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Experimental Investigation on Mechanical Properties of Aluminium - Boron carbide Composites

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ABSTRACT

In this investigation, metal-matrix composites of aluminium matrix reinforced with boron carbide (B_4C) particles were fabricated by stir casting technique. Aluminium is selected as the matrix material and boron carbide as reinforced particles are mixed in different weight percentages (0, 2.5, 5 and 7.5 wt %). The test samples were prepared as per ASTM standards to investigate mechanical properties. The experimental result reveals that the tensile strength and hardness increases with the increase in B_4C percentage, whereas percentage elongation decreases with the increase in B_4C percentage.

Keywords: Aluminium, Al 7050, B_4C, boron carbide, Tensile strength, Percentage elongation, Hardness.

I. INTRODUCTION

Today, there is a requirement for engineering materials which show better physical and mechanical properties in application fields. In order to achieve that high-performance level, we need materials having high strength and superior mechanical properties, for that there is a need to fabricate composite materials. Composite material consists of more than one material which is delivered more strength than the individual material. There is an increased interest amongst the researchers all over the globe in disquisition on composite materials.

Metal matrix composites, ceramic matrix composites and polymer matrix composites are the various types of composites based on matrix phase. The aluminum matrix composites represent a class of metal matrix composites possessing properties like low density, high stiffness and strength, superior wear resistance, controlled co-efficient of thermal expansion, higher fatigue resistance and better stability at elevated temperature. The aluminium metal matrix composites are termed to be modern materials having applications such as aircraft, race car bodies, buildings, bridges, crank shaft, civil transport air craft, defense industries, electronics, automobile industries, nuclear power plants, satellite launch vehicles. The aluminium composites are mainly reinforced with hard materials like aluminium oxide, silicon carbide, graphene, boron carbide, titanium carbide and titanium diboride. The reinforcement materials for composites are selected based upon some specific property required in the base material. Boron carbide used as reinforcement in aluminium matrix composites because of low density, high-strength, exceptionally high hardness, good chemical stability and neutron absorption capability. Fabrication of

aluminium matrix composites can be accomplished by different techniques viz.stir casting, infiltration processes, squeeze casting, reactive in situ technique, powder metallurgy and friction stir processing (FSP). Manufacturing of aluminium composite by stir casting is one of the most economical methods of processing metal matrix composites.

II. LITERATURE REVIEW

Dr. Sumathy Muniamuthu et al [1] fabricated and investigated the effect of reinforcement on the mechanical properties of aluminium metal matrix composite. In the present case, the Al_2O_3 content is varying in composition of (2, 4, 6 and 8 wt %) in aluminum matrix, fabricated by stir casting technique. The authors reported that the tensile strength, impact strength and hardness of the composite increases as weight fractions of the Al_2O_3 particles increases.

N.R. Rajasekaran et al [2] developed TiB_2 reinforced aluminium composites and analyzed its mechanical properties. In this work two different sample were fabricated by changing the quantity of TiB_2 i.e. (5% and 10%). The analysis shows that the tensile strength, yield strength and hardness increases with the increase in TiB_2 percentage, whereas percentage elongation decreases with the increase in TiB_2 percentage.

Sunil Kumar Tiwari et al [3] developed the B_4C reinforced AMCs and study the effect of reinforcements on the mechanical properties. Three samples with different weight % of B_4C have been fabricated as Al-2.5wt% B_4C, Al-5wt% B_4C and Al-0wt% B_4C. Cast samples were prepared for mechanical characterization namely tensile testing and hardness testing. The results showed that the tensile strength and hardness of the composite increased with increase in weight percent of reinforcement in the matrix.

Pavitra Ajagol et al [4] produced Al /SiC composite and investigated its mechanical properties. The aluminium(1100)-silicon carbide composites were fabricated by the stir casting method with different particulate weight percentages (0%, 5%, 10%, and 15 %). Results revealed that, the addition of SiC reinforcement in the aluminum matrix increases the hardness and ultimate tensile strength gradually from 23 HV to 47 HV and 84 MPa to 130 MPa respectively.

