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Preparation and Characterization of B_4C Particulate Reinforced Al-Mg Alloy Matrix Composites

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ABSTRACT: *This paper describes the fabrication and mechanical testing of Al-Mg-boron carbide particulate composites using stir casting technique. The size of the boron carbide particulates is ranging between 30 to 100 µm. The boron carbide contents are varied from 3 and 7% by weight and are dispersed in the alloy matrix. The mechanical properties of the castings, particularly their tensile properties and hardness are measured. The micro structural features of the fabricated composite materials are evaluated using a Scanning Electron Microscope (SEM).*

Key words: *Aluminum-Magnesium alloy, Particulate reinforcement, Composites, B_4C, UTS, Microstructure.*

I. INTRODUCTION

Particulate-reinforced metal matrix composites are attractive materials for various light weight structural applications. Many materials have been tried on particulate materials in Al SiC particulate has been extensively utilized as reinforcement in various Al, Al-Mg, Mg-SiC alloy matrices [1-6]. Composites of SiC particulates in aluminum alloys have been successfully produced by powder metallurgy processing and casting techniques [7-11]. It has been demonstrated that significant improvements in stiffness, strength, fatigue crack propagation, creep strength, and wear resistance were achieved as compared with the unreinforced aluminum alloys. Besides, they can also be shaped by conventional metal working processes such as extrusion, forging, rolling or super plastic forming into complex structural parts. Hence, they are inexpensive to produce compared with other metal matrix composite systems. Potential applications of these composites include advanced aerospace structures, automobile engine components, electronic packaging, etc.

Boron carbide (B_4C) particulates are promising candidates as reinforcement for light weight metal matrix composites. B_4C has a lower specific gravity than either Al or SiC (2.52 (g/cm ^{3} compared with 2.7 for Al and 3.2 for SiC). It has a similar thermal expansion coefficient, higher specific stiffness and strength as compared to SiC. Increased application of chills in Al alloy B_4C composites and their mechanical properties have been studied [12-24]. In the present investigation, we have prepared B_4C particulate-reinforced Al-Mg matrix composites using stir casting technique. The purpose of this paper is to fabricate and characterize the microstructure and mechanical properties of the resulting composites, and to identify the failure mechanisms under various loading conditions.

A composite can be said to be a multifunctional system that provides characteristics not obtainable from any discrete material [2-5]. Aluminum and its alloys probly form the most widely used matrix materials for metals matrix composites [6]. Although reinforcements in the form of continuous and discontinuous fibers have already been investigated in depth [7], discontinues reinforcement such as that of dispersoid is becoming more and more popular. Subsequent working of such dispersoid-reinforcement metals matrix composites can also e enhance their mechanical properties. Al matrix composites have demonstrated improved mechanical properties compared to properties of un-reinforced Al alloys.

Metal matrix composites (MMCs) are emerging as advanced engineering materials for application in aerospace, defense, automotive and consumer industries (sports goods, etc.). aluminium or its alloy is favored as metallic matrix material because of its low density, easy fabricability and good engineering properties. In general, the benefits of aluminium metal matrix composites (AMCs) over unreinforced aluminium alloy include increased specific stiffness, improved wear resistance and decreased coefficient of thermal expansion. The reinforcement materials for AMCs are SiC and Al_2O_3. In the present work, boron carbide (B_4C) powder was chosen as reinforcement because of its higher hardness (very close to diamond) than the conventional and routinely used reinforcement such as SiC, Al_2O_3,etc. further its density (2.52g cm^{-3}) is very close to Al alloy matrix. Al-5% Mg alloy was chosen as matrix alloy in order to utilize the beneficial effect of Mg in improving wettability between B_4C particles and the alloy melt.

