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EXPERIMENTAL INVESTIGATION ON MECHANICAL PROPERTIES OF AA7050/B_4C COMPOSITES

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ABSTRACT

This paper presents the preparation and examination of the mechanical characteristics of AA7050/B_4C MMC's. Boron carbide particles (B_4C) were used to strengthen the aluminum (AA7050) alloy. Stir casting was used to develop the AA7050/B_4C MMC's. AA7050/B_4C MMC samples with various B_4C weight fractions were produced (0, 3, 6, 9, and 12wt. percent). In this research, mechanical properties such as tensile strength, hardness were investigated. The inclusion of 9wt. % boron carbide in aluminum matrix enhanced the tensile strength of the composites by 30.3%. The composites tensile strength improves significantly up to 9wt. % B_4C, after which the rise in tensile strength is decreased mainly because of the cluster formation of the reinforcements. Elongation of the MMC's decreased as the proportion of boron carbide (B_4C) particles in the aluminum alloy increased. Scanning electron micrographs (SEM) revealed that the homogenous dispersal of B_4C reinforcing particles in the AA7050 alloy. The distribution of reinforcement particles in the aluminum alloy increased the composites hardness and tensile strength.

Keywords: AA7050, B_4C, hardness, ultimate tensile strength, scanning electron micrographs.

1. INTRODUCTION

Aluminum matrix alloys are mostly used in the automotive and aircraft industries to develop applications that meet emerging modern needs owing to their unique and superior characteristics [1, 2]. Aluminum composite materials are made with adding hard ceramic particles like silicon carbide, aluminum oxide (Al_2O_3) and boron carbide into an aluminum alloys. B_4C is an excellent reinforcing material because of its hardenability, low coefficient of thermal expansion and high hardness, good corrosion resistance, high temperature resistance. Boron carbide (B_4C) may be a suitable replacement for SiC and Al_2O_3 due to its high hardness (after diamond and boron nitride the third hardest material) [3]. Pankaj *et al*. used a stirring process to create an A356-B_4C (4 wt. %) and graphite particulate metal matrix composite, reporting that with the incorporation of B_4C and graphite particles in the base alloy hardness and strength were increased [4]. Senthilvelan *et al.* [5] investigated the mechanical characteristics of Al7075 MMC's made with the liquid stirring process and containing a 10% volume portion of B_4C, SiC and Al_2O_3. The author identified that compared to other reinforcements with Al7075, B_4C reinforced composite had improved mechanical properties. Dinesh Kumar *et al*. [6] utilized a liquid stirring procedure to make aluminum 6063-based metal matrix composites, one of which was added with SiC and graphite and the other with SiC and B_4C. The results of various mechanical tests like ultimate tensile strength, flexural strength, and hardness tests were compared. The authors concluded that adding of reinforcements in the alloy improved the mechanical characteristics.

Liquid metallurgy techniques were used by S. Ramarao and G. Padmanabhan [7] to fabricate aluminum alloy boron carbide composites with particulate weight fractions of 2.5, 5, and 7.5 percent. SEM images revealed a homogenous dispersion of boron carbide particulates in the aluminum matrix. Suresh Gudipudi *et al*. [8] utilized an ultrasonic stirrer method in AA6061-B_4C composites to minimize wetting and joining issues. 2, 4, 6, 8% of B_4C reinforcements were used to make composites. When compared to other wt. % reinforcements the micro structural, compressive, and hardness properties of AA6061- 4wt. % B_4C composite showed excellent improvement. Yu Li *et al*. [9] investigated the effects of AA6061-31% B_4C composites made by stir casting. A scanning electronic magnifying instrument, XRD analysis were used to investigate the uniform distribution of reinforcements. As compared to AA1100-31%B_4C composites, the AA6061-31% B_4C composites had better mechanical properties. N. Siddhartha Prabhakar *et al*. [10] identified the wear properties of an Al/5 wt% B_4C MMC produced by stir casting. The strengthening particles were uniformly dispersed in the alloy according to microstructure tests. The Taguchi method has been used to perform wear tests with wear loads of 10N, 20N and 30 N, speeds of 1 m/s, 2 m/s and 3 m/s and sliding distances of 1000 m, 1500 m and 2000 m to determine optimal parameter values. Prasad DS *et al*. [11] examined aluminum composites made with rice husk garbage (RHA) and silicon carbide particles. The findings revealed that increasing the amount of reinforcements in aluminum compound increased hardness and yield strength.

