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INVESTIGATIONS ON MECHANICAL PROPERTIES OF MICRO PARTICULATES (AL_2O_3/B_4C) REINFORCED IN ALUMINIUM 7075 MATRIX COMPOSITE

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ABSTRACT

Metal Matrix Micro Composites (MMMCs), with the addition of micro-particulate reinforcements, can be significant for automobile, aerospace and numerous applications due to their low density and good mechanical properties, better corrosion and wear resistance, and low coefficient of thermal expansion compared to conventional materials. Designing the metal matrix composite material aims to combine the desirable attributes of metals and ceramics. The present work is focused on studying the mechanical properties of Aluminium alloy (7075) with Al_2O_3 and B_4C micro-composite produced by the Stir Casting method. Different % age of reinforcement is used. The Stir casting technique is used to achieve a uniform dispersion of micro-particulate Al_2O_3 and B_4C in molten aluminium alloy. A tensile test, Hardness test, and Impact test were performed on the samples obtained by the fabrication processes. A microstructural study will be carried out through an optical Microscope to know the distribution of Al_2O_3 and B_4C micro particulates in Al alloy.

Keywords: *Al7075, Stir Casting, optical Microscope, and Micro composite*

1. Introduction

A composite material is made up of reinforcement embedded in the matrix. A matrix holds the reinforcement to form the desired shape, while the reinforcement phase improves the overall mechanical properties of the matrix. MMNCs are advanced engineering materials resulting from combining two or more materials in which tailored properties are achieved. Engineering MMCs consisting of continuous or discontinuous fibres or particulates in a metal or alloy possess a combination of properties not achievable in monolithic. These properties could include high specific strength, specific stiffness, machinability, wear resistance and low coefficient of thermal expansion.

A high-temperature electro-chemical reaction of sand and carbon originally produces Al_2O_3 and B_4C. It is used in abrasive, refractories, ceramics and numerous high-performance applications. Some of the key properties of B_4C are low density, high strength, low thermal expansion, high thermal conductivity, high hardness and high elastic modulus.

Boron carbide is a superior ceramic reinforcement material for AMCs than B_4C and Al_2O_3 due to its high hardness, low density, high strength, high wear and impact resistance, high melting point, low coefficient of thermal expansion and good chemical stability. The use of micro-sized Al_2O_3 and B_4C particles to improve the mechanical properties of the AMCs is attractive because this approach could maintain good ductility and improve fracture toughness.

Many techniques are currently available to fabricate metal matrix micro composites (MMMCs), such as mechanical alloying, high-energy milling, spray deposition, powder metallurgy, micro-sintering and various casting techniques. The powder metallurgy processing method cannot be used for the bulk production of large and complex structural MMNCs components. The fabrication of MMMCs by powder metallurgy route is time-consuming, expensive and energy-intensive. The liquid phase processing method can produce AMC parts with a uniform reinforcement distribution and complex shape, and this method offers better matrix-particle bonding and easier control of the matrix structure. It is economical for bulk production. Uniform distribution and dispersion of micro-sized Al_2O_3 and B_4C particles in molten aluminium is complicated due to their large surface-to-volume ratio and poor wettability using a conventional mechanical stir casting. The conventional mechanical stir casting method can disperse micro-sized Al_2O_3 and B_4C particles in molten aluminium without agglomeration and clustering. Several researchers have proposed the stir casting technique to distribute and disperse ceramic micro-sized particles in an aluminium melt, enhancing their wettability, the degassing of liquid metals and the

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dispersive effects for homogenizing. The liquid phase processing of MMMCs using high intensity could be helpful to disperse Al_2O_3 and B_4C particles in molten aluminium because this process features transient capitation. Stir casting is the formation and collapse of thousands of micro-bubbles in molten aluminium liquids under cyclic high intensity. The collapsing of micro-bubbles in molten aluminium produces transient micro-hot spots with pressures of approximately 1000 atm, temperatures above 5000ºC and heating and cooling rates exceeding 1010 K/s. Transient cavitation could result in a strong impact coupling with the local high temperatures. It is sufficient to break up the clustered microparticles, disperse microparticles, refine grains, remove gas and homogenize the material.