B_4C particulates are other promising candidates as reinforcement for light weight metal matrix composites. B_4C has a lower specific gravity than either Al or SiC (2.52 g/cm^3 compared with 2.7 for Al and 3.2 for SiC). It has a similar thermal expansion coefficient, higher specific stiffness and strength as compared to SiC [5]. In this study, a B_4C particulate – reinforcement 7091 Al matrix composite has been developed.

The Mg-9 wt% Li matrix alloy was prepared by vacuum casting and consisted of two phases, α (hexagonal-close-packed structure) and β (body-centered-cubic structure).The α phase, making up about 30 vol% of the material, is elongated and dispersed within the β matrix. The as-cast material was cut into plates, and these were given a repeated sequence of cold-rolling and annealing treatments until foils of about 0.20 mm thick were obtained. The total reduction of the individual foils was 200 to 1. The B_4C particles (less than 20 μm in size) were suspended in an ethanol solution and then painted on one side of the foils.

II. EXPERIMENTAL PROCEDURE

2.1 **Preparation of test specimens**

Al–Mg alloy matrix–B_4C particulate reinforced composites were fabricated by stir casting method. In this method Al–Mg alloy was first melted as per their weight proportions and super heated to 800°C in closed type electrical resistance furnace. The melt was degassed with argon gas and then stirred at a rate of 300–400 rpm by using a mechanical impeller. The blades were made of inconel plate. Argon gas was purged in to the melting chamber to reduce the oxidation of the melt. B_4C powder was preheated to 600°C for 1 h, in a separate furnace and it was added slowly to the Al-Mg molten melt. Complete mixing of powder and melt was done by uniform stirring. This ensure the dispersion of the B_4C particles uniformly in to the melt. The process was continued for 15min to obtain a homogeneous composite of alloy and particulates. During the entire process argon atmosphere was maintained. The homogeneous molten alloy composite was then poured into a graphite mold, which was preheated to 200° C. Cylindrical rods of 10mm diameter and 100mm height were machined and extruded in the form of rod. Composites with 3 and 7wt % of B_4C particulates were fabricated. The fabricated composite materials were characterized using various analytical techniques such as XRD, EDAX and SEM. The mechanical behavior of the composite materials was assessed an Instron tensile testing machine. The hardness of the composites was determined using a standard Micro hardness test machine.

2.2 Microstructure characterization

For the micro structural studies, specimens were cut from extruded rods and mounted in Bakelite, ground with grit paper, using copious amounts of water as lubricant. The mounted samples were then mechanically polished using a 1µm alumina-powder suspended in distilled water. Fine polishing to near mirror like finish was achieved using 0.5 µm diamond paste and etched with Keller's reagent. Reinforcement morphology and its distribution in the metal matrix along with other intrinsic micro structural features were identified by examining the samples in a JEOL JSM 3.5 CF Japan make Scanning Electron Microscope (SEM).

2.3 Mechanical testing

Tensile tests were performed using an instron tensile testing machine on ASTM standard tensometer specimens. Each test result reported in this paper, is the average obtained from at least three test specimens taken from the same location in the mould and cast under identical conditions.

Bulk hardness measurements were performed using a standard Micro hardness test machine. The measurements were carried out in order to investigate the influence of particulate volume fraction on the matrix hardness.

III. RESULTS AND DISCUSSION

3.1 MICROSTRUCTURE OF CAST COMPOSITES

The microstructures of the composites were evaluated by scanning electron microscope (SEM). The micrographs revealed a relatively uniform distribution of B_4C particles and good interfacial integrity between matrix and B_4C particles. The microstructures of Al-Mg- B_4C composites containing 3 and 7 wt. % boron are shown in Figs. 4.1, 4.2 and 4.3 respectively. These photo micro graphs show that the boron particles are of nearly uniform size and are uniformly dispersed in the aluminum matrix. However, micro structural studies reveal that, Mg migrated to the grain boundaries. This migration of alloying elements into the grain boundaries leaving behind the dispersoids in the grains result in a higher concentration of boron within the grains, which may be one of the main reasons for the increase in strength and soundness of the composite developed, as will be described below.

