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Impact of Micro B_4C Particulates Addition on Mechanical Behavior of Al2024 Alloy Composites

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Abstract: *In this paper an attempt made for investigating the effect of addition of B_4C particulates into the Al2024 alloy. Here microstructural study of the 4 wt. percentage Boron Carbide reinforced composite is studied.90-micron size particulates reinforced composite is characterized with some of the mechanical properties. First the Al2024 alloy composite is fabricated using two stage novel Stir casting method and then the reinforced composite is prepared by adding 4 wt. percentage of boron carbide by continuously stirring the molten metal. Scanning electron microscope (SEM) and Energy Dispersive X-Ray Spectroscope (EDS) are two techniques used for microstructural evaluation. SEM had shown the presence of B_4C in the matrix with uniform distribution also EDS test confirmed the presence of Boron Carbide in the matrix. Further specimens were prepared according to ASTM standard for mechanical properties like tensile strength, compression strength shear strength and hardness value. The results showed the increase in the value of all mechanical properties after adding 4 wt. percentage of boron carbide.*

Keywords: *Al2024 Alloy, B_4C Particulates, Ultimate Tensile Strength, Yield Strength, Stir casting*

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I. Introduction

Applications of metal matrix based composites have taken a great advancement in various fields of engineering aspects especially aluminum based composites are growing in the aircraft industries mainly because of its low density, good mechanical and tribological properties [1, 2]. Aluminium based metal matrix composites are prepared by introducing hard ceramic particles in micro and macro sizes such as Al_2O_3 and B_4C into the aluminium matrix. As boron carbide is the third hardest material after diamond and cubic boron nitride having better properties also most suitable to aluminium because of the density which matching with aluminum and with high hardness, low density, high strength, high wear and impact resistance, high melting point, low coefficient of thermal expansion and good chemical stability [3]. Pankaj et al. fabricated the A356-B_4C (4 wt. %) and Gr particulate metal matrix composite by two stage stirring casting process and concluded that hardness was higher for the case of 4wt. % of B_4C and shown increase in ultimate and yield tensile strength with addition of boron carbide and graphite particulates [4]. Krishna Dama et al. synthesized the effects of addition of micro size B_4C particles to ZA27 alloy on properties like hardness, ultimate tensile strength and yield strength and observed the increase in all this property as the wt. percentage of boron carbide addition increased. They also concluded that percentage of elongation degreased with the addition of reinforcement. [5].

Numbers of techniques are available for fabricating this metal matrix composite via mechanical alloying [6, 7] high-energy ball milling [8], spray deposition, powder metallurgy, and various casting techniques [9]. Most common and economical stir casting process can be used for preparation of composites which gives better properties than made with powder metallurgy without any agglomeration, voids and clusters. [10].

II. Experimental Work

Material

For this particular work we have taken aluminium 2024 alloy as the base matrix and ninety micro sized boron carbide as the reinforcing particulate and its chemical composition is as shown below table 1.

Table1. Chemical Composition of Al2024 alloy

Element	Al+	Cu	Mg	Si	Fe	Mn	Zr	Zn	Cr
% by Wt	Rest	4.5	1.6	0.45	0.25	0.40	0.10	0.20	0.05

Fabrication of Al2024 – B_4C micro Composites

As mentioned earlier the composite is prepared using two stage stir casting technique. First the required wt. percentage of aluminium and boron carbide are weighed in and electronic precession weighing machine. 4wt. percentage of 90-micron boron carbide is used as the reinforcement. Then into a graphite crucible the charge al2024 is placed in an electric furnace and is heated for around 750˚C mean while the reinforcements along with cast iron die are preheated at around 350˚C. Once the charge in the crucible is completely melt than into it a degassing tablet known as Hexa Chloro Ethane (C_2Cl_6) is added in order to remove any observed gases from the molten metal. Now the preheated ceramic reinforcement is added along with Potassium Titanium Nitride (K_2TiF_6) which basically improves the wettability between the reinforcement and the matrix. The molten melt is disturbed by dipping a zirconium coated mechanical stirrer to form a clear vortex by stirring mechanism at a speed of 300rpm.as the vertex is formed we weigh the reinforcements along with K_2TiF_6 which divide it into two equal weights and are addend into the matrix in equal time interval with continuous stirring at constant feed rate in order to avoid the formation of clusters. After continues stirring, the entire molten metal was poured into preheated cast iron die. The prepared micro composites were machined as per the standards for characterization purpose.

