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Effect on Addition of Reinforcement on Mechanical Properties of Al7050/B4C Metal Matrix Composites

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Abstract: -- Aluminium metal matrix composites (AMMCs) have considerable applications in aerospace, automotive and military industries due to their high strength to wear ratio, stiffness, light weight, good wear resistance and improved thermal and electrical properties. Ceramic particles such as Al2O3, SiC are the most widely used materials for reinforcement of aluminium. Boron carbide (B4C) could be an alternative to SiC and Al2O3 due to its high hardness (the third hardest material after diamond and boron nitride).

In the present study, an effort has been made to develop and study the mechanical properties such as Tensile strength, Compression strength, hardness and density measurement of Al7050-B4C metal matrix composites. The composites were prepared by stir casting route (liquid metallurgical technique) in which amount of reinforcement is varied from 2-8 wt% in steps of 2 wt%. In case of each prepared composites of Al7050-B4C, the reinforcement particles were pre-heated to a temperature of 5000Cand mixed with Potassium titanium fluoride before adding into the vortex of the molten metal to improve wettability and distribution of B4C particles.

The microstructural studies were carried out using scanning electron microscope which shows the uniform distribution of B4C particulates in the matrix alloy. EDS analysis will be carried out to analyze the microstructure and the dispersion of the reinforced particles in the alloy matrix. The tensile strength and compression strength Al7050 and Al7050-B4C were carried out using UTM and hardness test using Brinell hardness tester, which results in increase in tensile strength, compression strength and hardness of the composites as the increase on wt% of B4C, The obtained results were compared with ascast Aluminium Alloy.

Keywords: Al7050 alloy, B4C, Microstructure, Tensile Strength, Compression Strength, Brinell Hardness

1. INTRODUCTION

Aluminium metal matrix composites(AMMCs) have considerable applications in aerospace, automotive and military industries due to their high strength to wear ratio, stiffness, light weight, good wear resistance and improved thermal and electrical properties [1-2]. Ceramic particles such as Al2O3, SiC are the most widely used materials for reinforcement of aluminium. Boron carbide (B4C) could be an alternative to SiC and Al2O3 due to its high hardness (the third hardest material after diamond and boron nitride). Boron carbide has attractive properties like high strength, low density (2.52 g/cm3), extremely high hardness, good wear resistance and good chemical stability [3]. There has been an increasing interest in composites containing low density [4-6]. Suggested applications for Al-B4C composites include their use as structural neutron absorber, armour plate materials and as a substrate material for computer hard disks. [7-8]. Aluminum matrix composites (AMMCs) are emerging as advance engineering materials due to their strength, ductility and toughness. The aluminium matrix can be strengthened by reinforcing with hard ceramic particles like SiC, Al2O3, B4C etc.

The aluminum matrix is getting strengthened when it is reinforced with the hard ceramic particles like SiC, Al2O3, and B4C etc. Aluminium alloys are still the subjects of intense studies, as their low density gives additional advantages in several applications. These alloys have started to replace cast iron and bronze to manufacture wear resistance parts[9]. MMCs reinforced with particles tend to offer enhancement of properties processed by conventional routes. 6061Al is widely used in numerous engineering applications including transport and construction where superior mechanical properties such as tensile strength, hardness etc., are essentially required [10]. 6061Al is quite a popular choice as a matrix material to prepare MMCs owing to its better formability characteristics.

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2. EXPERIMENTAL DETAILS

➢ ***Selection of Materials***

Matrix metal

Al7050 will be used as Matrix alloy due to its excellent casting properties, reasonable strength and its suitability for mass production.

Table 2.1. Chemical Composition of Al7050

Element		Composition
Silicon	Si	0.12
Iron	Fe	0.15
Copper	Cu	2.6
Manganese	Mn	0.10
Magnesium	Mg	2.6
Chromium	Cr	0.04
Zinc	Zn	6.5
Aluminium	Al	87.89

Reinforcement

B4C of 90 microns size were used as the reinforcement content in the composites was varied from 2 to 8% in steps of 2% by weight. B4C is a robust material having excellent chemical and thermal stability, high hardness (HV = 30 GPa), and low density (2.52 g/cm3) and it is used for manufacturing bullet proof vests, armor tank etc. Hence, B4C reinforced aluminum matrix composite has gained more attraction with low cost casting route, Boron Carbide (B4C) of Varying particle sizes is used as reinforced materials.

