Mechanical 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 was taken as the base matrix and B_4C particulates as reinforcement material to prepare metal matrix composites by stir casting method. For composites the reinforcement material was varied in 6 & 8 wt. %. For each composite, the reinforcement particulates were preheated to a temperature of 300°C 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, B_4C, Stir Casting, Hardness, Tensile Strength

I. INTRODUCTION

Metal matrix composites (MMCs), a metal/alloy with ceramic reinforcements, are known for their high specific strength, modulus and hardness properties [1]. These share a good fraction in aerospace applications. Though there are many applications with MMCs, secondary processing, compatibility between matrix and reinforcement and characterization are still the major problems in the manufacturing of these composites. To limit the limitations associated with metal-ceramic composites, metal-metal composite systems were chosen. Thought has been given by Madhu et al. [2], to have the advantage of MMCs and metal metal combination system by choosing the conventional alloy systems for the manufacture of composites with restricted solubility, termed as metal-metal composites. To have good compatibility between the matrix and the reinforcement, an established alloy system with proven application needs to be chosen, where the solvent acts as the matrix and the solute as the reinforcement. Solute dissolution needs to be restricted / controlled to have the reinforcement effect. Strengthening of the resultant composite can be achieved by a combination of reinforcement, alloying, and heat treatment. The other advantages include use of conventional foundry facilities for manufacturing of these composites [3, 4], secondary processing of these composites at much lower energy level than the alloy and the MMCs etc.

Particle reinforced aluminium metal matrix composites (AMC's) have been developed in the last few years, to reduce the wt. of components used in structural applications and also to improve their mechanical and physical properties. Fabrication of composites having metals with limited mutual solubility can be produced, utilizing the properties of the alloy and the resulting composite [5, 6]. With their high formability and low work hardening rates, these composites can be produced at low cost. In terms of applications, Al–Cu-Mg alloys shares a larger fraction of aluminium alloys due to their high specific mechanical properties and wide range of alloys and properties. The basic idea of developing metal matrix composites is to derive high strength materials.

Large number of products have been designed and manufactured for various applications. Many of the investigations have shown improved mechanical properties, but limited with low & poor ductility. In the present investigation, an attempt has been made to achieve a good combination of strength & hardness properties with composites.

There are several aluminium alloys are available to fabricate the metal matrix composites. Among all the alloys 2XXX, 6XXX and 7XXX series are the most commonly using materials for aerospace, structural and aerospace applications. AA2024 and 2014 alloys are wrought alloys used in aerospace structural applications. AA6061 alloy is the light weight and medium strength Al alloy commonly considering for the automotive and home appliances [7].

AA7475 alloy is the class of 7XXX series alloy having high strength and good fracture toughness. In the present investigation an attempt has been made to develop AA7475-B_4C reinforced composites by melt stirring concept. Further, prepared AA7475-B_4C composites were evaluated for mechanical properties to know the influence of reinforcement particulates on the AA7475 alloy.

II. MATERIALS AND EXPERIMENTAL DETAILS

AA7475 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. AA7475 alloy is one type wrought Aluminium alloy, which is suitable to carry out the secondary operations. The density of AA7475 is taken as 2.81 g/cm^3 theoretically.

