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Microstructure and tensile behavior of AA7475-B_4C composites

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Abstract: The work is carried out to investigate and study the mechanical properties of B_4C reinforced AA7475 alloy metal matrix composites. In the present work AA7475 alloy is taken as the base matrix and B_4C particulates as reinforcement material to prepare metal matrix composites by stir casting method. For metal matrix composites the reinforcement material was varied from 0 to 4 wt. % in steps of 2 wt. %. For each composite, the reinforcement particulates were preheated to a temperature of 300ºC and dispersed into a vortex of molten AA7475 alloy. The microstructural characterization was done using scanning electron microscope. Mechanical properties like hardness, ultimate tensile strength and yield strength were evaluated as per ASTM standards. Further, scanning electron microphotographs revealed that there was uniform distribution of B_4C particulates in AA7475 alloy matrix. Hardness, ultimate tensile strength and yield strength increased as wt. % of B_4C increased in the base matrix.

Keywords: AA7475 Alloy, B4C, Stir Casting, Hardness, Tensile Strength

I. INTRODUCTION

Composite material is a combination of two or more different materials; it gives superior quality than its constituents. Due to their excellent mechanical properties composite materials can be used not only for structural applications but also in various other applications such as automobiles, aerospace, marine, etc. Aluminium alloys are broadly classified into casting alloys andwrought alloys. Major alloying elements in Aluminium alloys copper, manganese, silicon, magnesium and zinc. Aluminium metal matrix composites (Al MMCs) are being considered as a group of advanced materials due to light weight, high strength, high specific modulus, low co-efficient of thermal expansion and good wear resistance properties. The Aluminium matrix gets strengthened when it is reinforced with the hard ceramic particles like SiC, Al_2O_3, B_4C, etc. resulting in enhanced wear resistance and strength to weight ratio.Based on the type of reinforcement, size and morphology, the AMCs are fabricated by different methods such as Stir Casting, Squeeze Casting, Spray Deposition, liquid infiltration and powder metallurgy ratio than the conventional alloys.The processing method influences the mechanical and the tribological behavior of the AMCs.The above listed processing methods can be categorized into solid state processing and liquid state processing. Liquid method of processing is preferred because of its simplicity, ease of adoption and applicability to mass production.Stir casting is the widely used liquid method of processing to prepare AMCs where the Aluminium matrix is completely melted and ceramic particles are added into the molten metal in a vortex created using a mechanical stirrer.

A limited research work has been carried out on Aluminium Matrix Composites (AMCs) reinforced with B_4C due to higher raw material cost. B_4C is a robust material having excellent chemical and thermal stability, high hardness and low density. Hence, B_4C reinforced Aluminium Matrix Composite has gained more attraction with low cost casting route.

From the literature survey, there is a lack of data available for mechanical behaviour of AA7475 alloy reinforced with B_4C particulates. The microstructure and the mechanical behaviour of AA7475 alloy matrix with reinforced B_4C particulates have been studied. Mechanical properties like hardness (BHN) and tensile strength of AA7475 alloy andAA7475 alloy with 2 and 4 wt. % of B_4C composites were evaluated as per ASTM standards.

II. MATERIALS AND EXPERIMENTAL DETAILS

Al7475 is one of the 7xxx series alloys, in which zinc is the major alloying element; usually it is in combination with the magnesium and copper. Alloys of this series have the highest strength among all series. Alloys of this series possess the highest mechanical strength when heat treated.

The matrix material used in the experimental investigation is Aluminium 7475 alloy whose chemical composition is listed in Table 1. Al7475 alloy is one type wrought Aluminium

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alloy, containing zinc as a major alloying element. The density of Al7475 is taken as 2.81 g/cm^3 theoretically.