The mechanical properties of aluminum based composites reinforced with fly ash were investigated by J. David Raja Selvam, D.S. Robinson Smart and I. Dinaharan [5]. Aluminum alloy AA6061 reinforced with various amounts (0, 4, 8 and 12 wt.%) of fly ash particles were prepared by compo casting method. The result of this test showed that the tensile strength and hardness increases with the increase in fly ash percentage, whereas percentage elongation decreases with the increase in fly ash percentage.

K. Punith Gowda et al [6] fabricated Al2024-WC composite and investigated the effect of reinforcement (tungsten carbide) on the mechanical properties of aluminium metal matrix composite. The reinforcing particulates in the Al2024 alloy were varied from 0% to 5% by weight. The vortex method of cast production was employed to fabricate the MMCs, in which the reinforcement was poured into the vortex created by stirring the molten metal by means of a mechanical agitator. The composite so produced was subjected to a series of mechanical tests. The results of this study revealed that as the tungsten carbide particle content was increased, there were significant increases in the ultimate tensile strength, hardness and young's modulus, compressive strength, accompanied by a reduction in its ductility.

Karunesh G et al [7] investigated the effect of TiC particles on mechanical properties of Al 6063 alloy metal matrix composites. The fabrication of Al 6063 composites with different weight percentage of TiC

particles up to 0-6% was processed by liquid metallurgical technique. The researchers observed that the tensile strength and hardness of the metal matrix composite increases as weight percentages of the TiC particles increases.

III. METHODS AND MATERIAL

Materials

Al7050 alloy was used as a matrix material in the present investigation. This material has been selected as matrix material due to its high strength to weight ratio, sufficient strength, low density and low cost. The chemical composition of the Al7050 aluminum alloy is shown in Table-1. Boron carbide has attractive properties like high strength, low density, high melting point, extremely high hardness, good wear resistance and good chemical stability.

Table-1: Chemical Composition of Al7050

Element	Weight %	
	Minimum	Maximum
Cu	1.2	2.0
Cr	0.18	0.28
Mn	_	0.3
Mg	2.1	2.9
Si	_	0.4
Ti	_	0.2
Zn	5.1	6.1
Fe	_	0.5
Al	_	balance

Preparation of composites

All aluminum composites were prepared using the stir casting method. The preparation of the aluminum metal matrix composite started with an aluminium alloy matrix and B_4C proportions of 0, 2.5, 5 and 7.5 weight percent. Now the required amount of AA7050 has been placed in crucible and left inside the muffle furnace until it melts completely. Boron carbide (B_4C) particles were preheated at 500°C for about one hour. Preheated boron carbide particles are then added into the crucible having molten matrix material. The reinforcement particles have been mixed by mechanical stirrer mounted on the top of the muffle furnace. The molten mixture has been superheated in muffle furnace which leads to increase in fluidity of alloy for pouring. The molten mixture is poured into a preheated mould and allowed for solidification.

Mechanical Testing

Tensile test:

The tensile testing of the composites is done in a computerized universal testing machine. Four different composite specimens are made by varying the weight percentage of the reinforcement. The testing is done by placing the specimen between the jaws of the machine and tensile load is applied until fracture of the composite specimen occurs. This test is used to determine tensile strength and % elongation.

Hardness Test

The hardness test was performed on brinell hardness testing equipment using a 5 mm ball indenter. The brinell hardness number is a number proportional to the load or test force of a hard steel ball to the calculated curved area of the indentation formed. This testing is typically used in testing aluminum and copper alloys (at lower forces) and steels and cast irons at the higher force ranges. Brinell numbers for commonly used metals range from HB 15 to 750.

IV. RESULTS AND DISCUSSION

The prepared composite samples are investigated for their mechanical properties and are compared with the pure aluminium. The mechanical properties of the composite specimens are presented in table-2.