In the present work, Stir casting-based solidification processing was utilized to fabricate Al_2O_3 and B_4C microparticle-reinforced aluminium matrix composites by varying the concentration of SiC and B_4C. Micro-sized SiC and B_4C particle-reinforced AMCs were produced by the ultrasonic-assisted cavitation method. Moreover, the mechanical and wear properties of AMCs reinforced with Al_2O_3 and B_4C microparticles were compared and analyzed.

2. Materials and Methods

Pure aluminium was selected as a primary matrix material because it can be readily casted and has been widely used. Al_2O_3 and B_4C were used as a secondary reinforcement particles to fabricate the samples. The pure aluminium was purchased from M/s. BMC Enterprises, Bangalore, India. The size of the Al_2O_3 and B_4C particles was measured by SEM (SU1510) as 25 µm. B_4C milling particles were synthesized by milling the received B_4C powders in a high-energy planetary ball mill. The ball milling operation was performed at room temperature under an argon gas atmosphere for 30 h.

The size of Al_2O_3 and B_4C particles was measured by SEM and Atomic Force Microscopy (AFM). To avoid the agglomeration of particles, a minimal quantity of micro-sized Al_2O_3 and B_4C particles was mixed with 50 ml of acetone, and this mixture was placed in the ultrasonic sonicator for 10 min. The mixture was then characterized using SEM and AFM (XE70 park system). The final mean size of the Al_2O_3 and B_4C particles was Avg.25 µm.

3. Experimental Setup and Procedure

The metal matrix composite was prepared with a liquid metallurgical process using stir casting. Fig.1 shows the experimental setup for the stir casting-based fabrication of micro-sized Al_2O_3, and B_4C reinforced metal matrix micro composites. This setup consisted of an electric resistance heating furnace.

Table 1 Experimental setup parameters

Parameters	units	values
Spindle Speed	RPM	700
Stir time	Seconds	600
Stirring temperature of molten metal	°C	800
Preheating temperature of reinforcement	°C	250
Preheating time of reinforcement	min	50
Preheating Temperature of Die	°C	500

Fig. 1 Experimental setup for fabricating Al– Al_2O_3 and B_4C. Micro composites

The amount of aluminium was melted in a crucible at 750ºC in an electric resistance furnace for the stir processing of molten aluminium. The micro-sized Al_2O_3 and B_4C particles were added to the molten aluminium from the top of the crucible at proportions of 2,3,4,5,6 and 8% by weight. The mechanical stirrer was used for 10 min to achieve a primary distribution of micro particles in the molten aluminium.

After mechanical stirring, the molten aluminium to a depth of approximately 30 mm. The molten aluminium was processed with Stir for approximately 1 h to break up the clustered micro particles. After the stir casting processing, the crucible was quickly removed from the furnace, and the molten metal was poured into the die set mould. The mould was made up of mild steel, which was preheated to 500 °C before being filled with the molten aluminium. AMCs containing micro-sized Al_2O_3 and B_4C particles at proportions of 2,3,4,5,6 and 8% were also fabricated by mechanical stirring in order to compare them with the micro composites.

Table 2 Composition analysis (% Wt.) of Al7075 alloy

Constituent	Weight (%)	Constituent	Weight (%)
Cu	1.2-2.0	Mn	0.3
Si	0.4	Cr	0.18-0.28
Fe	0.5	Ti	0.1
Mg	2.1-2.9	Zn	5.1-6.1
Al			87.1-91.4

Table 3 Density and hardness of Al7075 alloy (non-heat treated)

Density (g/cc)	2.918
Hardness (5 kg/25mm ball type)	164

The hardness of the composites was evaluated using a Brinell hardness testing machine. The applied load and dwell times for the hardness measurement were 5 kg and 5s, respectively. Each specimen was indented at an average of three times to determine the hardness. Tensile tests were performed on a universal testing machine according to the ASTM standard E8. The tensile properties reported in this paper are the average of three tensile tests. The Charpy impact tests were performed on an impact testing machine according to the ASTM standard E23.