Elements	Symbol	Wt. %
Zinc	Zn	5.2-6.2
Magnesium	Mg	1.9-2.6
Silicon	Si	0.10
Iron	Fe	0.12
Copper	Cu	1.2-1.9
Titanium	Ti	0.06
Manganeese	Mn	0.06
Chromium	Cr	0.18-0.25
Aluminium	Al	Balance

Table 1. Chemical composition of AA7475 alloy

The main advantage of introducing reinforcement material to base metal or alloy is to increase the properties there by enhancing the mechanical and tribological properties of composites. In the current research Boron Carbide particulates of size 70-80 microns (μm) were used as a reinforcement material, which was procured from Speedfam (India) Pvt. Ltd., Chennai. Boroncarbide is non metal material that poses very useful physical and chemical properties. This material among excellent potential material because it known as third hardest material after diamond and boron nitride and density of Boron carbide is 2.51g/cm3 which is lower than the base Al matrix, contributes in weight saving. Boron carbide retains high melting point which is 2450 ºC as well as high resistance to chemical agents.

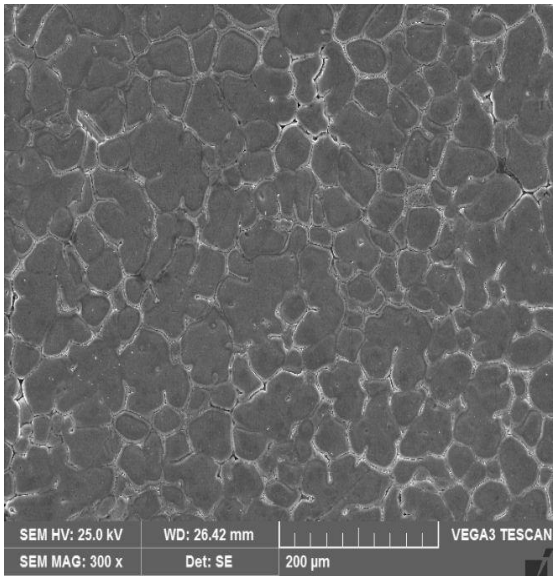
Preparation of AA7475-B_4C Composites

The fabrication of AA7475-B_4C composite used in this study was carried out by using a stir casting method. In this, firstly AA7475 alloy in the form of 25 mm diameter rods cut into 75mm length was placed in a clay graphite crucible. It was then melted in a resistance heated muffle furnace to the desired temperature of 718˚C. In the mean time B_4C particulates of size 70-80 μm were heated in another crucible to a temperature of 250˚C to remove moisture, and the die was preheated to a temperature of 300˚C. Then the boron carbide particulates were mixed into themolten metal. The crucible was covered with a flux and degassing agents to improve the quality of Aluminiumcomposite casting. The mixture was stirred continuously by using mechanical stirrer for about 10-15 minutes at animpeller speed of 300 rpm. The melt temperature was maintained at 730˚C during addition of the particles. Themolten metal was then poured into the preheated die to cast plates. Same procedureis followed to fabricate AMCs with 2 and 4 wt. % B_4C.

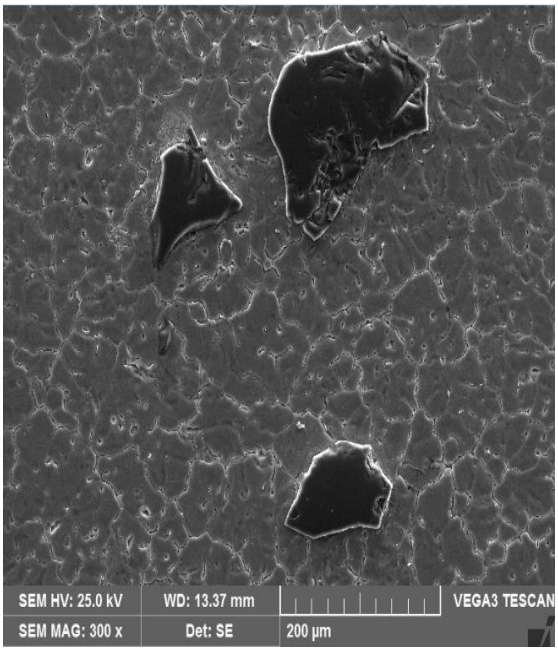
III. RESULTS AND DISCUSSION

Microstructural Analysis

(a)