➢ ***MMCs preparation***

In order to produce the composite, the following steps will be taken: The alloy will be melted in a graphite crucible, using an electrical resistance-heated laboratory furnace. Liquid metallurgy technique was used to fabricate the composite materials. The temperature will be raised more than recrystalisation and the melt will be stirred using a graphite impeller.

After specified time, a specific quantity of pre heated upto 5000C B4C particles, mixed along with Potassium titanium fluoride to improve wettability and distribution will be added to the matrix alloy at a low rate while stirring be continued for about 5 minutes. The slurry will be allowed to mix isothermally for another 15 minutes, then the impeller will be taken out and the composite slurry will be poured into metallic molds.

The produced ingots will be cut into definite size and shape. The process is repeated for different particle sizes.

➢ ***Specimen Preparation for microstructure and EDS***

Sectioning

Specimens were removed from the metal mass by specimen cutter, care was taken to prevent cold working of the metal, which can alter the microstructural and complicate interpretation of constituents.

Grinding

The rough polishing was done by series of abrasive belts made up of SiC sand belts. The polishing specimen was done in two stages, rough polishing and finish polishing. For rough polishing, emery belts of 100, 200, 400, 600, and 1200 (0-emery paper) were rotated on 500–600 rpm.

Polishing

Polishing machine wheels are used for both polishing stages consists of a medium-nap cloth (washable cotton), a suspension of MgO size of 5 □m particles mixed in distilled water (50 g per 500 ml ofH2O) was used on the wheel for smooth polishing.

Finally, for finish polishing, a diamond paste (1 □m) was used on the wheel. The specimen also rotated about its own axis across the face of the polishing wheel. And cleaned with alcohol then dried and finally etched by using acetic glycol. Metallographic test samples of 5mm thickness were obtained by as cast and B4C reinforced Al7050 alloy.

➢ ***Characterization of MMCs***

SEM micrographs for Al7050 and all the MMCs products were performed on a VEGA3 TESCAN scanning electron microscope.

