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Mechanical Characterization of 63 Micron Sized B_4C Particulates Reinforced Al2618Alloy Composites

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Abstract: In the current study, an investigation made on fabrication of 63 micron B_4C particles reinforced Al2618 alloy composites and evaluation of mechanical properties. Al2618-2 and 4 wt. % of B_4C composites were synthesized by liquid stir casting process. Microstructural characterization was carried out by using scanning electron microscope and energy dispersive spectroscope. Prepared composites were evaluated for mechanical properties as per ASTM standards. Scanning electron micro photographs revealed the distribution of B_4C particulates in the Al matrix and were confirmed by EDS analysis. Further, B_4C particulates reinforced composites were shown more enhanced hardness, ultimate tensile strength and yield strength as compared to Al2618 alloy. Ductility of Al2618 alloy was decreased with addition hard ceramic particles.

Keywords: Al2618 Alloy, B_4C particulates, Microstructure, Hardness, Tensile Strength

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I. INTRODUCTION

Aluminium is the most abundant material in the earth. Aluminium alloys are used as a main metal matrix element in the composite materials [1]. Aluminium alloys are used in automotive, marine, aerospace, electronics, defense and sports sectors due to having light in weight, high strength, ductility and corrosion resistance. But, aluminium alloys have low wear resistance. Different reinforcements are added to the aluminium alloys to improve the wear resistance. The reinforcements are added with the aluminium alloy to form aluminium metal matrix composites. The aluminium metal matrix composites have high tensile strength, high hardness light in weight and corrosion resistance over the un reinforced aluminium alloys. The reinforcements added to the aluminium alloys are three types 1. Synthetic ceramic reinforcement 2. Indudustrial dissipate materials used as reinforcements and 3. Agro dissipate material used as reinforcement. Synthetic reinforcements are Al_2O_3, Sic, TiC, SiO_2, BN, B_4C, MgO, ZrB_2. These are expensive reinforcements and with limited availability [2-3]. The Manufacturing cost of aluminium alloys reinforced with ceramic reinforcement is high, due to high cost of Ceramic reinforcement. Researchers are focusing on alternate reinforcements. In every country, industrialization increases and all the industries leave the dissipate materials to the environment, and agriculture sector also leave the dissipate material to the environment, which may cause environmental pollution and health problems.

Aluminium-based metal matrix composites (MMCs) reinforced with ceramic particles is interesting structural and functional materials. They have been found in a wide range of applications in automotive and aerospace industries because of their lightweight, high stiffness and strength, high thermal stability and their superior wear resistance, compared to the unreinforced aluminium alloys [4, 5].

Particulate reinforced metal matrix composites (PMMC), constituted of high-strength metallic alloys reinforced with ceramic particulates or whiskers, are advanced materials that have emerged from the perpetual need of lighter-weight, higher-performance components in the aerospace, aircraft and more recently the automotive industries. Indeed, these "new" materials offer promising perspectives in assisting automotive engineers to achieve improvement in vehicle fuel efficiency. Their distinctive properties of high stiffness, high strength and low density have promoted an increasing number of applications for these materials. Several of these applications require enhanced friction and wear performances, for example brake rotors, engine blocks and cylinder liners, connecting rod and piston, gears, valves, pulleys, suspension components, etc [6].

Ultra fine particles such as micro particles noticeably reduce inter-particle spacing resulting in the increase of mechanical properties. On the other hand, they have a high tendency to form agglo-micro-particles merates. Thus, for each technique and matrix, it is important to find out the optimum size, reinforcement content and parameters of fabrication to minimize agglomeration. Factors such as different particle sizes, density, geometries, flow or the development of an electrical charge during mixing may lead to agglomeration. In this process, mixing of matrix and reinforcementis a critical step to obtain a homogenous distribution of reinforcing particles in matrix. Since by reducing ceramic particle size, the stress concentration level on each particle decreases and makes it difficult to be fractured, micro and nano scale ceramic particles have attracted attentions in academia and industry [7, 8].

Recently, B_4C reinforced composites have been manufactured via various techniques. B_4C is the third hardest material after diamond and cubic boron nitride (CBN). Furthermore, B_4C has a lower specific gravity (2.51 g/cm3, which is less than that of Al with 2.8 g/cm3), high wear and impact resistance, high melting point, good resistance to chemical agents and high capacity for neutron absorption. B_4C is a proper candidate as reinforcement in Al matrix composites. It can be considered as an alternative to SiC reinforced composites, where a high stiffness or a good wear resistance is required.