Testing of Composites

Using Vegas Tescan made scanning electron microscope the microstructural study was conducted. The specimens after casting are machined in lathe for dimensions of 10 to 12 mm dia and 20 mm thickness. Than one side it is finely polished used polishing machine and it is etched with Keller's reached for better surface finish and then finally it is used with diamond paste dipped in distilled water in order to get the mirror like structure.

By focussing high energy X-Ray on the surface in EDS which excites the atomic energy spectrum of each constituent in the composites by giving peaks in graph for various materials based on the abundance of material in the composite. Also the specimens were prepared according to ASTM E10 for checking out the hardness value which is nothing but the resistance scratch, indentation and abrasion by using conventional Brignell's Hardness testing machine. Testing was carried out by applying a load of 250kgf and dwell time of 30 seconds. The depth of ball indenter is noted on the specimen and using microscope the deformations are noted and using the formula the values of Brinell hardness number are calculated. For each sample, the indentation test was repeated 3 times and the averaged data were reported.

Tensile and compression specimens were prepared from the cast samples. The tensile specimens of circular cross section with a diameter of 12 mm and gauge length of 54mm were prepared according to the ASTM E8 standard testing procedure using Instron made Universal Testing Machine. At a rate of 0.1 mm/min all the tests were conducted in a displacement control mode. Reading was taken for multiple specimens and average values are calculated. Various tensile properties like ultimate tensile strength, yield strength for as cast Al2024 alloy, Al-2024 and 4 wt. % B_4C composites are tabulated. Compression test was conducted on the same machine as per ASTM E9 standard. Also the graphs were plotted as load vs deformation. Figure 1 showing the tensile test specimen dimensions used to conduct the experiments.

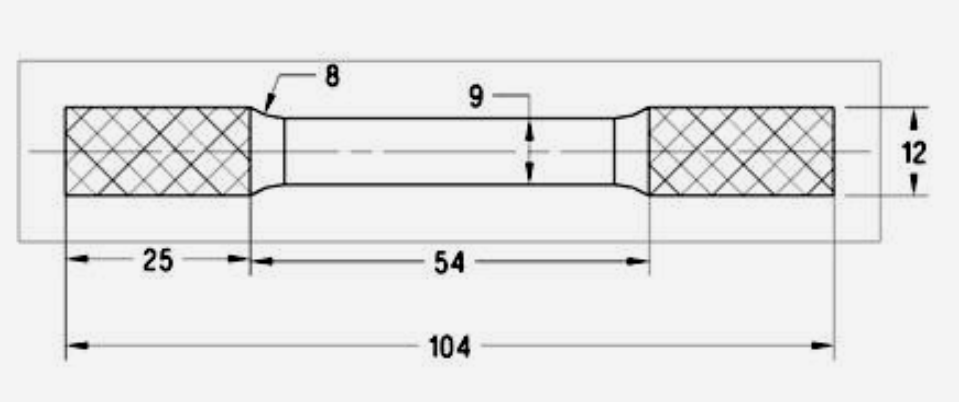

Figure 1: Tensile specimen according to ASTM E8 with all dimensions in mm

III. Results and Discussion

Microstructure Study

From the below Figure 2 (a-b) showing the results of microphotographs of Al2024 alloy as cast and Al2024 with 4 wt. % of micro B_4C particulate composites in Scanning electron microscope. Also we can clearly make out the presence of reinforcing hard ceramic particle in the matrix which confirms the uniform dispersion of boron carbide in al2024 alloy and low agglomeration and segregation of particles, and porosity.