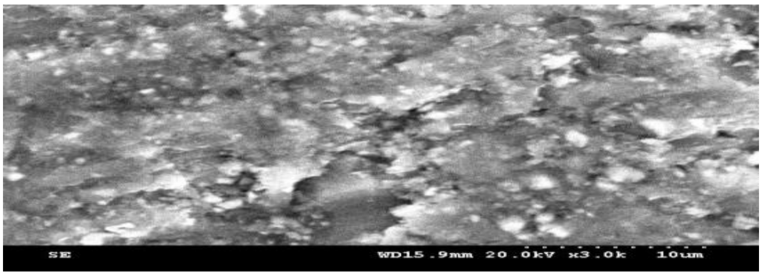

Fig 3.1: Micro structure of unreinforced Al-Mg alloy

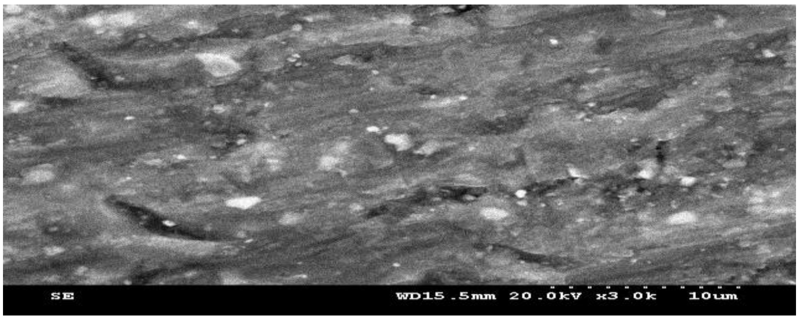

Fig 3.2: Micro structure of Al-Mg-B_4C MMC (3wt. % B_4C)

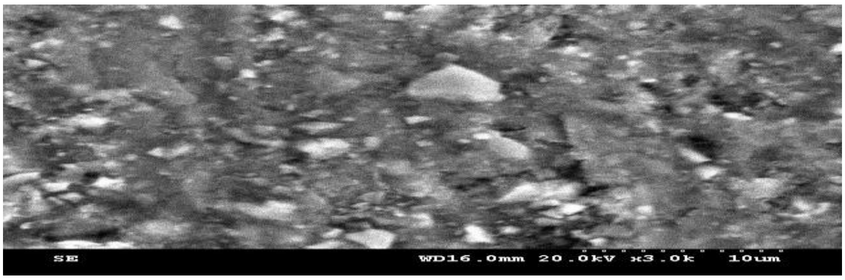

Fig 3.3: Micro structure of Al-Mg-B_4C MMC MMC (7 wt. % B_4C

3.2 EDAX

The element composition of Al-Mg alloy was assessed by EDAX spectral analysis. The EDAX spectrum exhibits presents of Al and Mg in appropriate weight ratio. The EDAX values are shown below figure 4.4, 4.5 and 4.6.