Among various techniques to fabricate metal matrix composites (MMCs) reinforced with ceramic particles, stir casting is one of acceptable routes for commercial production. However, this method needs delicate optimization of parameters like casting temperature, stirring velocity, reinforcement content. In as-cast AMCs, inferior ductility limits their performance and applications. Parameters like matrix microstructure, distribution of reinforcements, porosity content affect the ductility [9,10].

In this research, composites with different B_4C content as reinforcement were fabricated via stir casting. The aluminum–micro B_4C composites play an important role in the industry because of the increase demand of advanced light weight materials in different industrial applications. Keeping the above observations in view, it is proposed to develop Al2618 composites with 2 and 4 wt. % of nano B_4C particulates.

II. EXPERIMENTAL DETAILS

Table 1- Chemical Composition of Al2618 alloy by weight%

Zn	Mg	Si	Fe	Cu	Ni	Mn	Cr	Al
0.1	1.8	0.2	1.3	2.7	0.9	0.3	0.1	Balance

The aluminum alloys are basically classified into two categories these are cast aluminum and wrought aluminum. In the present research work Al2618 alloy is used as the matrix material which is one type of wrought aluminium alloy designated by 4 numbers, having copper as the primary element and combined with various other elements like zinc, magnesium, silicon and many more elements which are listed in chemical composition of Table 1. 660°C is the melting point of Al2618 alloy is and the density is 2.80 g/cc.

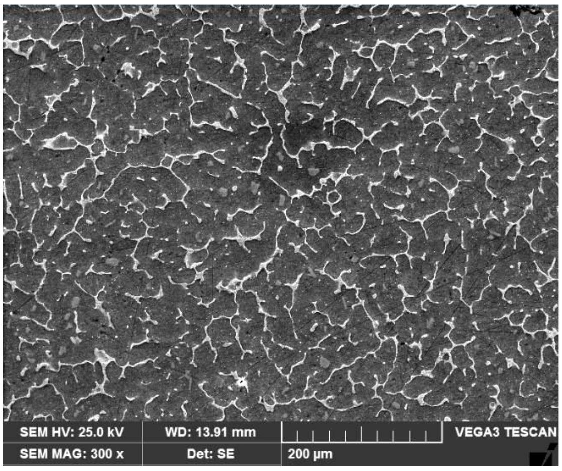
Boron Carbide is one of the hardest man-made materials available in commercial quantities. Boron carbide ceramics have excellent physical and mechanical properties, such as a high melting point, hardness, good abrasion resistance, high impact resistance and excellent resistance towards corrosion. As 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.

63 micron ceramic B_4C particles were used as the reinforcement in the Al2618 alloy base matrix. Micro composites were produced by simplest and most economical used technique known as stir casting technique or vortex technique. Al2618 alloy is heated to the temperature of 750ºC in electrical resistance furnace. Thermocouple is used to check the temperature of the melt in the graphite crucible. At around 750ºC, powder of hexa-chloroethane (C_2Cl_6) is added to the melt to remove all the unwanted trapped gasses and thus prevents casting defects like blow holes and porosity. Next, magnesium was added to decrease the surface tension and viscosity of the melt. The required quantities of preheated B_4C were taken in separate containers and added to Al2618 melt with continuous stirring for about 5-6 minutes at 300-350 rpm by zirconium-coated stirrer until a clear vortex is formed leading to good bonding, increase in the wettability between matrix and reinforced particles and to avoid agglomeration aimed at obtaining uniform homogenous distribution of reinforced particulates in the melt.