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3. RESULTS

➢ ***EDS Analysis***

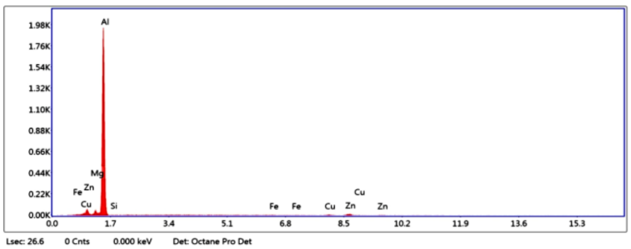

Fig 3.1 EDS spectrum analysis of Al7050 alloy

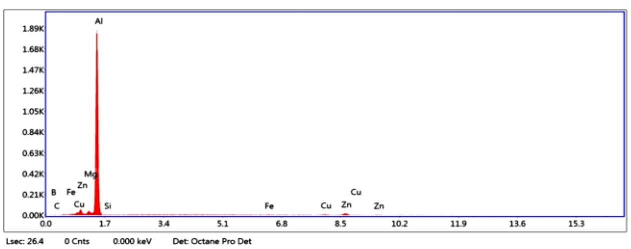

Fig 3.2 EDS spectrum analysis of Al7050 alloy + 2% of B4C

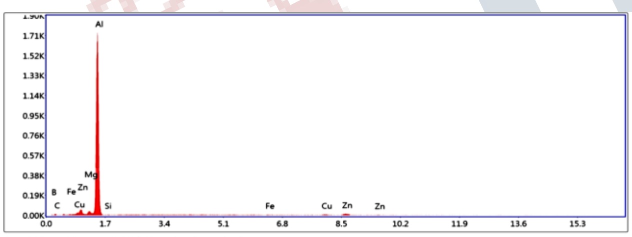

Fig 3.3 EDS spectrum analysis of Al7050 alloy + 4% of B4C

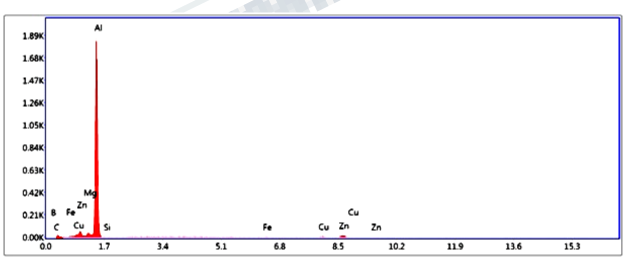

Fig 3.4 EDS spectrum analysis of Al7050 alloy + 6% of B4C

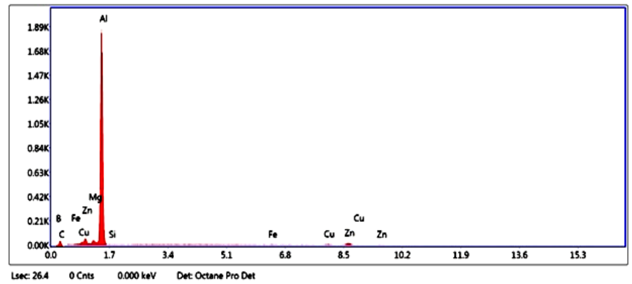

Fig 3.5 EDS spectrum analysis of Al7050 alloy + 8% of B4C

The EDS investigations were done by using a Phillips XL-30 type scanning electron microscope with EDAX Genesis analyser. These measurements needed careful preparation. Fig.3.1 to 3.5 show EDS spectrum analysis of Al7050 alloy and Al7050/(2 to 8) wt. % of B4C composite. The EDS analysis confirmed the presence of B4C particulates in the Al matrix alloy. The presences of B4C are shows in the form of B (Boron) and C (Carbon), which is evident from the EDS spectrum

➢ ***Microstructure Studies***

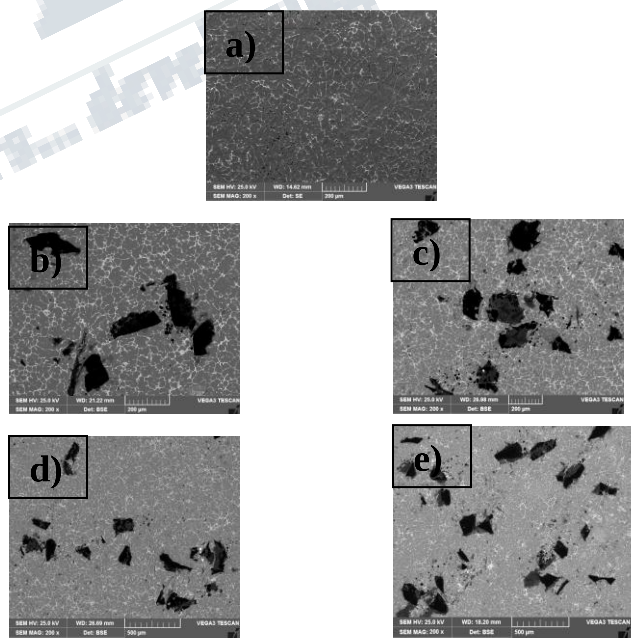

Fig.3.6 SEM microphotograph of a) Al7050 alloy, b) Al7050+2% B4C, c) Al7050+4% B4C

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d) Al7050+6% B4C. e) Al7050+8% B4C

Figure 3.6 (a-e) shows the SEM microphotographs of Al7050 alunimium alloy and Al7050 with 2, 4,6 and 8 wt. % of B4C particulate composites. In the figures it shows that there is the uniform distribution of B4C particles and very low agglomeration and segregation of particles, porosity and clearly showing and even distribution of B4C particles in the Al7050 aluminium alloy matrix. In other words, no clustering of B4C particle is evident and also reveals good bonding among matrix and reinforcement particles which yields better load transfer from matrix to reinforcement material

- ***Ultimate Tensile Strength (UTS) and Yield Strength (YS)***

Table 3.1. UTS and YS of Al7050 alloy and Al7054 + (2-8 Wt %) B4C

Sl No	Composition	Ultimate Tensile Strength (Mpa)	Yield Strength (Mpa)
1	Al7050 Alloy	163.6	143
2	Al7050+2% B_4C	171.7	162
3	Al7050+4% B_4C	186	168
4	Al7050+6% B_4C	204	190
5	Al7050+8% B_4C	239	219