TABLE I. CHEMICAL COMPOSITION OF AA7475 ALLOY

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

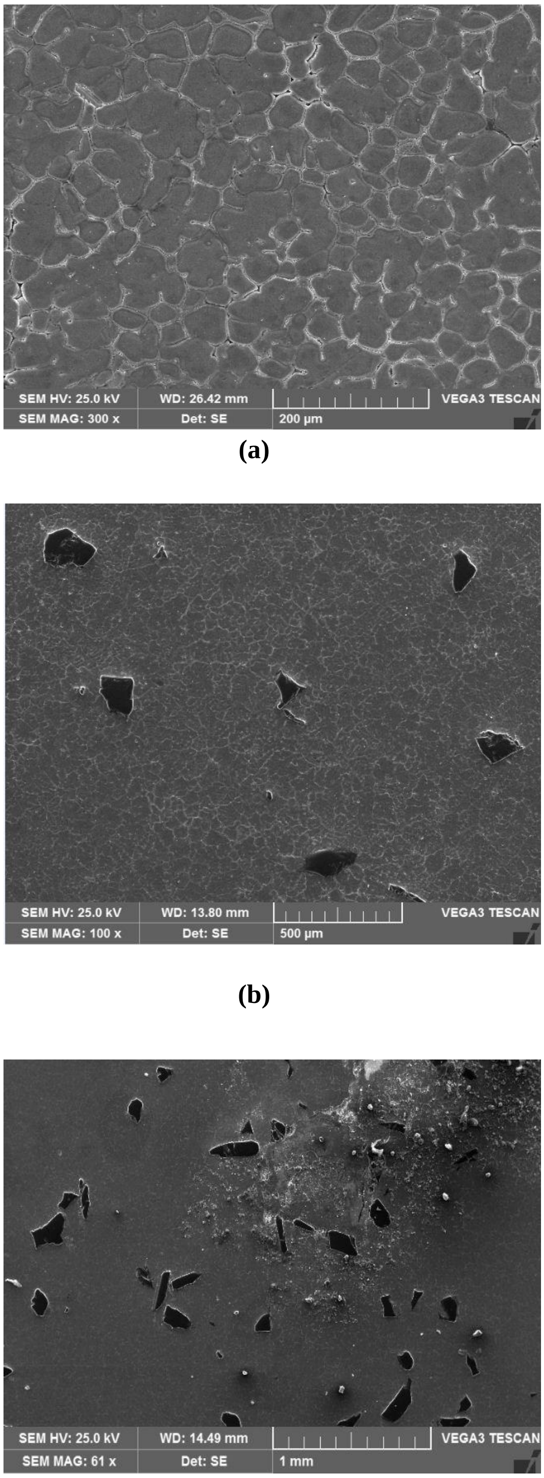
The main advantage of introducing reinforcement material to base metal or alloy is to increase the properties there by enhancing the mechanical and tribological properties of composites. In the current research Boron Carbide particulates of size 70-80 microns (µm) were used as a reinforcement material, which was procured from Speedfam (India) Pvt. Ltd., Chennai. Boron carbide 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/cm^3 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.

A. 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 750°C. In the mean time B_4C particulates of size 70-80 µm were heated in another crucible to a temperature of 300°C to remove moisture, and the die was preheated to a temperature of 200°C. Then the boron carbide particulates were mixed into the molten metal. The crucible was covered with a flux and degassing agents to improve the quality of Aluminium composite casting. The mixture was stirred continuously by using mechanical stirrer for about 10-15 minutes at an impeller speed of 300 rpm. The melt temperature was maintained at 730°C during addition of the particles. The molten metal was then poured into the preheated die to cast rods. Same procedure is followed to fabricate AMCs with 6 and 8 wt. % B_4C.

III. RESULTS AND DISCUSSION

A. Microstructural Analysis



(a) (b) (c)

Fig.1. Showing SEM micrographs of (a) as cast AA7475 Alloy (b) AA7475-6% B_4C (c) AA7475-8% B_4C

Figure 1 (a) - (c) shows the scanning electron microscope micrographs of as cast AA7475 alloy and its composites. Figure 1(b) – (c) shows the SEM micrographs of 6 & 8 wt. % of B_4C particulate composites. This reveals the uniform distribution of B_4C particles and very low agglomeration and segregation of particles. The vortex generated in the stirring process breaks solid dendrites due to higher friction between particles and Al matrix alloy, which further induces a uniform distribution of particles.

B. Hardness

The figure 2, it is observed that there is an increase in the hardness of AA7475 with addition of 6 and 8wt % 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 [8].