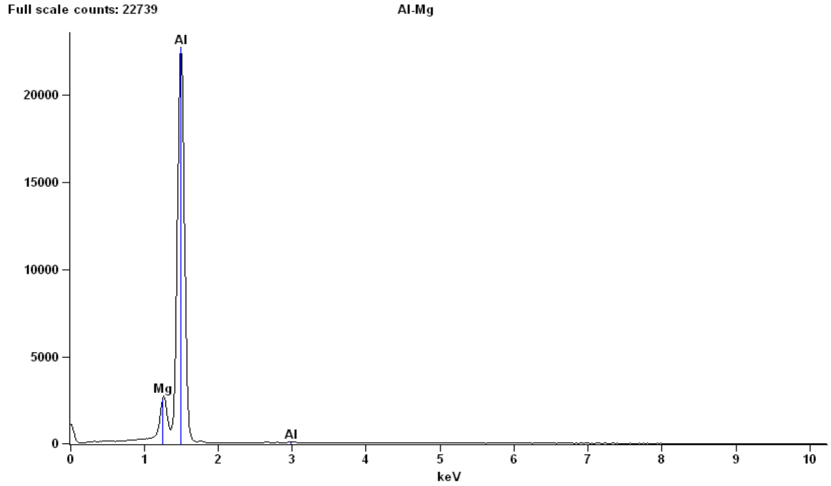

Fig 3.4: EDAX analysis of 92.5% Al –7.5% Mg

Table 3.1: Quantitative Results 92.5%Al-7.5%Mg

Element	*Net Counts*	***Weight %***	***Atom %***
Mg	25180	7.67	8.44
Al	243589	92.33	91.56
Total		100.00	100.00

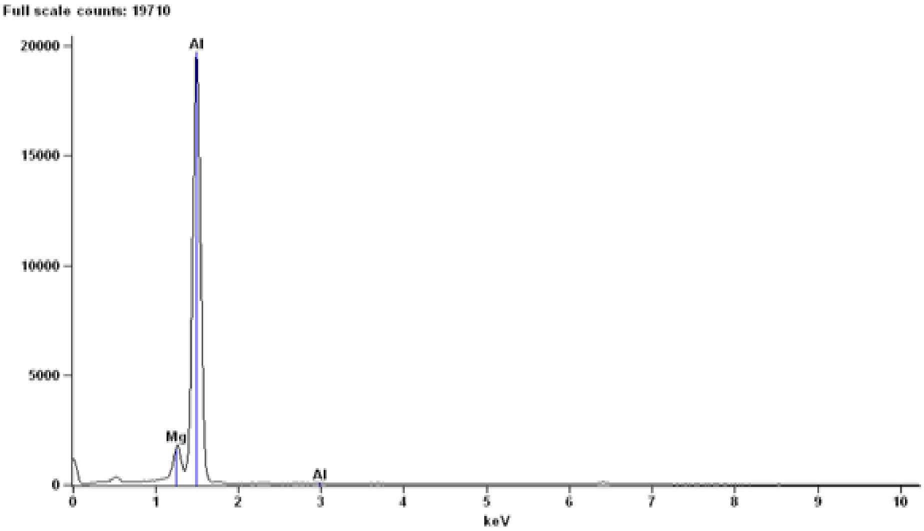

Fig 3.5: EDAX analysis of 92.5% Al – 7.5% Mg - 3% B_4C

Table 3.2: Quantitative Results 92.5%Al-7.5%Mg-3%B_4C

Element	***Net Counts***	***Weight %***	***Atom %***
Mg	15793	7.51	7.75
Al	213346	92.49	92.25
Total		100.00	100.00