(b)



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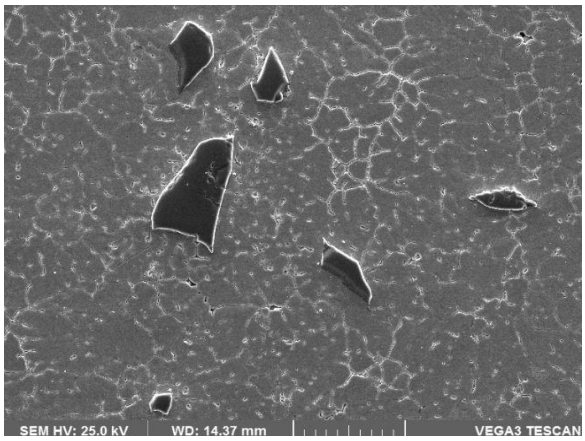

(c)

Figure 1. Showing SEM micrographs of (a) as cast AA7475 Alloy (b) AA7475-2% B_4C (c) AA7475-4% B_4C

Figure1(a) - (c)shows the scanning electron microscope micro graph so fascast AA7475alloy and its composites.
Figure 1(b) – (c) shows the SEM micrographs of 2 & 4wt.%ofB_4Cparticulatecomposites.
This reveals the uniform distribution of B_4Cparticles and very low agglomeration and segregation of particles. Thev or tex generated in the stirring process breaks solid dendrites duetohigherfrictionbetweenparticlesandAlmatrixalloy,whichf urther induces a uniform distribution of particles.

Hardness

The figure 2, it is observed that there is an increase in the hardness of AA7475 with addition of 2 and 4wt % of B_4C particulate. The graph shows the variation of hardness of AA7475 alloy with B_4C reinforcement particulate. It can be concluded that the addition of wt. % of B_4C particulate results in increasing the hardness. The hardness of a soft material such as aluminum matrix is increased when it is reinforced with a hard particulate i.e., B_4C.

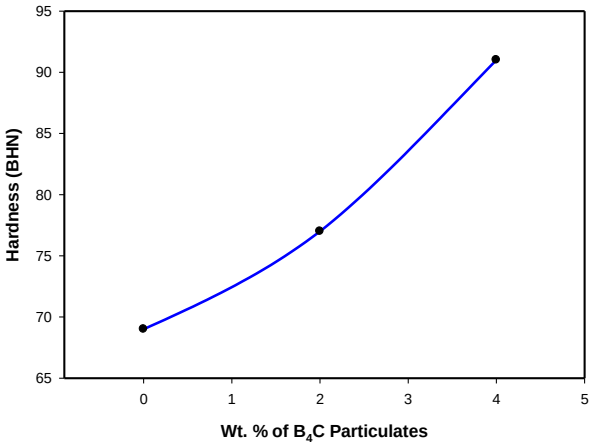

Figure 2. Showing thehardness of AA7475-B_4C composites

3.3 Ultimate Tensile Strength

Figure 3 shows the variation of ultimate tensile strength (UTS) of base alloy, when reinforced with 2 and 4 wt. % of B_4C particulates. The ultimate tensile strength of AA7475-B_4C composite material increases as compared to the cast base AA7475 alloy. The microstructure and properties of hard ceramic B_4C particulates control the deformation of the composites. Due to the strong interface bonding, load from the matrix transfers to the reinforcement resulting in increased ultimate tensile strength. This increase in ultimate tensile strength mainly is due to presence of B_4C particles which are acting as barrier to dislocations in the microstructure [9, 10]. The improvement in ultimate tensile strength may also be due to alloy strengthening of the matrix, followed with a reduction in grain size of the composites, and the formation of a high dislocation density in the AA7475 alloy matrix due to the difference in the thermal expansion between the metal matrix and the B_4C reinforcement [11].

