Investigations on Microstructure and Mechanical behavior of B_4C nano-particles reinforced Al 6063 Composites

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Abstract: In recent days, the demand of light weight materials being increased in industrial applications especially nano composites are used in aerospace, automobiles and bio medical applications due to their favorable properties. The aluminium alloy matrix can be strengthened by reinforcing with hard ceramic particles. In this present investigation is focuses on characterization of metal matrix composites of Al6063 alloy reinforced with boron carbide nano-particles with varying weight percentages of 2, 4 and 6%, the Al 6063was choose as base material owing to its good formability lightweight and moderate strength The composites were fabricated by using stir casting techniques The fabricated composites were characterized using scanning electron microscope. The micro structural studies reveals that the uniform distribution of boron carbide nano-particles in the aluminium alloy matrix by showing good bonding with matrix and EDS confirmed the presence of Boron and Carbon elements. Mechanical properties have been studied for the composite samples. It was observed that the mechanical properties like yield strength, ultimate tensile strength, and hardness were improved by the addition of the B_4C nano –particulates compared with the base metal.

IndexTerms **- Stircastng, NanoB_4C, Metal Matrix Composites.**

I. INTRODUCTION

Aluminium based metal matrix composites significant demand in the field of aerospace and automotive industries, owing to their improved mechanical properties. Efforts have been made to develop aluminium metal matrix nano composites in recent years, due to their high strength, low-density, corrosion resistance, and have great potential in automotive and aerospace applications. [1,2].The micro and nano ceramic particles such as SiC, and Al2O3, etc have been used as reinforcements materials with aluminium alloy matrix, Many researchers
[3-5] have reported that addition of these hard ceramic particles to aluminium alloy matrix lead to strengthening of the matrix with improved mechanical properties. Hence, aluminum reinforced with ceramic particles is one of the popular choices of MMCs [6]. Boron carbide (B_4C) could be an alternative to SiC and Al_2O_3 due to its attractive properties like high strength, low density (2.52 g/cm3), extremely high hardness, good wear resistance and good chemical stability. B_4C is considered to be promising material for a variety of applications like bullet proof vests, armor tanks and as neutron absorber material, [7].pankaj et al. synthesized the A356 – B_4C and graphite particulate metal matrix composites by stirring process and reported that hardness was higher in case of 4wt% B_4C particulates and shown improvements in tensile strength, yield strength with addition of B_4C and graphite particulates.[8].Harichandran et al.Investigated mechanical properties of B4C nano particles reinforced aluminium metal matrix composites and stated impact energy, ductility were better with nano b4c reinforcement with significant increase in wear resistance, From the Literature survey it can be concluded that, most of the studies on aluminium based MMCs are devoted to SiC and Al_2O_3 particulate reinforcements, A limited research work has been done on AMCs reinforced with B4C nano-particles due to higher cost of raw material and poor wetting. Hence B_4C reinforced aluminum matrix composite has gained more attraction with low cost stir casting route [9].The possible processing techniques for MMCs are 1) liquid state processing; 2) powder metallurgy; and 3) semisolid processing; however particulate reinforced Al composites can be synthesized more easily by liquid state processing. It is an attractive processing method and inexpensive. Hence the present research work mainly focused on Investigate the mechanical properties of Al6063 alloy with 2, 4 and 6wt% of nano B_4C composites.

II. EXPERIMENTAL DETAILS

2.1 Material Selection

Al6063 is a medium strength alloy with silicon and magnesium as major alloying elements chosen as matrix material for present study because of its excellent characteristics' like good formability, weld ability, higher corrosion resistance good surface finish and high strength to weight ratio. The Chemical composition of AA6063 is given below in Table 1 below.

Table 1: chemical composition of AA6063

Si	Fe	Cu	Mn	Mg	Zn	Cr	Ti	Al
0.45	0.22	0.02	0.03	0.50	0.02	0.03	0.02	Bal

Boron carbide nano-particles were used as a reinforcement which was procured from Reinste Nano Venture, Delhi, having a particle size of 500nm. The percentage of reinforcement was varied from 2wt% to 6wt%.boron carbide possesses low density which is less than the matrix material and high hardness.