4. Results and Discussions

4.1 Tensile test

Table 4 shows that the yield strength of adding 2% weight Al_2O_3 is decreased, and ultimate tensile strength is increased compared to the base metal. Correspondingly, adding 4% weight Al_2O_3 increases yield strength, ultimate tensile strength and elongation decrease. The experimental result showed that the yield strength of adding 2% weight B_4C is increased and ultimate tensile strength is also increased compared to the base metal. Correspondingly, adding 4% weight B_4C increases yield strength, and ultimate tensile strength and elongation are decreased. It is concluded that by comparing the result of micro size B_4C particulates, yield strength and ultimate tensile strength are higher than that of $Al_2O_3$3.By adding 6 and 8% weight Al_2O_3 reinforcement, ultimate tensile strength decreases and behaves as brittle. By adding 6% weights B_4C reinforcement, ultimate tensile strength decreases and behaves as a brittle nature.

Table 4 Comparison of the tensile test analysis of Al7075 alloy with reinforcements at different % wt.

Weight% of reinforcement (micro size)	Yield strength(MPa)	Ultimate tensile strength(MPa)	Elongation in 50 mm GL (%)
0% of Al_2O_3	95	107	2.00
2% of Al_2O_3	72	114	1.00
3% of Al_2O_3	98	114	1.00
4% of Al_2O_3	147.90	169.25	0.50
5% of Al_2O_3	Ultimate tensile strength (MPa) - 135		
6% of Al_2O_3	Ultimate tensile strength (MPa) - 138		
8% of Al_2O_3	Ultimate tensile strength (MPa) - 90		
2% of B_4C	113	119	1.0
4% of B_4C	171	178	0.5
6% of B_4C	Ultimate tensile strength(MPa) - 92		

4.2 Hardness test

From the experimental result, It is clearly shown that in Table 5, the Brinell hardness values increase with an increase in the weight percentage of reinforcement ($A_{l2}O_3$/ B_4C) compared with base metal.

Table 5 Comparison of hardness test results of Al7075 alloy with reinforcements at different % wt.

Weight% of reinforcement (micro size)	Observed value in BHN(5mm ball/250 kg load)	Mean value	Standard deviation
0% of Al_2O_3	68,69,70	69	1
2% of Al_2O_3	78,78,79	78	0.707
4% of Al_2O_3	80,80,81	80	0.707
6% of Al_2O_3	93,93,94	93	0.707
8% of Al_2O_3	95,94,96	95	1
2% of B_4C	95,94,93	94	1
4% of B_4C	109,110,111	110	1
6% of B_4C	112,114,111	113	1.792

4.3 Impact test

Table 6 shows no change in impact test values adding the reinforcements in different % wt. due to particulate reinforcements.

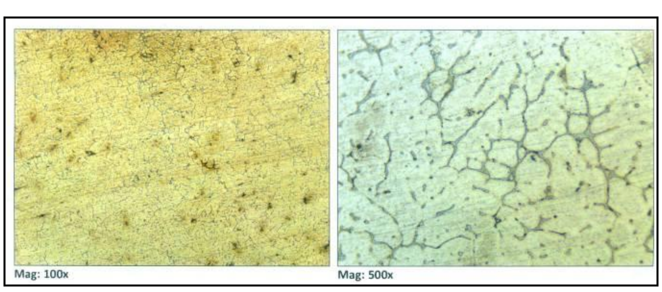
Specimen size (mm): 7.5 X 10 X 55
Notch Type : 'V'
Test temperature : 24◦C

Table 6 Comparison of Impact test (Charpy) results of Al7075 alloy with reinforcements at different % wt.