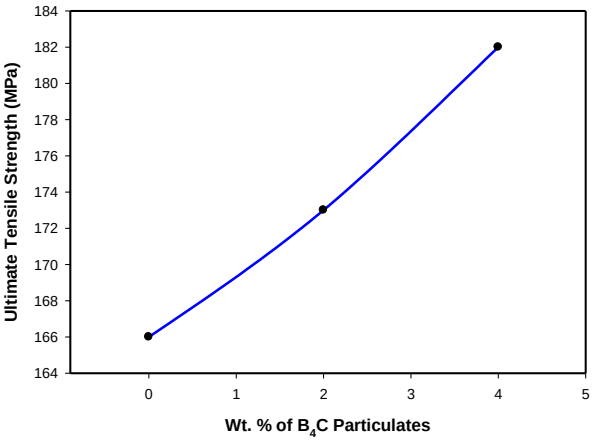

Figure 3. Showing theultimate tensile strength of AA7475-B_4C composites

Yield Strength

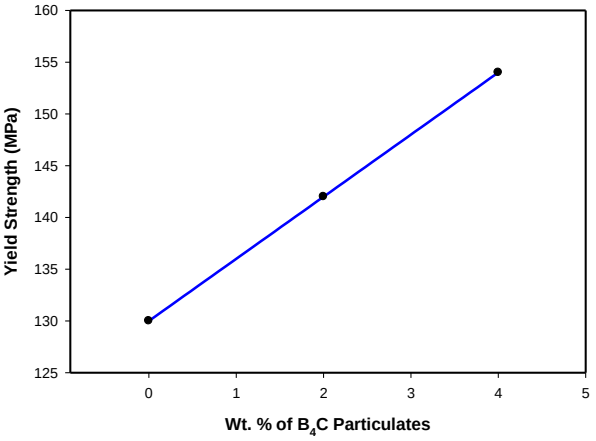

Figure 4. Showing theyield strength of AA7475-B_4C composites

Figure 4 shows variation of yield strength (YS) of AA7475 alloy matrix with 2 and 4 wt. % of B_4C particulate

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reinforced composite. It can be seen that by adding 4 wt. % of B_4C particulates yield strength of the AA7475 alloy increased from 130 MPa to 154 MPa. This increase in yield strength is in agreement with the results obtained by several researchers, who have reported that the strength of the particle reinforced composites is highly 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 zinc-aluminum matrix resulting in greater resistance of the composite against the applied tensile load [15]. In the case of particle reinforced composites, the dispersed hard particles in the matrix create restriction to the plastic flow, thereby providing enhanced strength to the composite [12].

VI. CONCLUSIONS

The present work entitled, "Microstructure and tensile behavior of AA7475-B_4C composites",has led to following conclusions:

- AA7475 alloy-B_4C particulate composites were successfully produced by liquid stir casting route with different weight percentage (2 and 4) of reinforcement.
- Aluminum based metal matrix composites have been successfully fabricated by liquid stir casting method by two step addition of reinforcement combined with preheating of particulates.
- The hardness of AA7475-2 and 4 wt. % B_4C composites increased with the addition of B_4C particulates in AA7475 base alloy.
- Improvements in ultimate tensile strength of the AA7475 alloy matrix were obtained with the addition of B_4C particulates. The extent of improvement obtained in B_4C alloy after addition of 2 and 4 wt. % B_4C particulates were 4 and 10 percentages respectively.
- Improvements in yield strength of the AA7475 alloy matrix were obtained with the addition of B_4C particulates. The extent of improvement obtained in B_4C alloy after addition of 2 and 4 wt. % B_4C particulates were 10 and 18 percentages respectively.

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