There is no evidence of casting defects such as porosity, shrinkages, slag inclusion and cracks which is indicative of sound castings. Here the reinforcements get suspended in the matrix whose moments are retarded by increasing the wettability upon adding the K_2FiF_6leading to uniform distribution.

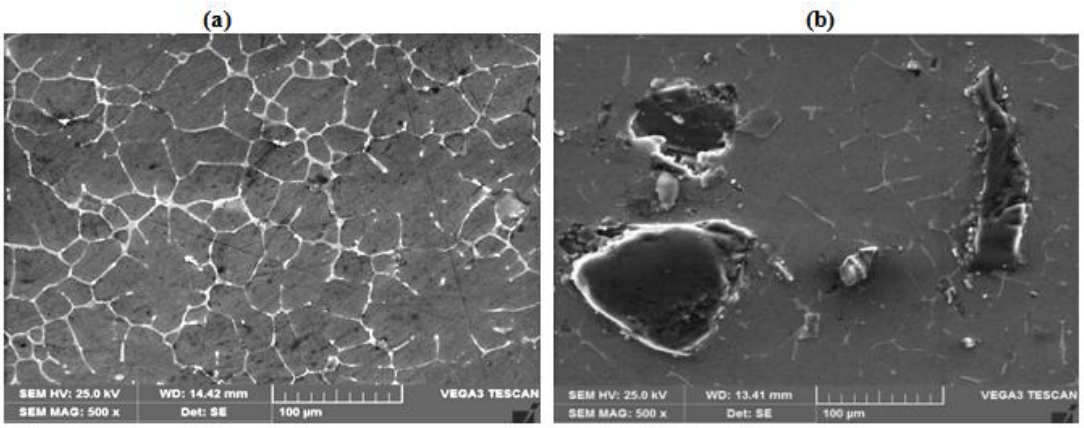

Figure 2. a-b Showing the scanning electron microphotographs of (a) as cast Al2024 alloy (b) with 4 wt.% of B_4C.

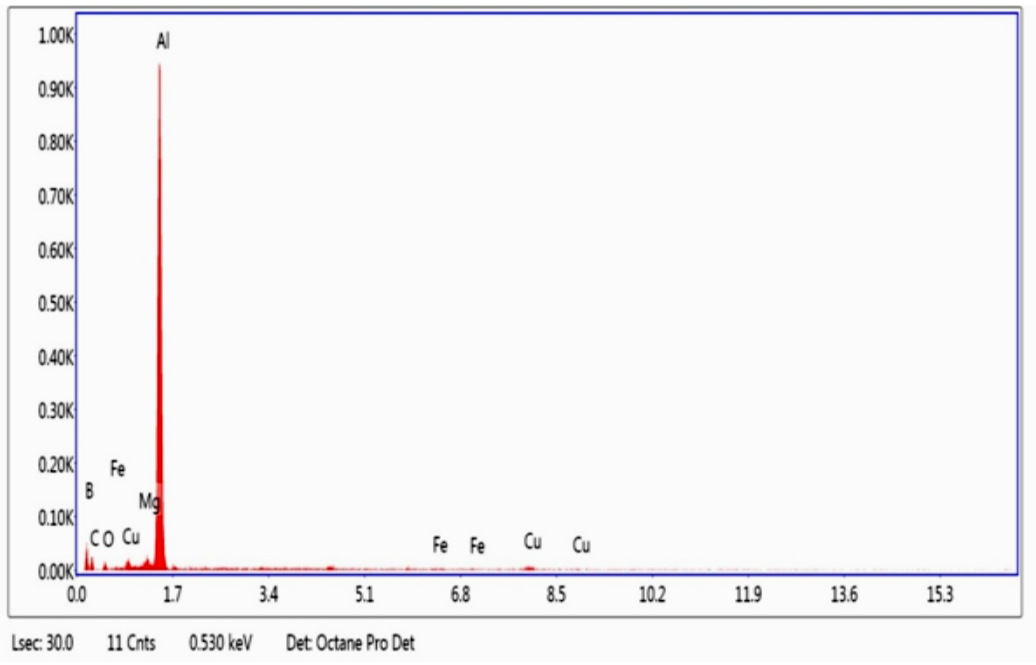

Figure 3a:EDS spectrum of Al-2024 alloy

Confirmation of constituent materials in the alloy as well as composite are done by the use of Energy Dispersive Spectroscope analysis is carried. The EDS spectrum reveals the presence of Al, Zn, Cu, Mg, B and C in the interface reaction layer (fig. 3b).