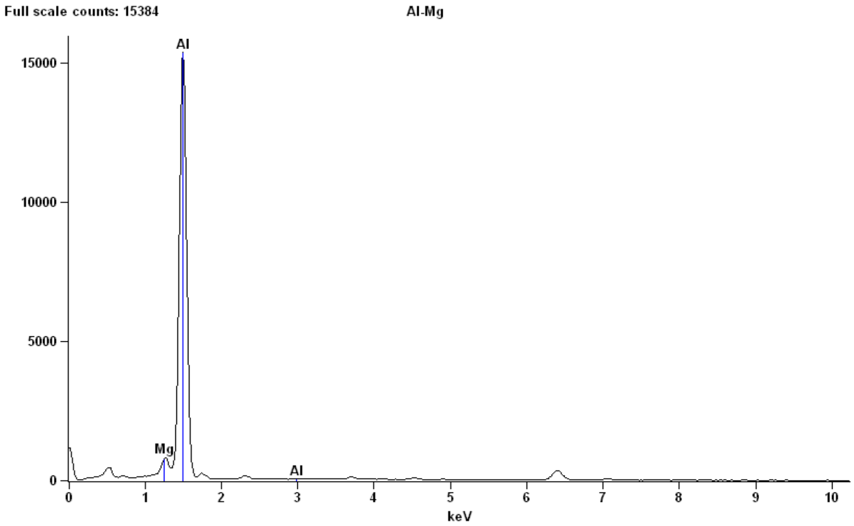

Fig 3.6: EDAX analysis of 92.5% Al – 7.5% Mg - 7% B_4C

Table 3.3: Quantitative Results 92.5%Al-7.5%Mg-7%B_4C

Element	***Net Counts***	***Weight %***	***Atom %***
Mg	5833	7.42	7.32
Al	164862	92.58	92.68
Total		100.00	100.00

3.3 XRD

The synthesized Al-Mg alloys were analyzed by XRD spectral analysis. 100% peak shows that the compound is in pure form. The XRD measurement shown in figure: 4.7,4.8 and 4.9.

