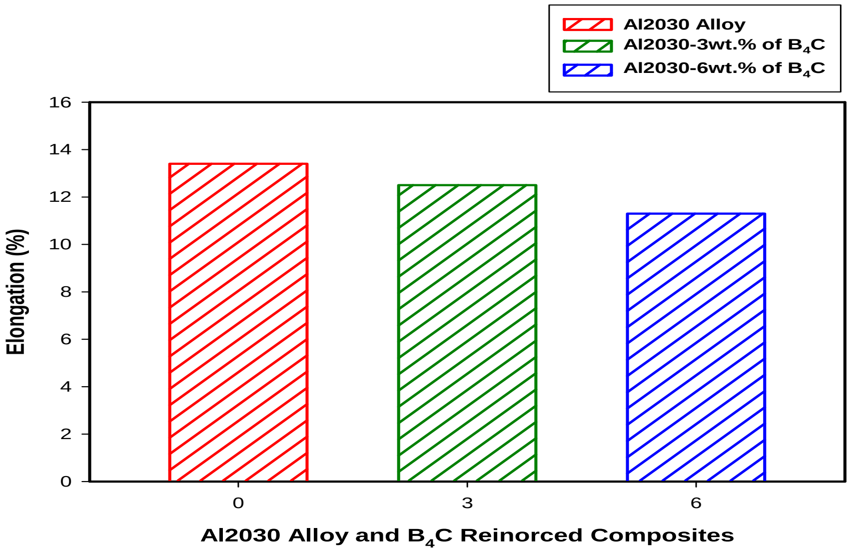

Figure 5: Percentage Elongation of Al2030 alloy and its B_4C composites

Figure 5 and table 5 illustrates the impact of B_4C with reference to malleability of the composite. It can be observed that the graph is falling down with addition of 3 and 6 wt.% of B_4C particulates but the rate of diminishing is less, between 3 – 6 % wt addition. This is due to the strength acquired by the composite with addition of B_4C owing to its properties. The reduced ductility in Al2030-3 and 6 wt. % composites can be attributed to the presence of B_4C particulates which may get fractured and have sharp corners that make the composites prone to localised crack initiation and propagation. The embrittlement effect that occurs due to the presence of the hard ceramic particles causing increased local stress concentration sites may also be the reason [19, 20].

IV. CONCLUSION

This present research is centered on the development and characterization of the microstructure and mechanical behavior of Al2030 alloy and B_4C composites containing 3 and 6 wt. From the above results and discussion the following conclusions are made:

1. From the liquid metallurgy techniques Al2030-3 and 6 wt. % of B_4C composites were prepared successfully.
2. The scanning electron micrographs revealed the uniform distribution of B_4C particulates in the Al2030 base alloy.
3. The hardness of Al2030 base alloy increased with the addition of 3 and 6 wt. % of B_4C particulates.
3. The ultimate tensile strength of Al2030 alloy with 3 and 6 wt. % of B_4C particulates addition increased from 206 MPa to 244.9 MPa.
4. The yield strength of Al2030 alloy with 3 and 6 wt. % of B_4C particulates addition increased from 161.4 MPa to 197.7 MPa.
6. The ductility of base alloy Al2030 reduced with the addition of 3 and 6 wt. % of B_4C particulates.

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