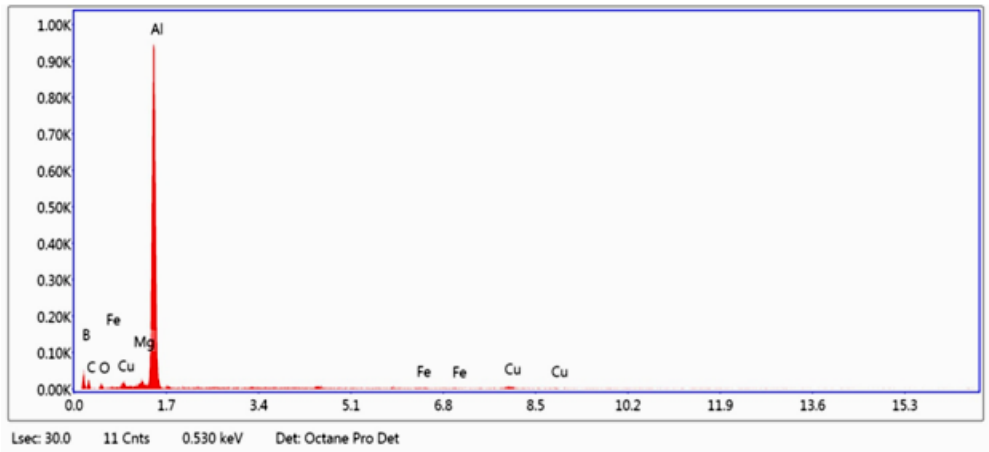

Figure 3b: EDS spectrum of Al-2024 alloy and 4% B_4C

Tensile Properties

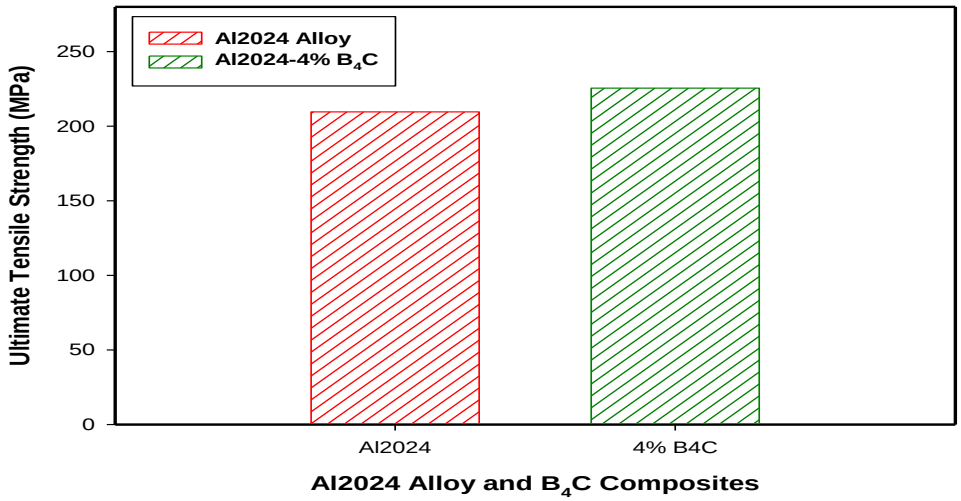

Figure 4a: Ultimate tensile strength of Al2024 and 4 wt. % of micro B_4C composites