Table-2: Mechanical properties of composites.

% of B_4C	Tensile Strength (MPa)	Percentage Elongation	Hardness
0	142	5.8	70
2.5	158	5.4	73
5.0	171	5.0	76
7.5	181	4.5	80

Tensile strength

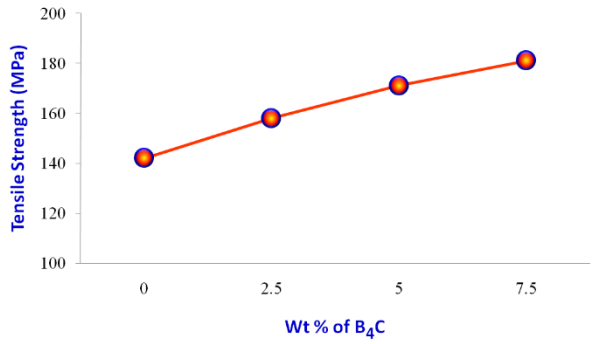

Figure-1: Tensile strength of composites

Figure-1 represents the variation in tensile strength of Al7050-B_4C composites with respect to weight percentage of B_4C particles. From Figure-1 it can be observed that, with the inclusion of B_4C particles, the tensile strength of composites increased than the matrix material. Furthermore, increment in the reinforcement weight percentage increases the tensile strength. The ultimate tensile strength of Al7050-7.5% B_4C composite is 181 N/mm^2, which is 27.46% higher than that for Al7050alloy. The strength improvement of composites can be attributed to the good bonding between the matrix and reinforcement material. P. Senthilkumar [8] fabricated the Aluminium 6061-Al_2O_3 composite by stir casting to investigate the mechanical properties. Percentage of Al_2O_3 was varied from 0 to 7.5wt% in steps of 2.5wt%. Results indicated that the tensile strength of the composite is higher than the base matrix. Also, the tensile strength of the composite increased with increase in weight percent of Al_2O_3 in the matrix. Shivraj Koti et al [9] investigated the mechanical behavior of a new composite, which was manufactured by stir casting method where matrix as AA7475 used and reinforced with B_4C. In the processing of composites, B_4C particles have been used as reinforcement materials with different weight percentages (0, 2, 4, 6 and 8). The researchers observed that the tensile strength of the composite increased with increase in weight percent of reinforcement in the matrix. The mechanical and wear properties of aluminum based composites reinforced with Al_2O_3–graphite were investigated by A. Baradeswaran and A. Elaya Perumal [10]. The composites were fabricated using liquid metallurgy route. The Al 7075/ Al_2O_3/graphite hybrid composite was prepared with 5 wt.% graphite particles addition and 2, 4, 6 and 8 wt.% of Al_2O_3. The authors observed that uniform distribution of the Al_2O_3 particles in the matrix phase, tensile strength of the composites increased with increasing the amount of the Al_2O_3 in the matrix phase.