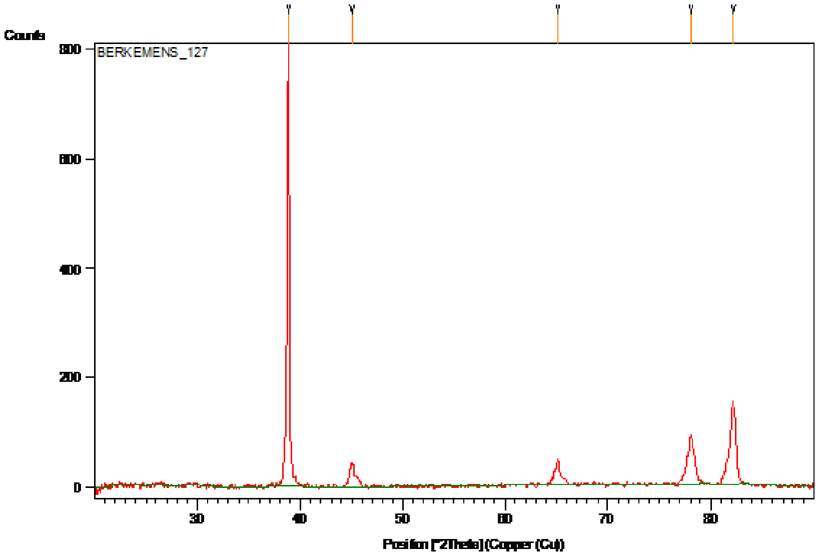

Fig 3.7: XRD measurement –Al- Mg

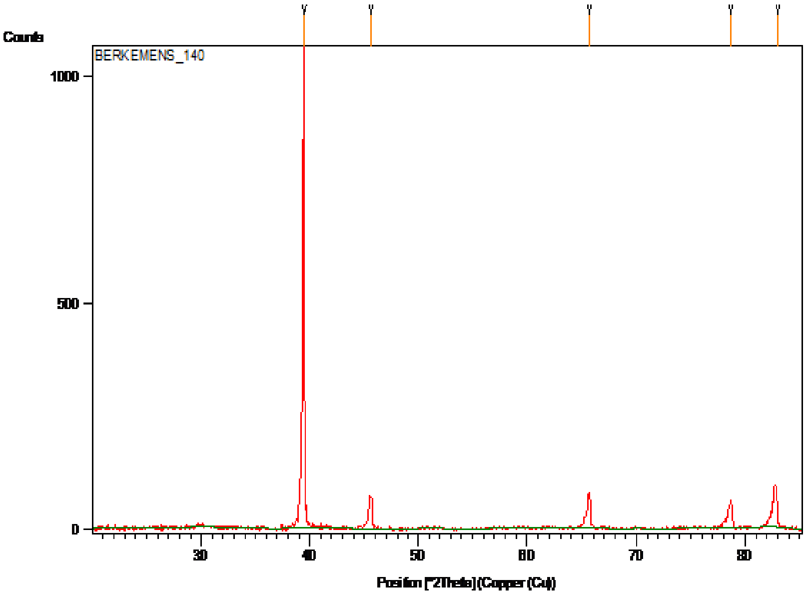

Fig 3.8: XRD measurement –Al- Mg - 3% B_4C

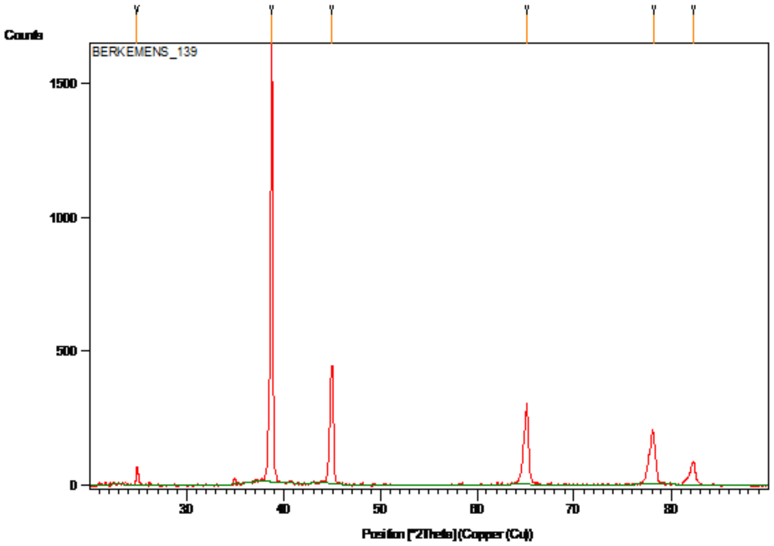

Fig 3.9: XRD measurement –Al- Mg- 7% B_4C

3.4 MECHANICAL PROPERTIES

Table 3.4: Tensile properties and Micro hardness test of composites

SPECIMAN	**UTS (MPa)**	**%Elongation**	**%Area Reduction**	**Hardness (Rockwell)**
92.5%Al-7.5%Mg	108.85	6.66	7.7	79
92.5%Al-7.5%Mg-3%B_4C	113.39	6.25	6.8	82
92.5%Al-7.5%Mg-B_4C	127.63	6.18	6.4	85

From the above table it is clear that addition of B_4C leads to improvement in the ultimate tensile strength of the aluminium alloy and increase in hardness value is more in case of 92.5%Al-7.5%Mg -7%B_4C as compared with others. The addition of Magnesium improves the strength of the composites significantly.