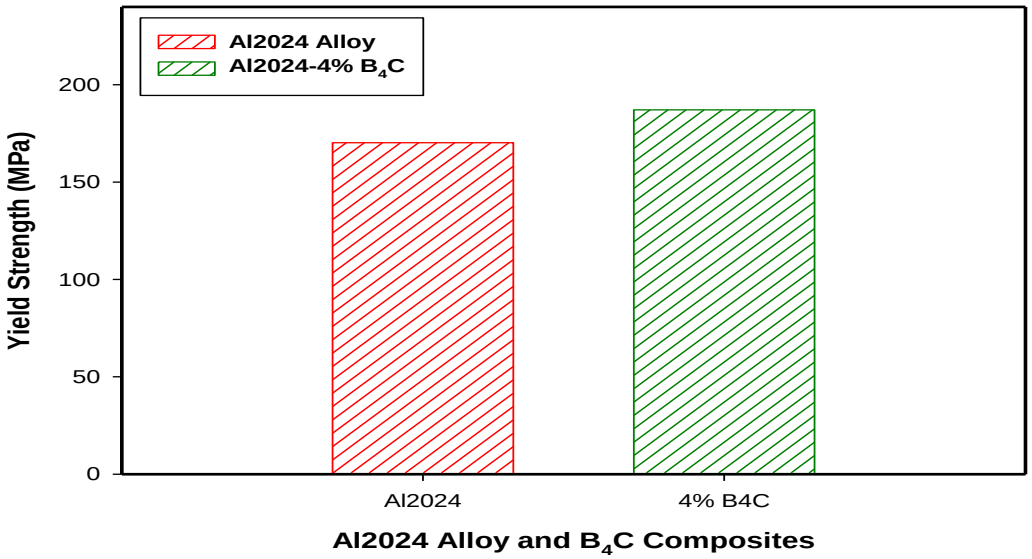

Figure 4b: Yield strength of Al2024 and 4 wt. % of micro B_4C composites

Figure 4a, indicates there is gradual increase in the Ultimate Tensile Strength with 4 % wt. addition of B_4Cdue to the fact that the mechanical properties are mainly controlled by this hard ceramic particle. Hence there is an increase in UTS. The variation in the UTS and Yield strength may be due to strong interface between reinforcement and alloy. Figure 4b indicates yield strength improved from 170.24 MPa to 187.10 MPa with addition of 4 % wt. B_4C. due to the close packing of boron carbide which increases the molecule strength with the aluminum lattice in turn composite.

