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Mechanical Characterization of Stir Cast Al-7075/Al2O3/B4C Hybrid Metal Matrix Composites

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Abstract: *The Aluminum hybrid metal matrix composite materials are fabricated with reinforcements as Al2O3 and B4C using stir casting method. Morphology of the aluminum composite materials was studied for the distribution of reinforced particles in the matrix material. The mechanical characterization of Al7075 composite materials is studied by varying the weight percentages of Al2O3 as 2, 4, 6, 8 and 10%, while the weight percentage of B4C is kept constant at 4%. The maximum micro hardness was obtained at 143 VHN and the tensile strength on the scale was 311 MPa. The enhanced mechanical properties of aluminum composite materials obtained at 10% Al2O3 and 4% B4C. The increase in weight percentage of reinforcement particles has increased the hardness and the tensile strength of theAluminum hybrid composites.*

Introduction: The metal matrix composites are used in aerospace, marine and automobile industries due to their its low density, high strength to weight ratio, improved stiffness, excellent wear and corrosion resistance, thermal expansion coefficient [1,2]. . Among the various materials and alloys, aluminium and its alloys are most commonly used for structural and functional applications due to the fact that these alloys possess lower density and excellent mechanical properties compared with other materials. The chemical composition of Al alloy is shown in the table [1]. The Al7075 has a chemical composition with more concentration of Mg and Zn [3]. From the literature, various ceramic like Al2O3, B4C, SiC, TiB2 etc., are used as reinforcements for aluminum alloys[4].The mechanical characteristics of aluminum alloy is enhanced by incorporating the hard ceramic particles[5].

From the past research works, the addition of two ceramics as reinforcements gave better mechanical and wear properties than compared with single reinforcement.[6]. The stir casting method was cost effective among various composite fabrications techniques.

Table 1: Chemical composition of Al7075 alloy

Elements	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
Amount [wt %]	0.4	0.5	1.6	0.3	2.5	0.15	5.5	0.2	Balance

Materials and Methods:

The Al7075 hybrid composite material samples are fabricated by using liquid metallurgy technique (stir casting). The composition of the samples are with Al7075 as the base metal and the reinforcements as Al2O3 and B4C. The Al2O3 reinforcement material was added with different weight percentages (2, 4, 6, 8 and 10%). The weight percentage of the second reinforcement material B4C is kept constant at 4%. The experimental set-up for stir casting is shown in the figure [1]. The materials are added to the crucible after pre- heating for the removal of the moisture content. The speed was maintained at 500rpm and a rotating rod was continuously stirred for 15 minutes and the molten material was poured into mold cavity [7-8]. The required samples are obtained. The Stir casting process is performed according to the parameters as mentioned in the table [2].

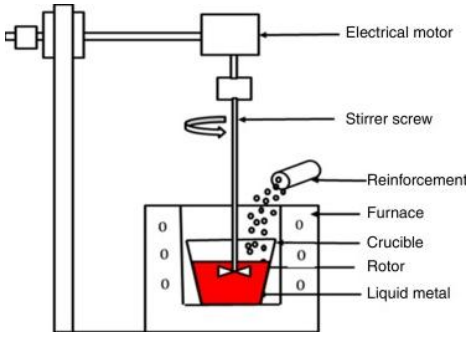


Figure 1: Experimental set-up for stir casting

Table 2: Stir casting process parameters

Parameters	Value
Spindle speed [rpm]	500
Temperature of melt [°C]	750-800
Stirring time [min]	10
Preheated temperature of mould [°C]	300
Preheat temperature of Al_2O_3 particles [°C]	420
Preheat temperature of B_4C particles [°C]	450

Experimentation:

The mechanical behavior of the materials is known by various parameter like hardness, tensile strength, impact strength, compressive strength, yield strength etc. The present study focused on the hardness and tensile strength. The study of microstructure analyzes the properties of the material. The samples are treated with etching agents and the microstructure of the hybrid composite materials Al7075 are examined under microscope. The Properties of matrix (Al7075) and reinforcement materials (Al_2O_3 and B_4C) are mentioned in the table [3]. The sample are prepared according to the percentages mentioned in the table [4].

