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Investigations on Tensile Behavior of Al7475-6%B4C Particulates Reinforced Composites

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ABSTRACT
This work is carried out to investigate and study the tensile behavior of B4C reinforced Al7475 alloy metal matrix composites. In the present work Al7475 alloy is taken as the base matrix and B4C particulates as reinforcement material to prepare the metal matrix composites by stir casting method. 6 wt. % of B4C particulates were taken to prepare the Al alloy based composites. The reinforcement particulates were preheated to a temperature of 400ºC and dispersed into a vortex of molten Al7475 alloy. The microstructural characterization was done by using scanning electron microscope and EDS analysis. Tensile properties like ultimate tensile and yield strength were evaluated as per ASTM standards. Further, scanning electron microphotographs revealed the uniform distribution of B4C particulates and energy dispersive spectrograph confirmed the presence of B4C in Al7475 alloy matrix. Ultimate tensile strength and yield strengths were increased with the addition of 6 wt. % of B4C particulates in the Al7475 alloy matrix.

Keywords: *Al7475 Alloy, B4C particulates, Stir Casting, Ultimate Tensile Strength, Yield Strength.*

I. INTRODUCTION

Aluminium alloys are extensively used in advanced engineering applications such as aerospace and automotive industry due to its high strength, machinability, low density, easy availability and cost effectiveness compared to other materials. The scope of aluminium can be further extended by using it as a matrix material in the production of metal matrix composites (MMCs). Aluminium metal matrix composites (AMMCs) possess significantly improved properties including high strength to weight ratio, higher elastic modulus, damping capacity and good wear resistance compared to unreinforced alloys [1, 2].

Among aluminium alloys, 7XXX series is an Al-Zn alloy widely used in structural and engineering applications due to its good strength to weight ratio, corrosion resistance, heat treatability – forms precipitates on heat treatment and thus increasing strength with the cost of ductility. Harder ceramic particles such as TiC, Al_2O_3, Graphite, B_4C, Al_2O_3 and SiC are widely used as reinforcement in composites. This ceramic particulate facilitates high strength and stiffness, good thermal conductivity, excellent size and shape capability and good wear resistance [3-5].

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. 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.

Senthilkumar and co-authors [6] studied the mechanical properties of Al_2O_3 reinforced AA5083 matrix composites. Al AA5083 MMCs reinforced with different sizes and weight percentages of Al2O3 particles (upto 10 wt. %, size micron - nano) was successfully fabricated by powder metallurgy route. In the study reported the enhancement of hardness and compression strength after addition of Al_2O_3 particulates.

In the present work an attempt is made to synthesize Al7475 based composites with reinforcements of B_4C particulates with 6 wt. % by stir casting route and to study the tensile behavior the prepared MMCs.

II. EXPERIMENTAL DETAILS

Materials Used

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. The chemical composition of Al7475 alloy is listed in Table 1. The density of Al7475 is taken as 2.80 g/cm^3 theoretically.

Table 1. Chemical composition of Al7475 alloy

Elements	Symbol	Wt. %
Zinc	Zn	6.0
Magnesium	Mg	2.40
Silicon	Si	0.10
Iron	Fe	0.12
Copper	Cu	1.80
Titanium	Ti	0.06
Manganeese	Mn	0.06
Chromium	Cr	0.25
Aluminium	Al	Balance

In the current research Boron Carbide particulates of size 88 microns (μm) were used as a reinforcement material, which was procured from Speedfam (India) Pvt. Ltd., Chennai. Boron carbide is a 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.

Processing of Composites

Stir casting method was used to prepare the metal matrix composites of required dimensions. Al7475 alloy was melted in graphite crucible using electrical resistance furnace. Meanwhile, B_4C particles were preheated at 400°C for 30 minutes. The furnace temperature was maintained at 750°C, which is above the liquidous temperature of Al alloy in order to increase the viscosity of the melt. Mechanical stirrer maintained at 300rpm was used to stir the melt to form the vortex. Once the vortex is created, the preheated B_4C particles were introduced into the melt. The melt was stirred for 10 minutes. Then it was poured into cast iron permanent mould containing the cavity as per requirement.

Testing

Microstructure of prepared specimen was studied by taking the central part of the composite rod. The face of the specimen to be examined was prepared by polishing through 220, 400, 600, 800 & 1000 grit emery papers and polished using diamond paste. The specimen was etched using Keller's reagent, before it was examined using scanning electron microscope. Specimens for tensile test were prepared as per ASTM standards. Test was done by using computerized UTM as per ASTM standards and three specimens were tested for the particular composition.