Weight% of reinforcement (micro size)	Observed energy-Joules
0% of Al_2O_3	2
2% of Al_2O_3	2
4% of Al_2O_3	2
6% of Al_2O_3	2
8% of Al_2O_3	2
2% of B_4C	2
4% of B_4C	2
6% of B_4C	2

4.4 Optical Microscope

The properties of composites depend on the microstructure and interface characteristics between reinforcements and matrix. The microstructure analysis is carried out with the help of an optical microscope. The optical microstructures 2, 4, 6, and 8 weight% of Al_2O_3 reinforced aluminium metal composites, respectively. From microstructural analysis, porosity, clustering and non-homogeneous distribution of Al_2O_3 particles in aluminium matrix were observed. It was due to the variation of contact time between Al_2O_3 particles and molten aluminium during composite processing, high surface tension and poor wetting behaviour of Al_2O_3 particles in the liquid aluminium. Non-homogenization of Al_2O_3 particles in the aluminium matrix can be observed in the microstructure of 2, 4, 6 and 8 weight% of Al_2O_3 reinforced aluminium metal composites as shown in figure 2 to figure 5. Some places in the aluminium matrix can be identified without Al_2O_3 reinforcing particles.



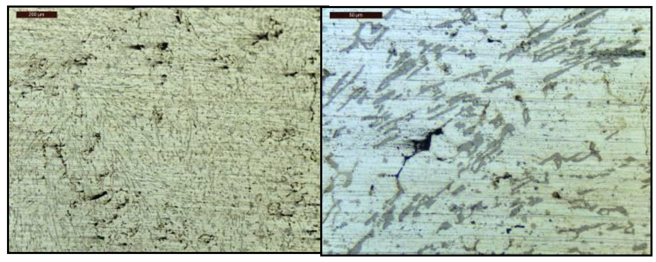


Fig. 2 Microstructure of 2 % Al_2O_3 reinforced

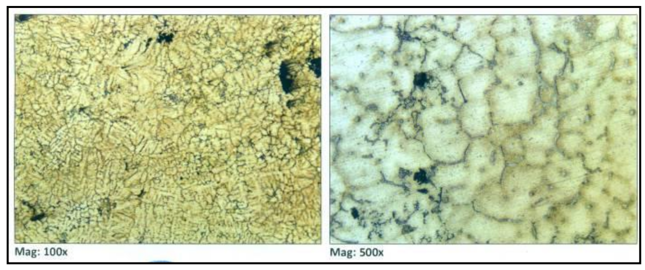


Fig. 3 Microstructure of 4 % Al_2O_3 reinforced

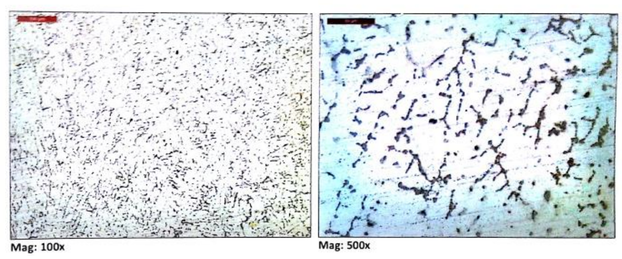


Fig. 4 Microstructure of 6 % Al_2O_3 reinforced

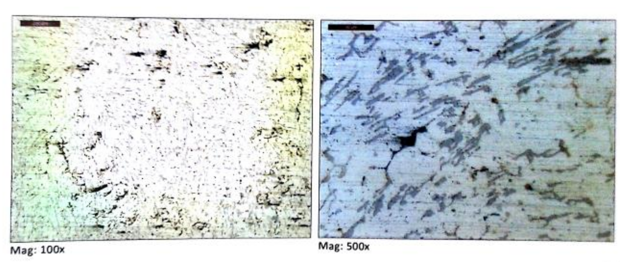


Fig. 5 Microstructure of 8 % Al_2O_3 reinforced

The properties of composites depend on the microstructure and interface characteristics between reinforcements and matrix. The microstructure analysis is carried out with the help of an optical microscope. The optical microstructures of 2, 4, and 6 weight % B_4C reinforced aluminium metal composites, respectively. From microstructural analysis, porosity, homogeneous and non-homogeneous distribution of B_4C particles in aluminium matrix was observed. It was due to the variation of contact time between B_4C particles and molten aluminium during composites processing in the aluminium matrix can be observed in the microstructure of 2, 4, and 6 weight% of B_4C reinforced aluminium metal composites as shown in Figure 6 to figure 8 some places in the aluminium matrix can be identified without B_4C reinforcing particles.