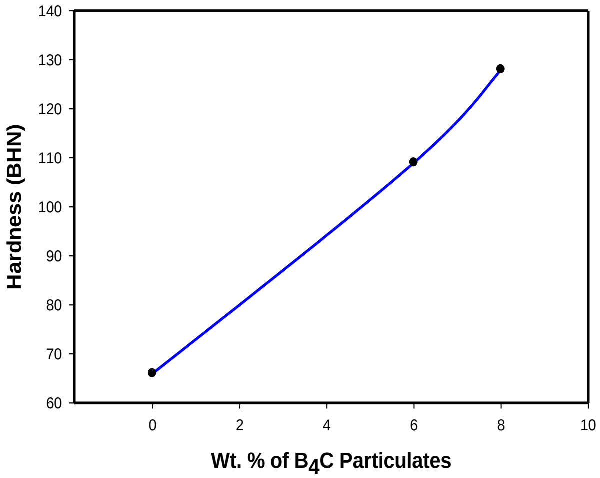


Fig. 2. Showing the hardness of AA7475-B_4C composites

C. Ultimate Tensile Strength

Figure 3 shows the variation of ultimate tensile strength (UTS) of base alloy, when reinforced with 6 and 8 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]. 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 [10].

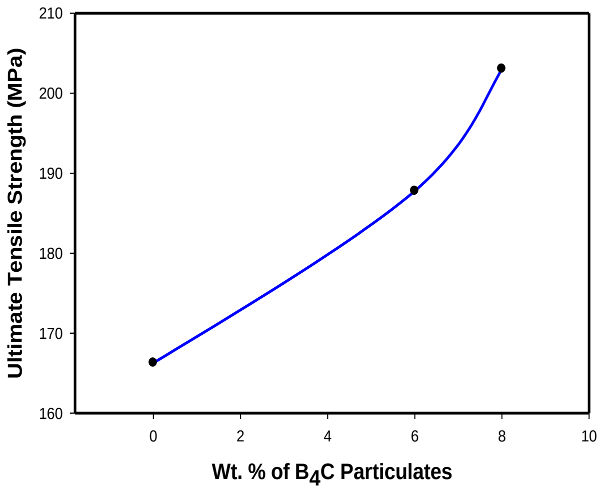


Fig. 3. Showing the ultimate tensile strength of AA7475-B_4C composites

D. Yield Strength

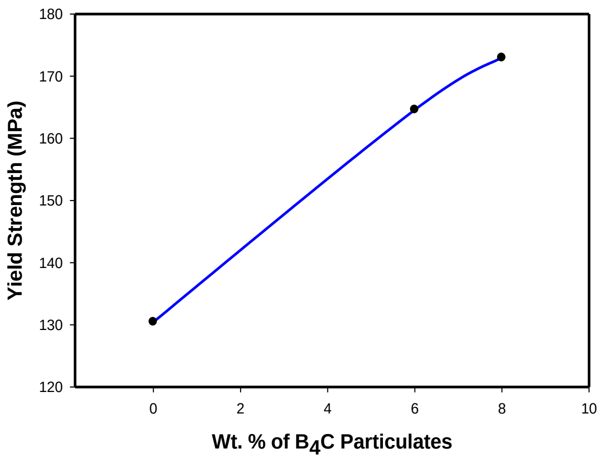


Fig. 4. Showing the yield strength of AA7475-B_4C composites

Figure 4 shows variation of yield strength (YS) of AA7475 alloy matrix with 6 and 8 wt. % of B_4C particulate reinforced composite. It can be seen that by adding 6 wt. % of B_4C particulates yield strength of the AA7475 alloy increased from 130 MPa to 164 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 [11]. 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].

IV. 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 (6 and 8) 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 AA7475-6 and 8 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 6 and 8 wt. % B_4C particulates were 12.63 and 23.49 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 alluminium alloy after addition of 6 and 8 wt. % B_4C particulates were 10 and 18 percentages respectively

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