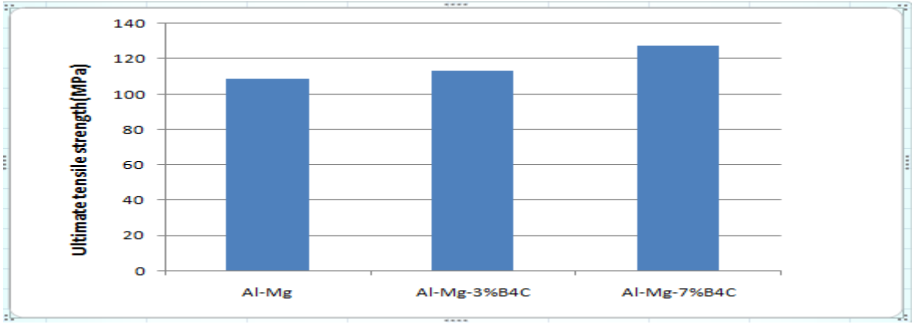

Fig 3.10 Ultimate Tensile Strength

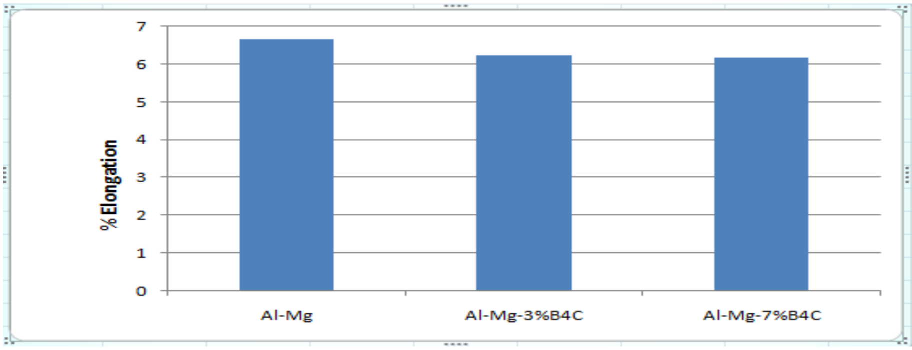

Fig 3.11 % Elongation

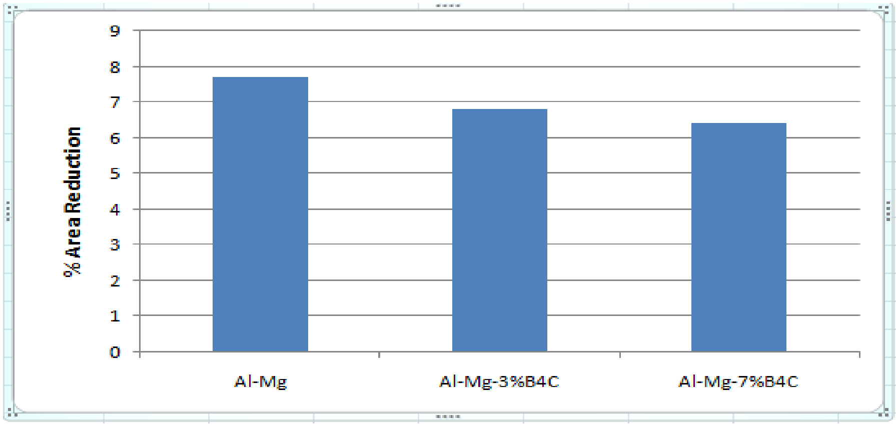

Fig 3.12 % Area Reduction

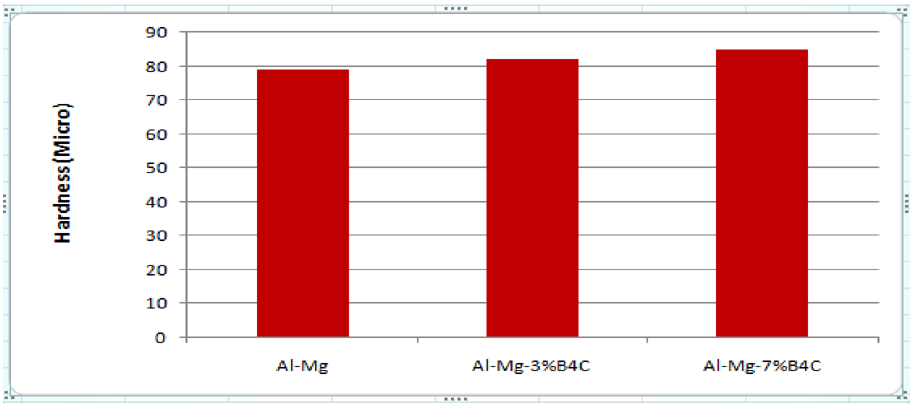

Fig.3.13 Graph showing variation in hardness with composition of MMCs

IV. Conclusion

- In the Al-Mg-B_4C composites both tensile and hardness properties of the composites are found to increase as the content of B_4C particulates is increased up to 6% by weight.
- From the micro structural studies, it has been concluded that the B_4C dispersoids are uniformly distributed in the alloy matrix, by influences the mechanical properties to achieve better hardness.
- There is a greater scope for the development of Al-Mg- B_4C composites for the application in the field of nuclear industries.

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