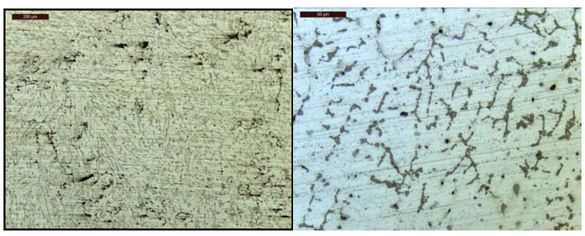


Fig. 6 Microstructure of 2% B_4C reinforced

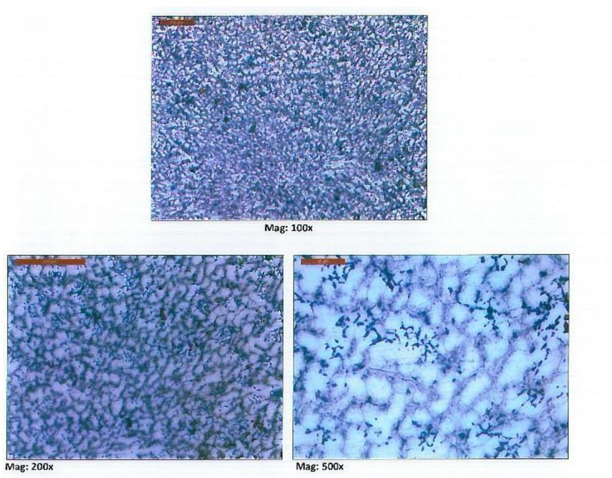


Fig. 7 Microstructure of 4% B_4C reinforced

Fig. 8 Microstructure of 6% B_4C reinforced

5. Conclusions

The metal matrix micro composites are fabricated using the mechanical stir casting method. The effects of micro Al_2O_3 and B_4C dispersion on microstructure and mechanical properties are investigated using optical Microscope

The following points are concluded from the present investigations:

i. The addition of 2 to 4% weight of ($A1_2O3$ / B_4C) microparticles to the Aluminium 7075 matrix has led to improved mechanical properties (hardness, yield strength, Ultimate tensile strength) when compared to matrix alone where, as elongation decreases
ii. It is found that elongation tends to decrease with increasing particle wt. Percentage, which confirms that Al_2O_3/B_4C addition increases brittleness.
iii. Dispersion of Al_2O_3/B_4C particles in an aluminium matrix increases the material's hardness.
iv. From the above observation of micro size particle reinforcement ($A1_2O3$ / B_4C), it is concluded that the Brinell hardness value is increasing with an increase in weight % of reinforcement.
v. From the above observation of micro-size particles, it is concluded that there are no changes in impact test values due to an increase in weight % of reinforcement ($A1_2O_3$ / B_4C).
vi. From the observation of the optical microscope image, there is a uniform and non-uniform distribution of particles in the matrix when the weight percentage added up to 8%. Exceeding that, there is a formation of cracks, porosity and agglomeration.
vii. By comparing all the above inferences (micro) experimental results, it is known that the 4% weight of micro $A1_2O_3$ / B_4C yields better mechanical properties.
viii. There is a greater scope for developing micro composites for application in the field of aircraft industries.

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