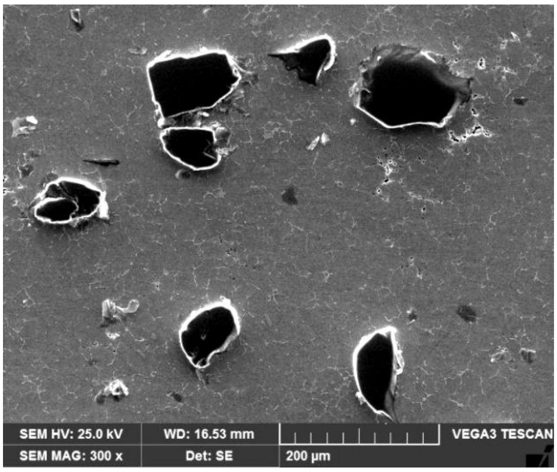
After mixing of the reinforcement particulates, the temperature of the melt reduced and started to solidify following which the melt was superheated above the liquid temperature with continued stirring and finally poured into permanent mould made of cast iron and allowed to solidify. After complete solidification, the casting is removed from the mould. Composites thus prepared were machined according to the ASTM standards. Now the Al2618-2 and 4 wt.% of B_4C composite samples were subjected to various tests. Samples were tested for microstructural characterization by using Scanning Electron Microscope (SEM) and Energy

Dispersive Spectroscope (EDS). Mechanical behavior like hardness, ultimate tensile strength and yield strength were evaluated as per ASTM standards.

III. RESULTS AND DISCUSSION



(a)



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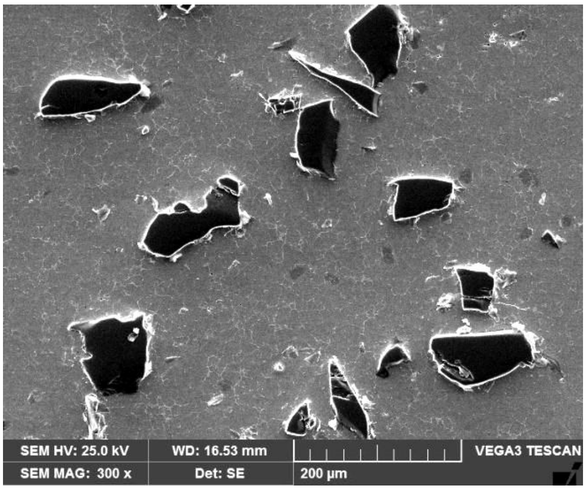

(c)

Figure 1: SEM micrographs of (a) as cast Al2618 alloy (b) Al2618-2 wt.% B_4C (c) Al2618-4 wt.% B_4C (63 micron) composites

To examine SEM images, the samples were preferred from the middle segment from the cylindrical specimens. Fig. 1a-c shows the SEM microstructure of as cast Al2618 alloy and the composite of 2 and 4 wt. % of nano B_4C reinforced with Al2618 alloy. The microstructure of as cast Al2618 alloy comprises of fine grains of solid solution of the aluminium along with an ample distribution of inter-metallic precipitates. In additionally, the prepared micro composite shows the great bonding among the framework and the reinforcement alongside the uniform homogenous circulation of estimated B_4C particulates without any agglomeration and bunching in the composites. This is essentially because of the practical mixing activity accomplished all through by two stage addition process of 63 micron sized B_4C. By the uniform distribution of micro particle in matrix, the grain limit of the lattice obstructs the grain improvement and opposes the separation development of grains amid stacking.

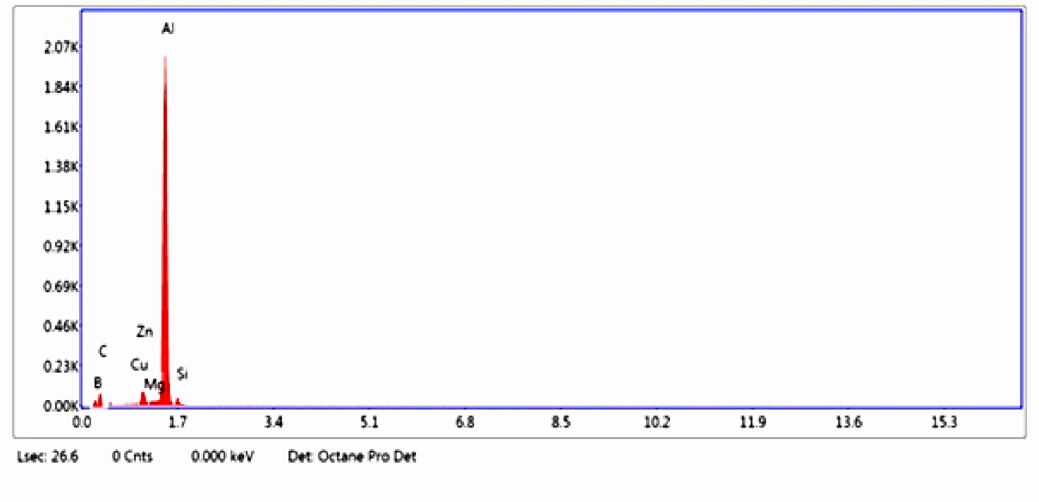

Figure 2: Showing energy dispersive spectrum analysis of Al2618-4wt. % micro B_4C composite