Percentage elongation

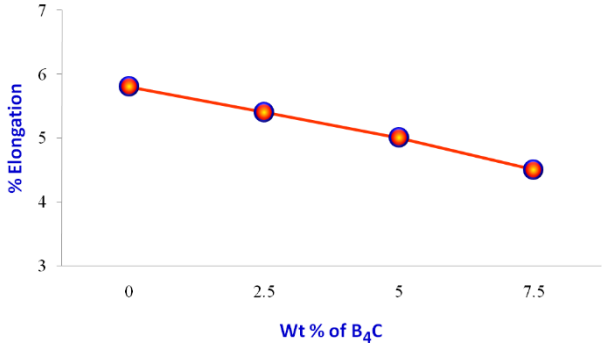

Figure-2: Percentage elongation of composites

Figure-2 represents the variation in elongation of Al7050-B_4C composites with respect to weight percentage of B_4C particles. From Figure-2 it can also be observed that, with the inclusion of B_4C particles, elongation of Al7050-B_4C composites decreases. Furthermore, increment in the reinforcement weight percentage leads to reduction in the percentage of elongation. Increase in the reinforcement weight percentage decreases the ductile matrix content, thus minimizing the elongation. P. Senthilkumar et al [11] succesfully developed composites containing Al6063 with 0, 3, 6 and 9wt% of silicon carbide (SiC) using stir casting process. The experimental result reveals that the percentage elongation of composites decreases with increasing SiC and it was lower than that of base alloy in all compositions. G. B. Veeresh Kumar et al [12] produced Al 6061 /TiC composite and investigated its mechanical properties. The aluminum alloy-titanium carbide composites were fabricated by the stir casting method with different particulate weight fractions (0%, 2%, 4%, 6%, and 8 %). The authors have revealed that the elongation of composites decreased with an increase in weight percentage of titanium carbide in the matrix material. Dipankar Dey et al. [13] developed the titanium diboride reinforced AMCs and study the effect of reinforcements on the mechanical properties. In the present case, the TiB_2 content is varying in composition of (0, 3, 6 and 9 wt %) in aluminum matrix, fabricated by stir casting technique. The results showed that the elongation of composites decreased with an increase in weight percentage of titanium diboride in the matrix material.

Hardness

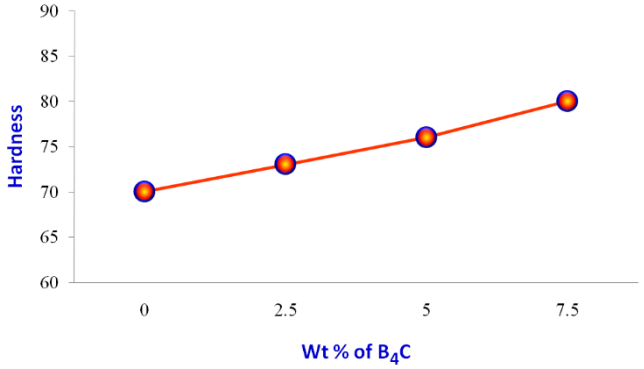

Figure-3: Hardness of composites

Figure-3 shows the variation in hardness of Al7050-B_4C composites with respect to wt.% of B_4C particles. From Figure-3 it is evident that, hardness of the developed composites are greater than the Al7050 matrix alloy. The hardness of composites increases with increment in the wt.% of B_4C particles. Priyaranjan Samal et al [14] fabricated and analysed the mechanical properties of titanium carbide (TiC) reinforced aluminium composites. Aluminium metal matrix composites are fabricated using stir casting method by varying the reinforcement percentage volumes between 0 and 9wt%. The authors reported that the hardness of the composites is higher than the unreinforced matrix metal and the hardness of the cast composites increases linearly with increasing the weight fraction of titanium carbide. P. Senthilkumar [8] investigated the mechanical properties of aluminium oxide reinforced aluminium metal matrix composites. The aluminum alloy Al6061 are used as the matrix metal for the fabrication of the composites that has been reinforced with 0 wt. %, 2.5 wt. %, 5wt. % and 7.5 wt. % of Al_2O_3. From test results, it was observed that the hardness of the composite increased with increase in weight percent of reinforcement in the matrix. Dr. Manjunatha H.S et al [15] have used aluminium as the matrix material and titanium diboride with weight percentage (0, 3, 6, 9 and 12 wt %) as the reinforcement to produce the composite by stir casting. The result of this test showed that uniform distribution of the titanium

diboride particles in the matrix phase, hardness of the composites increased with increasing the amount of the titanium diboride in the matrix phase.

V. CONCLUSION

The mechanical properties of Al 7050- B_4C composites are prepared by the stir casting process with different B_4C reinforcement proportions. The experimental results led to the following conclusions.

- The tensile strength and hardness increased with the increase in B_4C content.
- The percentage elongation decreased with increase in wt.% of B_4C in the Al7050 alloy matrix.

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