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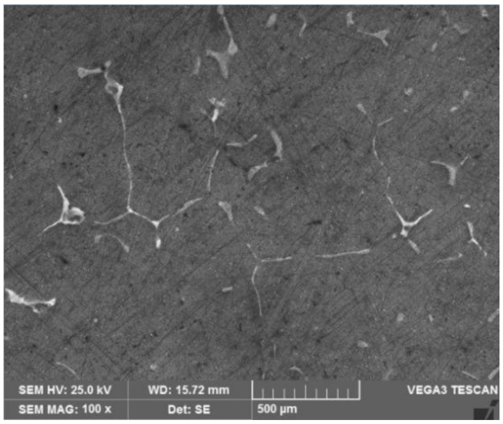
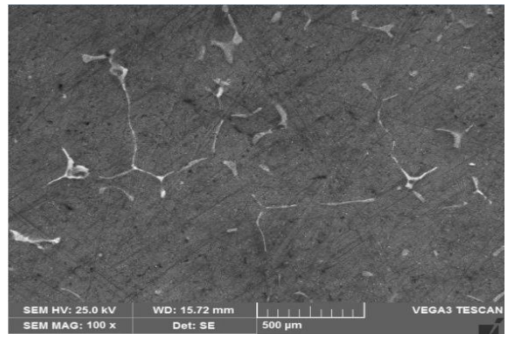
III. RESULTS AND DISCUSSION

Microstructural Studies



(a)



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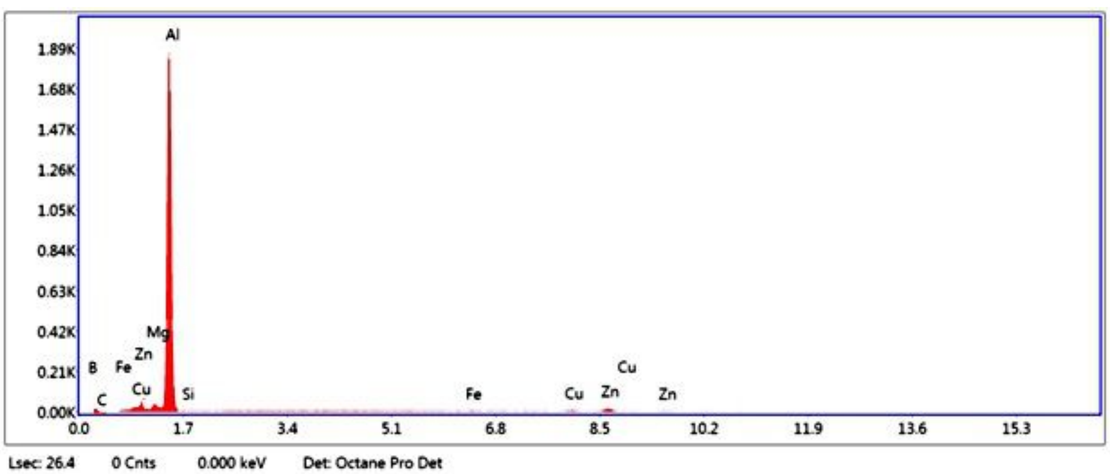

(c)

Figure 1: Showing SEM micrographs of (a) as cast Al7475 Alloy (b) Al7475-6% B_4C (c) Energy Dispersive Spectrograph of Al7475-6 wt. % B_4C composites

Figure 1 (a) - (b) shows the scanning electron microscope micrographs of as cast Al7475 alloy and 6 wt.% B_4C reinforced composites. Figure 1(b) shows the SEM micrographs of 6wt. % 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.

Figure 1c is showing energy dispersive X-Ray spectrograph of Al7475-6 wt. % of B_4C composites. The EDS analysis confirmed the presence of B_4C particulates in the Al matrix alloy. The presence of elements like B and C confirms the boron carbide particulates, further elements such as zinc, magnesium and copper is also available in the EDS plot, which shows the base matrix Al7475 alloy elements.