Energy dispersive spectrum analysis (fig.2) confirmed the presence of micro B_4C particulates in the form of B and C elements in the Al2618 alloy base matrix.

Hardness Measurements

The hardness is a mechanical parameter demonstrating the capability of resisting of prepared materials to indentation under a static load. The variation in the hardness can be observed from figure 3 with the addition of 2 and 4 wt. % of 63 micron B_4C particulates to the Al2618 alloy with respect to unreinforced alloy. The increase is observed from 62.9 BHN to 78.5 BHN for Al2618-4 wt.% of B_4C composites. This can be credited to the because of the of harder B_4C particles in the lattice than base alloy, and the higher constraint to the localized matrix deformation during indentation as an outcome of the presence of harder phase. Furthermore the B_4C, as other fortifications fortifies the matrix by making of high density dislocations amid cooling to room temperature because of the distinction of coefficients of thermal expansion developments between the micro B_4C and grid Al2618 compound. The mismatch strains developed between the micro reinforcement and the matrix obstructs the movement of dislocations, by resulting in the improvement of the hardness of the prepared nano composites [11, 12].

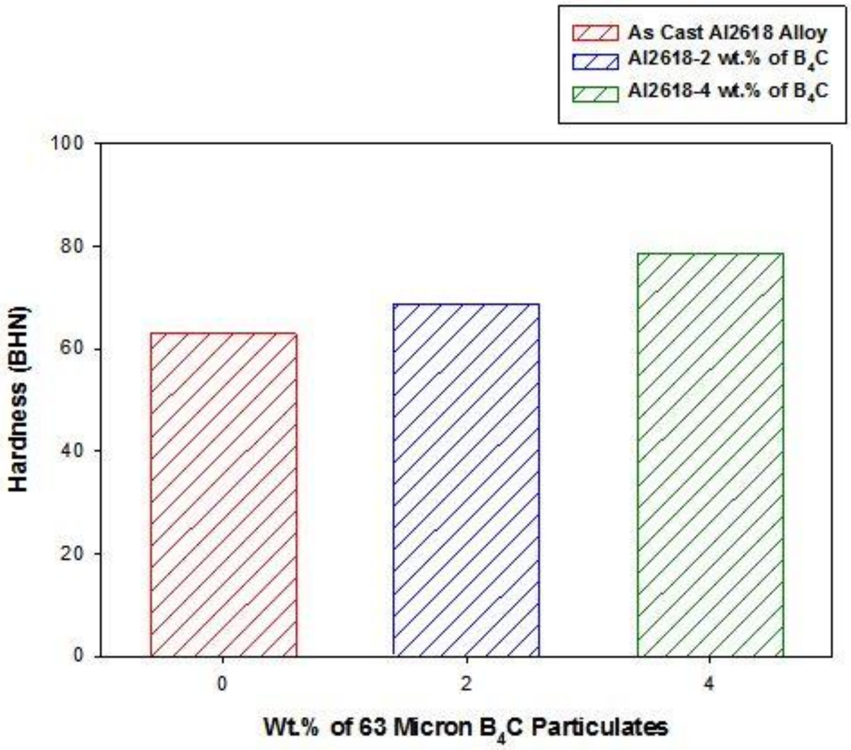

Figure 3: Hardness of Al2618 alloy and 63 micron size B_4C composites

Ultimate Tensile Strength and Yield Strength

Figure 4 represents the plot of ultimate tensile strength (UTS) with 2 and 4 wt. % of micron B_4C dispersoids in metal lattice composite. As a component of weight rate of B_4C particles the calculated estimations of ultimate tensile strength were plotted. When compared to base Al2618 alloy with 2 and 4 wt.% of B_4C composites, there has been a increase of 6 and 20% in UTS. The major increase in strength is credited because of legal contact between the framework mixture and the supporting materials. Better the grains estimate better is the hardness and additionally the better quality of composites prompting to enhance the wear resistance [13]. The improvement in UTS is credited by the hard micro ceramic B_4C particulates, which confers quality to the framework mixture, in this way giving improved solid rigidity. The expansion of these hard B_4C particles may have offered rise to huge lasting compressive unease created along with cementing because of contrast in coefficient of developed between flexible matrix and brittle particles. The improvements of quality are likewise attributed to closer packing of reinforcement and thus little inter particle spacing in the lattice.