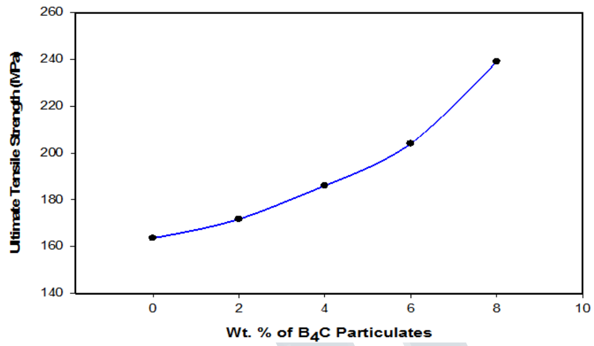

Fig.3.7 Effect of B4C reinforcement on Ultimate Tensile Strength

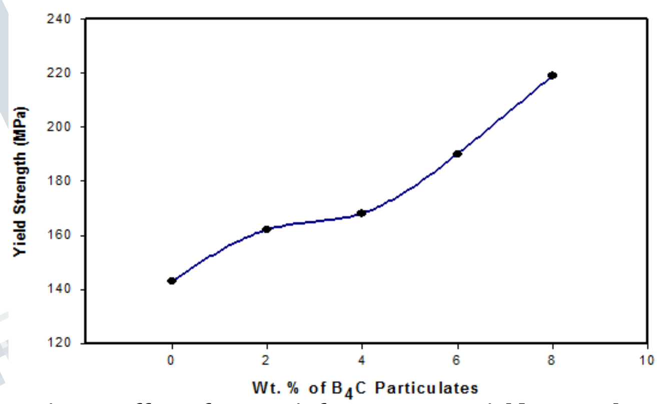

Fig.3.8 Effect of B4C reinforcement on Yield Strength

Figure 3.7 and 3.8 shows the graphs for the effect of reinforcement content on ultimate tensile strength (UTS) and Yield strength of the processed Al7050/B4C composites. Each value of UTS is an average of two experiments. From the graphs is noticed that improvement of both tensile strength and yield strength was achieved up to 8 wt % B4C, As the B4C content is increased from 0% to 8%, the UTS increased by about 31.54% and Yield strength by 34.70%. The increase in UTS and YS can be attributed to the presence of hard B4C particulates that impart strength to the matrix alloy, thereby providing enhanced resistance to tensile stresses.

- ***Compression Strength***

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Table 3.2. Compression strength of Al7050 alloy and Al7054 + (2-8 Wt %) B4C

Sl No	Composition	Compression Strength MPa
1	Al7050 Alloy	572
2	Al7050-2% B_4C	640
3	Al7050-4% B_4C	668
4	Al7050-6% B_4C	681
5	Al7050-8% B_4C	792

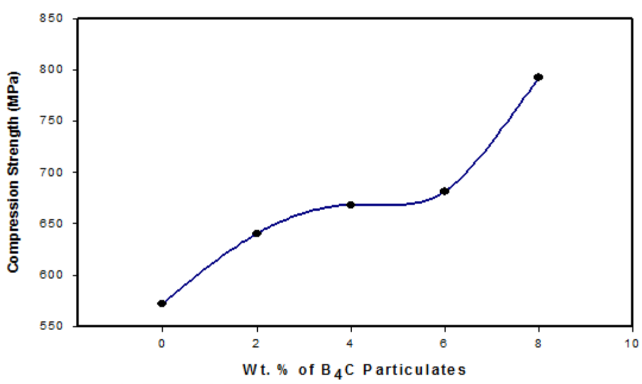

Fig.3.9 Effect of B4C reinforcement on Compression strength

From the Fig. 3.9 that the compressive strength of the composites is higher than that of the base Al7050 alloy due to the presence of hard B4C particles. The B4C particles have higher compressive strength than the matrix. Hence an increase in compressive strength is observed with increasing wt% of reinforcement. From the graph it is noticed that there is a sudden increase in compressive strength at 8 % of reinforcement which is said to be increased by 14%. However as the B4C content is increased from 0% to 8% the compression strength is increase by about 28%. Since B4C is much harder than the matrix. The hard ceramic B4C particles resist deformation stress while increasing compression strength of the composite. Nevertheless, the addition of hard ceramic particulates has caused the MMCs to behave as brittle rather than ductile materials, as is evident from the above results.

4. CONCLUSION

The significant conclusions of the studies on Al7050-B4C metal matrix composites are as follows.

- Al7050-B4C composite was prepared successfully using liquid metallurgy techniques by incorporating the reinforcing particulates.
- The SEM microphotographs of composites revealed fairly uniform distribution of reinforcement particulates in the Al7050-B4C metal matrix.
- There is no clustering of B4C particle, is an evident and also reveals good bonding among matrix and reinforcement particles which yields better load transfer from matrix to reinforcement material
- It was found that increasing the Boron carbide content within the aluminium matrix results in significant increase in the UTS, Yield strength and compressive strength.
- It was found that increasing the B4C content within the matrix material, resulted in significant improvement in mechanical properties like, Ultimate tensile strength, Yield strength and compressive strength at the cost of reduced ductility.
- Highest values of mechanical properties like, Ultimate tensile strength, Yield strength and compressive strength were found at 8 wt% B4C.

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