Kumar *et al*. [12] investigated the mechanical characteristics and wear conductivity of MMC's made of Al6061-SiC and Al7075-Al_2O_3. Hard ceramic particle expansion improved the hardness, strength and weight of the composite. The mechanical characteristics of Al7075/Al_2O_3/graphite hybrid composites have been analyzed by Baradeswaran and Parumal [13]. The mechanical properties of composites improved due to enhanced particles in the matrix alloy. The impact of B_4C addition on the aluminum alloy was investigated by K. Raj kumar *et al* [14]. The liquid stirring procedure was utilized to make composites of reinforcement ranging from 5 to 15% by weight. The mechanical and machining properties of aluminum- B_4C composites were discussed. The increased reinforcements with in aluminum based alloy improved the composites hardness. Keshav Singh *et al*. [15] have examined the mechanical characteristics of LM24-B_4C particle reinforcement composites. Mechanical features like the ultimate resistance to tensile strength, hardness and impact resistance enhanced with increasing weight percentage of B_4C reinforcement. Ravi *et al*. [16] used a stir casting process to make aluminum composites (AA6061) containing boron carbide at various weight ratios. Optical micrographs revealed that boron carbide reinforced particles were scattered equivalently in the AMCs. The reinforcement particles of B_4C improved the tensile strength and hardness. Reddy *et al*. [17] discovered that composites with two reinforcements have better mechanical properties than pure aluminum. The Al6061/SiC/B_4C composites were made with stir casting route. Flexural strength and hardness were increased as a result of the carbide content of the composites. The mechanical characteristics and wear properties of aluminum based composites reinforced with fly ash, graphite flakes were investigated by Venkat and Subramanian [18]. These reinforcing particles increased the mechanical characteristics and wear performance of the composites. Jaswinder singh and Amit chauhan [19] developed the minimal cost, high-strength hybrid aluminum composite materials for use in the automotive industry and high-wear applications. Liquid casting or powder metallurgy techniques may be used to make aluminum matrix composites. These methods are a low-cost way to make particle-reinforced composites. Due to the stirring phase in the manufacturing system, the stir casting process offers stronger particle bonding [20-21].

2. MATERİALS AND METHODS

2.1 Matrix Alloy

In this investigation, the AA7050 alloy was used as a matrix material. This is because zinc is the primary alloying ingredient in the AA7050 alloy, which is commonly, used in the aviation, oceanic, security and automobile sector because of its high strength to weight proportion, light weight and high corrosion resistance as well as its high thermal resistance and hardness. The chemical composition of AA7050 is shown in Table-1.

Table-1. AA7050 alloy chemical composition.

Elements	Weight (%)
Zn	6.40
Mg	2.360
Cu	2.450
Zr	0.130
Al	Balance

2.2 Reinforcement

Boron carbide (B_4C) was used as the composite reinforcement with a 50 micron particle size which is showed in Figure-1. B_4C is an intense substance with superior properties like low weight (2.52 g/cm^3), high strength (30 Gpa) and it is used in the manufacture of impenetrable jackets, defensive layer tanks and other military applications. Because of these advantages B_4C reinforcing aluminum based composite is becoming more common in automotive and aerospace structural applications. Table-2 shows the properties of B_4C.

Figure-1. B_4C Powder.

Table-2. Typical properties of B_4C.

Property	Value
Density	2.520 g/cm^3
Melting Point	24450 °C
Hardness	2900 - 3580 kg/mm^2
Young's Modulus	450 - 470 GPa
Thermal Conductivity	30 - 42 (W/m.K)

2.3 Fabrication of Metal Matrix Composites

The metal matrix composites were prepared using the stir casting technique. The preparation of the aluminum metal matrix composite started with an AA7050 alloy matrix and B_4C proportions of 0, 3, 6, 9, and 12 weight percent. In this step, the AA7050 alloy composition pieces were first placed into the furnace and at the same time, particles of boron carbide (B_4C) were weighed and heated. The melting took place at a temperature of about 850ºC in an electrical resistance heating furnace. From that point onward different weight ratios of preheated B_4C particles were physically poured in to the furnace. In this analysis the stirrer speed and time period have been set at 650 revolutions per minute and 10 min, to achieve uniform distribution of the reinforcement particles in the matrix alloy. The stirrer RPM was then gradually decreased after the composite combination mixture was prepared. The mixture was then placed through into the die to form the composite specimens, which had dimensions of 20 mm in thickness and 130 mm in length. The prepared AA7050/B_4C composite specimens are shown in Figure-2.