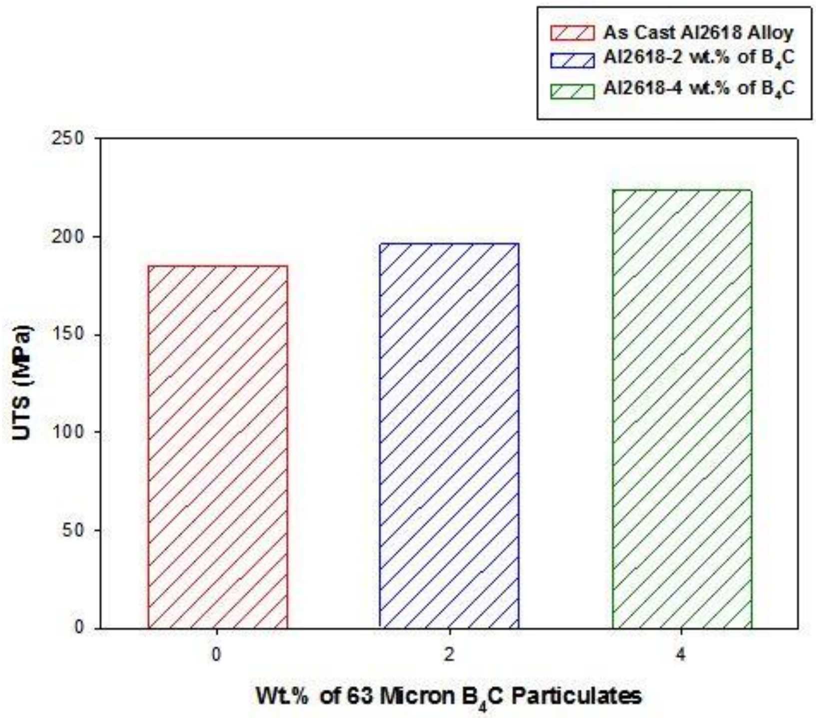

Figure 4: UTS of Al2618 alloy and 63 micron size B_4C composites

By noticing that the nature of the prepared composites is extremely dependent on the weight or volume division of the reinforcement leads to the increase in yield quality. Figure 5 showing the variation in yield strength (YS) of Al2618 alloy matrix with 2 and 4 wt. % of micro B_4C particulates reinforced composites. It is noticed that by adding 2 and 4 wt. % of micro B_4C particles the yield strength is improved from 147.2 MPa to 158.4 MPa and 147.2 MPa to 184.6 respectively. The expansion in yield strength of the composite is clear because of the hard B_4C ceramic particles which contribute to the quality by delectating the aluminum network and bringing about more quality resistance of the composite against the connected ductile load. On account of micro particle strengthened composites, the uniformly distributed hard ceramic particles in the grid make limitation till the plastic stream, in this way giving upgraded quality to the composite [14].