2.2 Preparation of Composites

The metal matrix nano composites containing 2, 4 and 6wt% of B_4C nano-particulates were prepared by using a stir casting process techniques [10]. In this process initially the calculated amount of matrix alloy (Al6063) is weighed and placed in a graphite crucible inside an electric furnace and the matrix alloy is heated to a temperature of 750°C, after complete melting of Al6063 alloy, the degassing was carried out using solid hexachloroethane (C_2Cl_6) is added into the molten melt to remove the all the unwanted slag and volatile gases from the molten metal[11], on the other hand the Ceramic B_4C nano-particulates are preheated to a temperature of 300^0C-400^0C in an oven to increase the wettability, The cast iron mould cavity also preheated to remove the moisture content from the surface, The molten melt is agitated with the help of a zirconium coated stirrer to form a fine vortex. A spindle speed of 300 rpm and stirring time of 10 min is maintained. once the vertex is formed then the 2% weighed amount of pre-heated B_4C nano-particulates was added into melt in steps of two at constant feed rate, the continuous stirring was done before and after pouring of reinforcement particles and to have uniform homogeneous distribution of reinforcements in to the molten melt, Then the entire molten melt was poured into a preheated cast iron mould having dimensions of 125mm length x 15mm diameter and allowed to cool at a room temperature. Similarly the process was repeated for different weight percentages of reinforcements. The prepared composites were machined as per ASTM standards for characterization [12].

2.3 Testing of Composites

The micro structural study was carried out on the properly polished and fine mirror finished samples by using optical microscope. The tests samples are of 10-12mm in diameter were machined from the cast composites. The tensile test specimens of circular cross sections of diameter of 9mm and gauge length of 45mm were machined from the cast composites. For each composite four tensile test samples were tested according to ASTM E-8 standards and the average values of the Ultimate Tensile strength, yield strength and percentage elongation were measured. The Brinell hardness tests were conducted on the samples according to ASTME-10 with ball diameter of 5mm and a load of 250kg, the compression tests were conducted on UTM according to ASTM E-9 at room temperatures. Stress versus strain graph was plotted to know the effect of B_4C Nano- particulates on tensile behavior of Al6063-nano-B_4C Cast composites.

III. RESULTS AND DISCUSSION

3.1. Microstructure Analysis

Figure-1(a)-(b) shows the optical micro photo graphs of Al 6063alloy and Al6063-B_4C nano particulate composites, it is observed from the micrograph fig: 2(b) the B_4C nano-particles are dispersed uniformly distributed along the grain boundaries of the Al6063alloy matrix and also images clearly indicate that nano-particles are bonded to the Al6063 alloy matrix and there exists very less agglomeration, segregation of particles and micro porosities in all the composites.

Figure-2, Show the energy dispersive X-Ray spectrograph of Al-6063alloy–6 wt. % of B_4C composite. The EDS analysis confirmed the presence of B_4C nano particles in the Al6063 matrix alloy. The presence of B_4C shows in the form of B (Boron) and C (Carbon), which is evident from the EDS image.

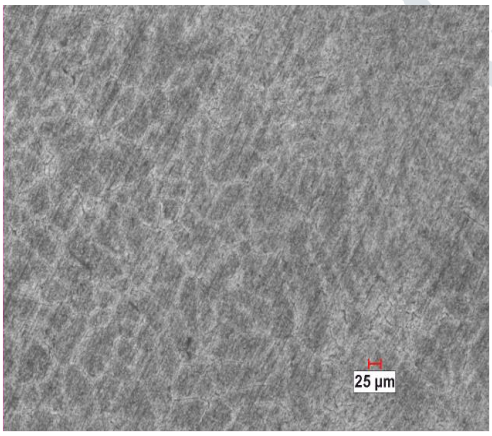

Fig (a)

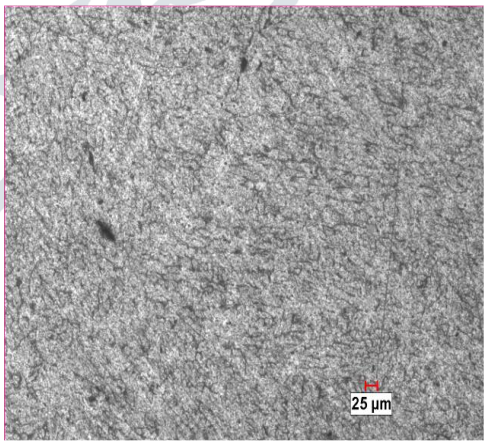

fig (b)

Fig: 1. shows the optical microphotograph of (a) as cast Al6063 alloy (b) Al-6063 Alloy -6 wt. % nanoB_4C