Ultimate Tensile Strength

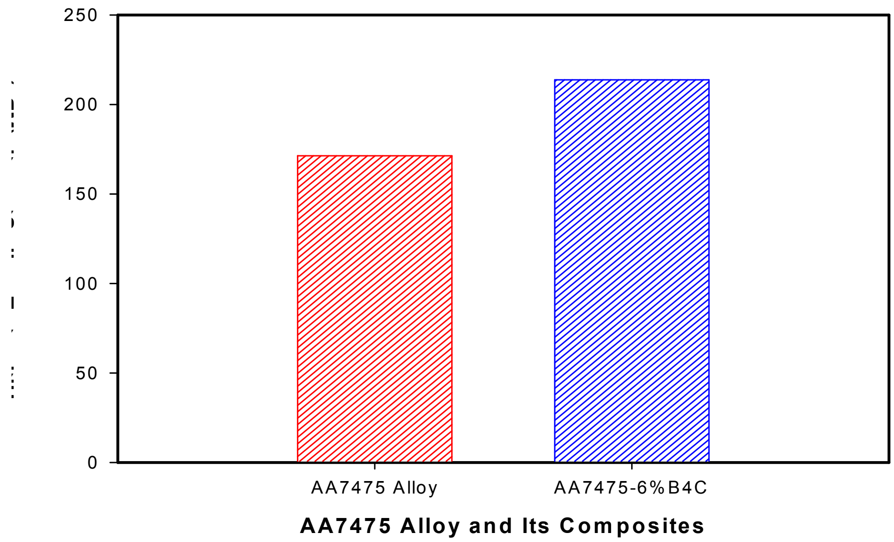

Figure 2: Ultimate tensile strength of Al7475 alloy and its composites

Figure 2 shows the variation of ultimate tensile strength (UTS) of base alloy, when reinforced with 6 wt. % of B_4C particulates. The ultimate tensile strength of Al7475- B_4C composite material increases as compared to the cast base Al7475 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 Al7475 alloy matrix due to the difference in the thermal expansion between the metal matrix and the B_4C reinforcement [7, 8].

Yield Strength

Figure 3 shows variation of yield strength (YS) of Al7475 alloy matrix with 6 wt. % of B_4C particulate reinforced composite. It can be seen that by adding 6 wt. % of B_4C particulates yield strength of the Al7475 alloy increased from 149MPa to 191MPa. 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 [9]. 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 [10].

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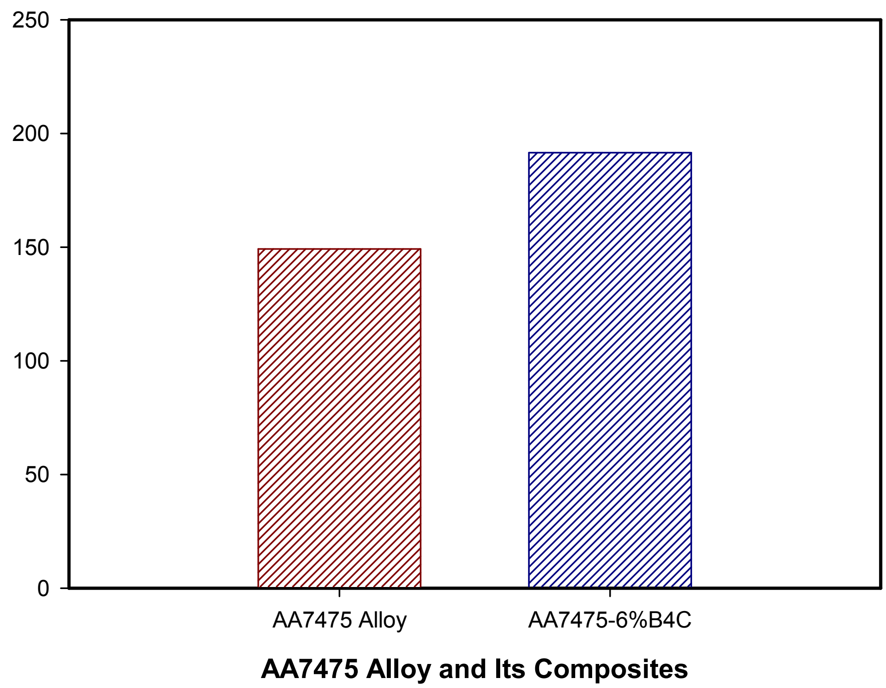

Figure 3: Yield tensile strength of Al7475 alloy and its composites

IV. CONCLUSIONS

The present work entitled, "Investigations on tensile behavior of Al7475-6% B_4C composites", has led to following conclusions:

- Al7475 alloy- B_4C particulate composites were successfully produced by liquid stir casting route with 6 wt. % of reinforcement.
- Scanning electron microphotographs revealed the uniform distribution of B4C particulates in Al7475 alloy matrix.
- Improvements in ultimate tensile strength of the Al7475 alloy matrix were obtained with the addition of B_4C particulates. The extent of improvement obtained in B_4C alloy after addition of 6 wt. % B_4C particulates was 24.5%.
- Improvements in yield strength of the Al7475 alloy matrix were obtained with the addition of B_4C particulates. Al7475-6 wt. % of B_4C particulate composites yield strength increased from 149MPa to 191MPa as compared to base alloy.

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