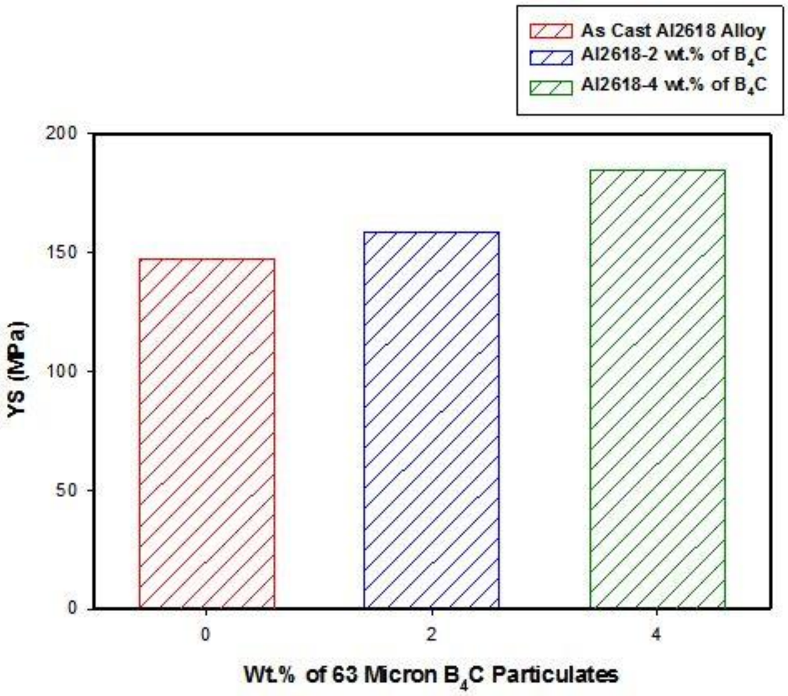

Figure 5: YS of Al2618 alloy and 63 micron size B_4C composites

Percentage Elongation

Figure 6 representing the impact of 63 micron sized B_4C content on the ductility (elongation) of the composites and the flexibility of the composites reduces essentially with the 2 and 4 wt. % B_4C prepared composites which can be noticed from the chart. This diminishing in rate prolongation in association with the matrix and reinforcement is a most commonly occurring disadvantage in particulate prepared metal matrix composites. The decreased malleability in micro composites can be attributed to the closeness of B_4C ceramic particulates which may get broke by stirring process and have sharp corners that make the composites distorted to limited part initiate and increase [15]. The delicate impact that happens because of the contact of the hard particles bringing on expanded locality stretch focus locales may like manner be the reason.

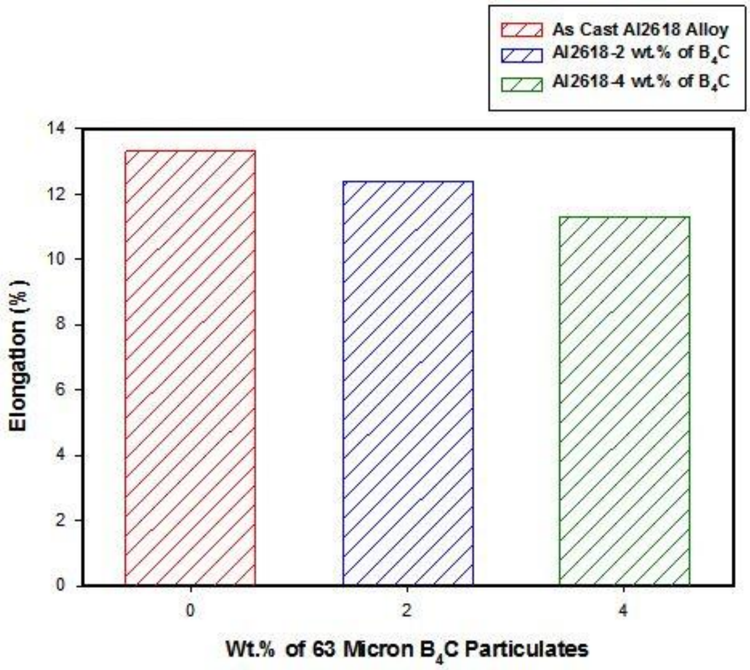

Figure 6: Percentage elongation of Al2618 alloy and 63 micron B_4C composites

IV. CONCLUSIONS

In this research, by using stir casting fabrication technique the 63 micron B_4C /Al2618 composites have been fabricated by considering 2 and 4 wt. % of reinforcement. The microstructures, mechanical properties like hardness, ultimate tensile strength, and yield strength and percentage elongation behavior of prepared samples are studied as per ASTM standards. The matrix is almost free from pores in as cast alloy and uniformly distributed of micron particles in the prepared composite, which is evident from SEM microphotographs. The EDS analysis confirms the presence of B_4C particles in the Al alloy matrix. Compared to unreinforced material the mechanical properties of Al2618-2 and 4 wt. % 63 micron sized B_4C composite are superior and enhanced. Further, as weight percentage of B_4C particulates increased from 2 to 4 wt.% in the Al alloy matrix, the ductility decreased.

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