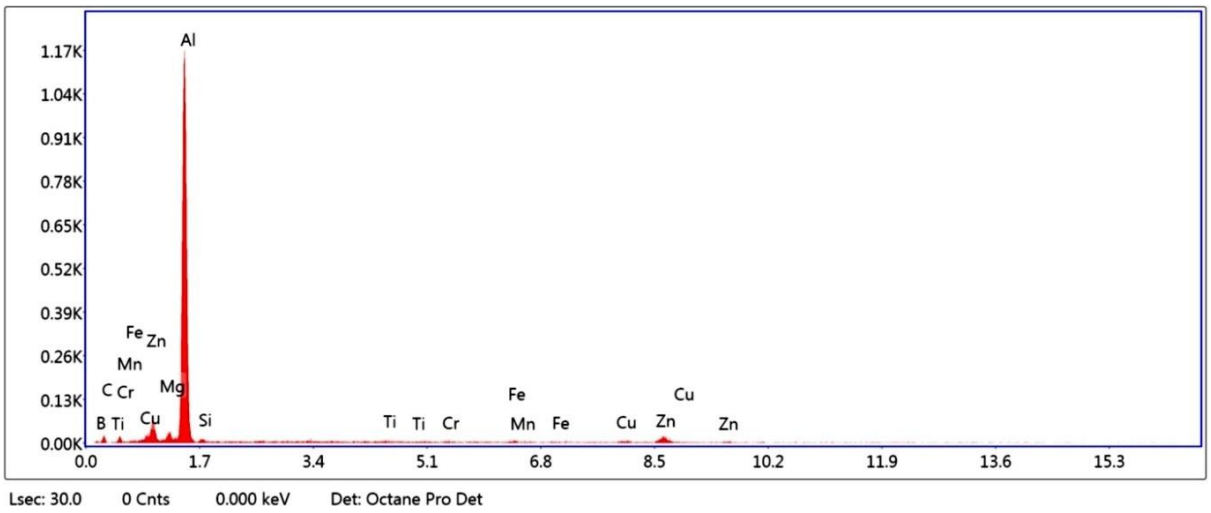

Fig 2: EDS image of Al 6063- 6% B_4C nano composites

3.2 Hardness Test

Hardness tests were carried out to observe the effects wt% addition of boron carbide nano-particles on aluminum alloy matrix (AA 6063) since hardness is an indicator of a materials resistance to plastic deformation.

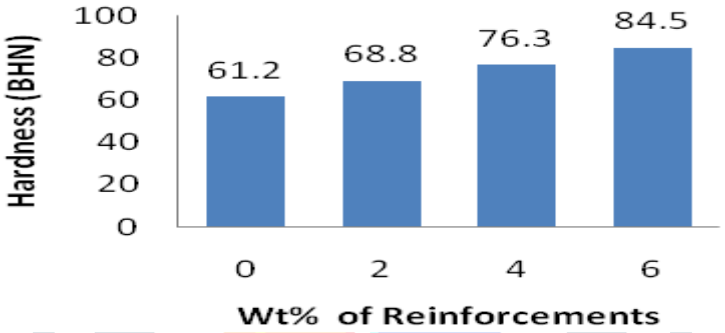

Fig -3: variation of Hardness with varying wt% of B4C

Figure -3, shows the variation of hardness values with volume percentages boron carbide nano- particles. From the graph it is clear that the hardness values were improved with the addition of the B_4C nano-particles into the Al 6063 alloy matrix. This is due to the presence of hard B_4C nano-particles this is expected since aluminium is a soft material and the B_4C nano-particles being hard contributes positively to the hardness of nano composites.