Table 3: Properties of matrix (Al7075) and reinforcement materials (Al_2O_3 and B_4C)

Properties	Al 7075	Al_2O_3	B_4C	
Elastic Modulus [GPa]	70-80	300	480	
Density [g/cm^3]	2.81	3.69	2.5	
Poisson's Ratio	0.33	0.25	0.21	
Hardness [VHN]	78.5	1800 – 2000	3000	
Tensile Strength (T)/ Compressive Strength (C)	220 (T)		2100 (C)	3000 (C)

Sample preparation:

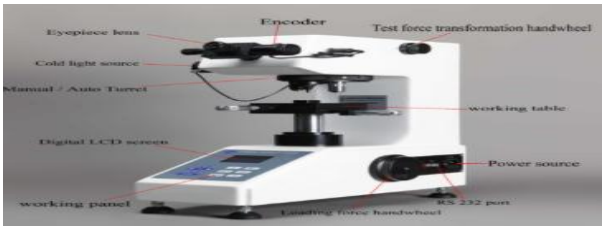
Table 4: Percentages of samples prepared

S.No.	Samples	Percentage Ratios
1	Sample 1	94%Al 7075 + 2% Al2O3 + 4% B4C
2	Sample 2	92%Al 7075 + 4% Al2O3 + 4% B4C
3	Sample 3	90%Al 7075 + 6% Al2O3 + 4% B4C
4	Sample 4	88%Al 7075 + 8% Al2O3 + 4% B4C
5	Sample 5	86%Al 7075 + 10% Al2O3 + 4% B4C

Hardness Test:

In the applications, materials are subjected to working loads, the hardness of the materials to overcome deformation that leads to failure. The micro hardness of polished samples was measured using Vicker's hardness tester at a load of 500 g for 15 s. The equipment used for testing hardnesss of the samples is shown in figure [2].

Figure 2: Vickers Hardness Testing Machine



Tensile Test:

The amount of axial load that a material can withstand before it breaks is observed using tensile tests. As per ASTM E8 standards, the samples are prepared with 8mm in diameter and 60mm gauge length [9].

Results and Discussion

Microstructure:

The observation of SEM images exhibit that the reinforcement particles were uniformly distributed in the base matrix metal as shown in figure [3]. The Al7075, Al2O3 and B4C materials possess different densities. These materials are mixed by stirring blades to get proper homogeneous mixture.

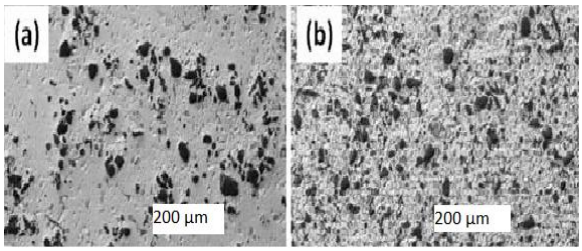


Figure 3: SEM images of Al7075-Al2O3-B4C composite materials

Hardness:

From the experimentation results, the hardness of Al7075 has improved. The hardness values for various samples obtained are shown in table [5]. This is due to the addition of hard reinforcement materials to the Al7075 alloy. The maximum hardness is obtained at 10% Al2O3 and 4% B4C. The hardness of different compositions of al-7075 samples are graphically shown in figure [4]. The uniformly distributed ceramic particles in the matrix material shares the load and opposes the deformation. This supports the matrix material to withstand the loads [10-11].