Compression Strength

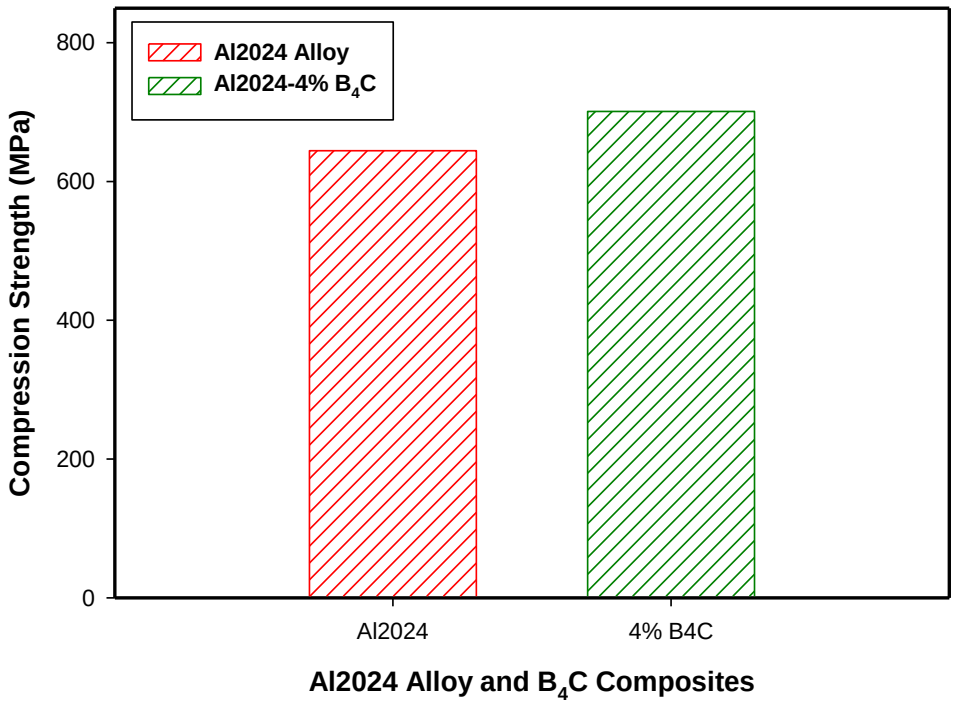

Figure 5: Compression strength of Al2024 and 4 wt. % of micro B_4C composites

The plot 5 indicates the compression strength of the test specimens with 4 wt.% of B_4C in Al2024 alloy. Here 12% increase in the compression strength indicates that there is an opposition for the moment of dislocations along the boundary of the composite.

Hardness Study

Hardness values are calculated using Brinell hardness Machine of Al 2024 alloy and 4% B_4C micro composites, with specifications of ball diameter 5mm, load 250Kgand the values obtained are in the range 69.2 to 78.9 BHN evident from the graph 6. The values indicate that there is gradual increase in the hardness because this hard particulate acts as barrier for scratch, indentation and abrasion.

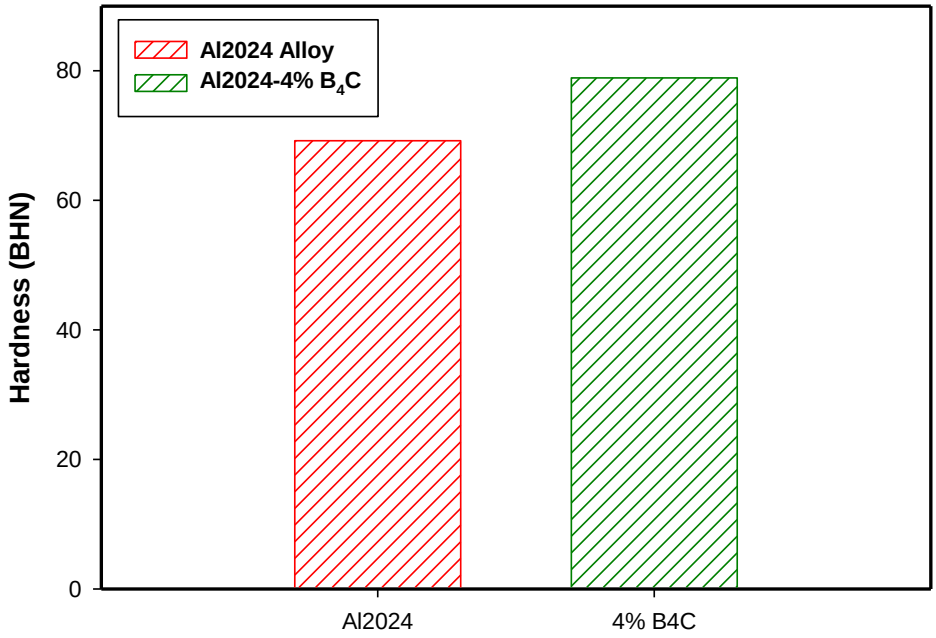

Figure 8: Hardness of Al2024 and 4 wt. % of micro B_4C composites.

IV. Conclusions

The mechanical characterizationof the Al2024 and 4 wt.% of micro B_4C composites materials produced by stir casting are remarked as below:

- Two stage novel Stir casting technique is best adopted for preparation of al-2024 with 4wt.% of B_4C composites.
- The microstructural studies revealed the uniform distribution of the micro B_4C particulates in the Al2024 alloy matrix.
- Mechanical properties like ultimate tensile strength and yield strength of the composites found to be higher than that of base matrix.
- Improvements in compressive strength of the Al2024 alloy matrix were obtained with the addition of micro B_4C particulates. The extent of improvement obtained in Al2024 alloy after addition of 4 wt. % micro B_4C particulates is 12%.
- There is an increase in Hardness value for the Al2024- micro B_4C composite

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