3.3. Ultimate Tensile Strength

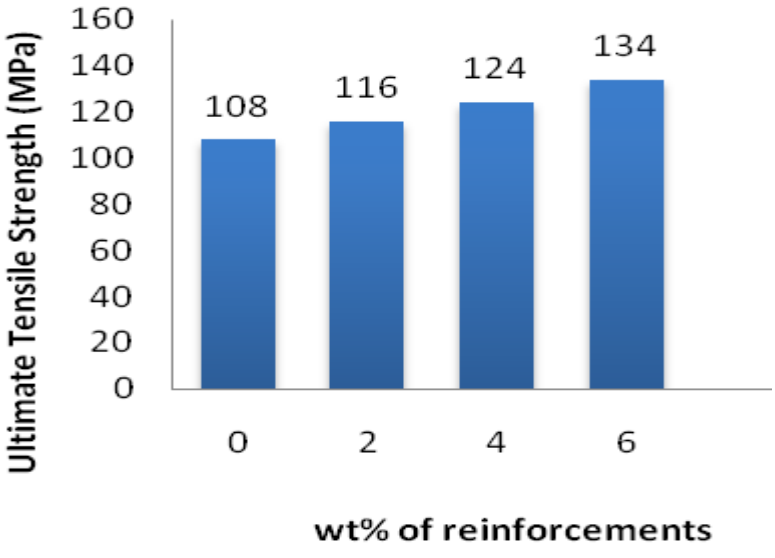

Fig-4: variation of ultimate tensile strength with varying wt% of nano B_4C

Figure-4, Graph shows that the variation of ultimate tensile strength (UTS) with 2 4 and 6 wt. % of B_4C nano-particulates. The tensile strength of Al-6063 – wt % B_4C nano composite material increases by an value of 108MPa to134Mpa as compared to as cast Al6063 alloy matrix. Due to the strong interface bonding load from the matrix transfers to the reinforcement exhibiting

increased ultimate tensile strength [13]. This increase in UTS mainly is due to B_4C nano sized particles acting as barrier to dislocations in the microstructure.

3.4. Compressive Strength

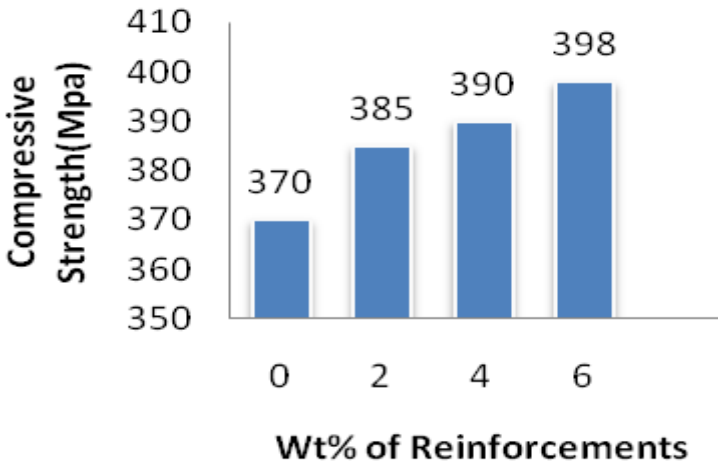

Fig-5: variation of compressive strength with varying wt% of B_4C

From the figure it is observed that the compressive strength of the composites is higher than that of the base alloy due to the presence of the hard ceramic B_4C nano-particles, with the addition of 2, 4 and 6 wt% of B_4C nano-particles in 6063Alloy has shown the increase in compressive strength from 370Mpa to 398Mpa.

3.5. Percentage of Elongation

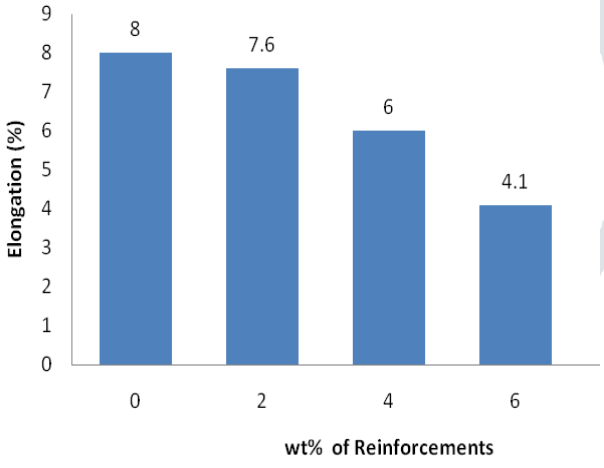

Fig-6: variation of percentage elongation with varying wt% of B_4C

Figure-6, Shows the graph of percentage elongation of nanoB4C reinforced aluminium matrix composites experimentally it is observed that elongation metal matrix composites were gradually decreased with increased weight percentages of nano B4C particles in Al6063 alloy matrix this is due to the increase in strength of the composite with addition of boron carbide nano particles owing to its properties [14].

IV. CONCLUSION

In this research, nano B_4C-Al 6063 composites were fabricated by stir casting method by taking, 2 to 6 wt. % of reinforcement. The microstructure and the mechanical properties like hardness ultimate tensile strength, compression strength and percentage elongation of composite samples were studied micro structural analysis was done. It is evident from the optical images that the matrix is almost pore free and B_4C particles are uniformly distributed. The mechanical properties of Al 6063-with 2, 4 and 6 wt. % B_4C nano composites are superior to those of unreinforced matrix alloy. The ultimate tensile strength of Al 6063 alloy is increased from 108 MPa to 134 MPa for 6 wt. % nano composites. The hardness and compressive strength values have been increased as compared to the unreinforced Al 6063 alloy, Percentage elongation of B_4C nano composites decreased as compared to the unreinforced Al6063 alloy.

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