Table 5: Hardness of the samples

S.No.	Samples	VHN
1	Sample1	130
2	Sample2	134
3	Sample3	137
4	Sample4	139
5	Sample5	143

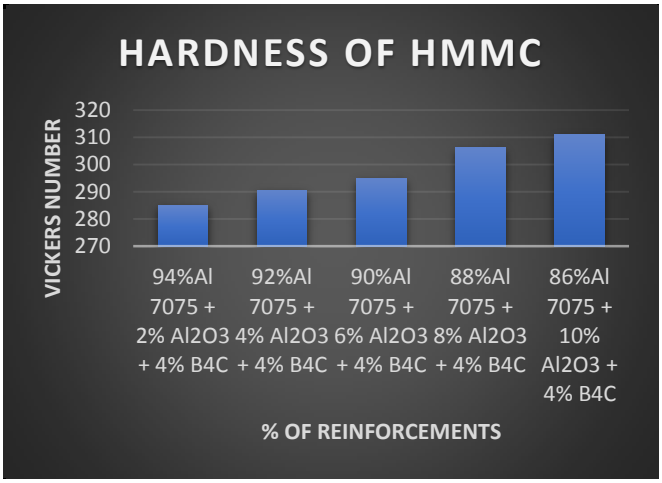


Figure 4: Graphical representation of Hardness of different compositions of Al-7075/Al_2O_3/B4C hybrid composites

Tensile strength:

The observations from the tensile test values indicate that there is an increase in the tensile strength with the addition of reinforcement particles. This is due to the uniform distribution of reinforcement in microstructure and the interfacial bonding between the matrix and reinforcement. These factors increase the strength of the composite materials. The tensile strength values are shown in table [6]. The formation of nucleation causes recrystallization in the material that opposes the movement of dislocations [12-13]. The strength of the material improves with the formation of grain boundaries. The percentage elongation in the Al7075 hybrid composite material reduced with increased percentage of reinforcement particles in the matrix. This increases the strength due to the decrease in the grain size. The graphical representation of tensile strength values are shown in figure [4]. The maximum tensile properties are exhibited at 10% of al2o3 and 4% of B4C reinforced al-7075 HMMC.

Table 6: Tensile strength of specimens

S.No.	Samples	Tensile Strength (mpa)
1	Sample1	285
2	Sample2	290.6
3	Sample3	294.8
4	Sample4	306.1
5	Sample5	311

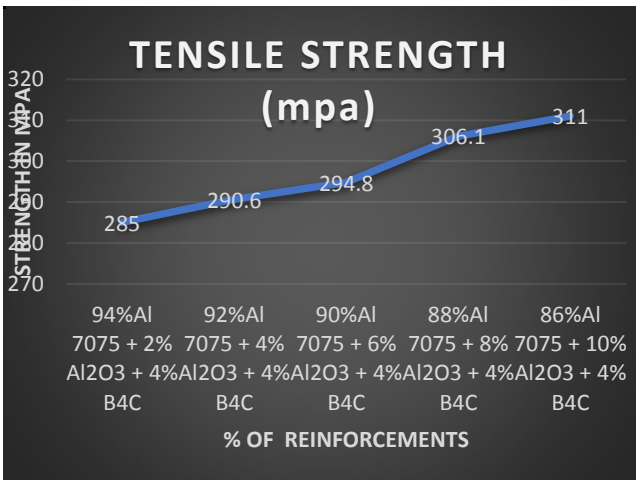


Figure 5: Graphical representation of tensile strength with different compositions of Al-7075/Al_2O_3/B4C hybrid composites

Conclusions:

The mechanical properties of Al-7075 HMMC materials improved by adding Al_2O_3 and B4C as reinforcement particles.

1. The microstructure studies disclose uniform distribution in the Al-7075 composites by the result of proper stirring in the liquid casting technique.

2. The HMMC exhibited optimized results in high hardness and tensile strength at 10% of Al2O3 and 4% of B4C.

3. The addition of hard ceramic particles reduced the deformation and elongation of the material, this tendency improves the mechanical properties of al-7075 hybrid metal matrix composite.

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