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Figure-2. Fabricated aluminum metal matrix composites.

3. RESULTS AND DİSCUSSİONS

3.1 Tensile Strength

The ASTM B557 standard was used to fabricate composite specimens for tensile strength testing. The dimensions of a typical test sample are depicted in Figure-3 (20 mm diameter, 50.88 mm thickness and 40 mm gripping surface length). A computerized universal testing machine was used to measure the tensile strength.

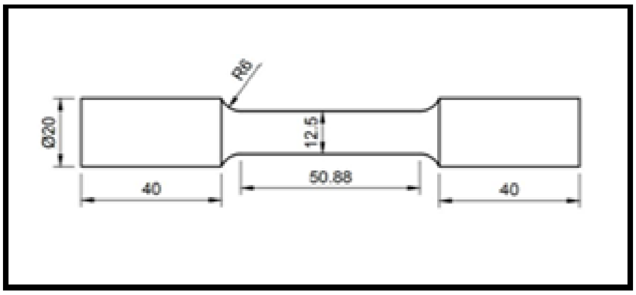


Figure-3. Tensile test specimen as per ASTM B557.

The results of this study show that increasing the weight level of B_4C increases the tensile strength of composites. The composite with 9wt. % B_4C had a maximum tensile strength of 189 N/mm^2, which is 30.3% higher than the AA7050 matrix alloy. Figure-4 shows the graph between the tensile strength versus the B_4C weight percent. Figure-4 shows that, increasing reinforcement weight raises the composite tensile strength up to 9wt. % and after which the rise in tensile strength was decreased and this is mainly caused by cluster formation of the reinforcing particles. The addition of a higher percentage of B_4C in composites improved the tensile strength and load bearing capability. The B_4C strengthening particles increased the tensile stress resistance in the composites. As the load is transferred from the matrix to the reinforcement particles, composites exhibit the greatest elasticity.

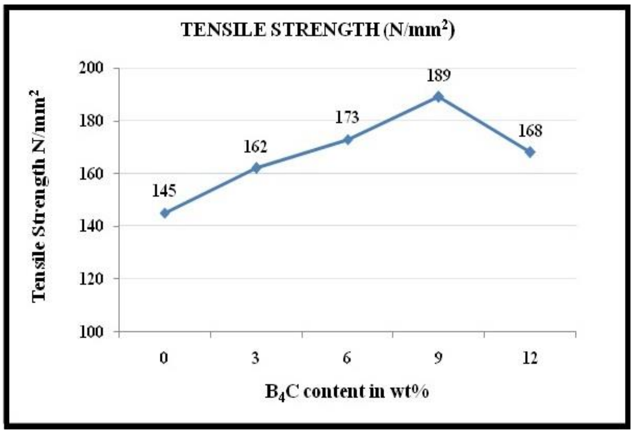


Figure-4. Tensile strength variation in composites.

As compared to the other composite materials, the 12wt. % B_4C composite had the least amount of extension. The expansion of a weight level of B_4C reinforcement decreases the percentage of elongation in the composites, as demonstrated in Figure-5. The intermolecular bonding between reinforcements and matrix alloy makes microscopic holes and crack initiation resulting in composite fracture. It reduced the ductility of the composites.

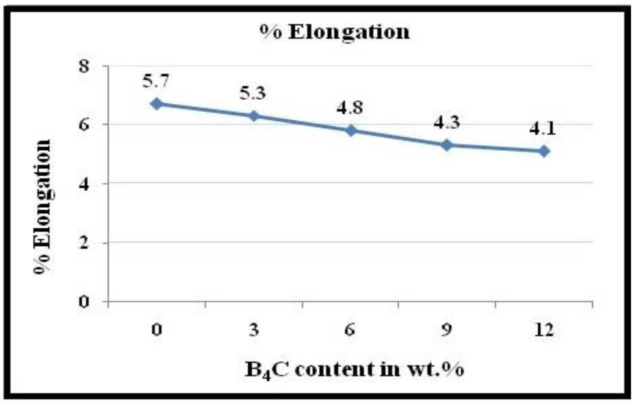


Figure-5. % Elongation variation in composites.

3.2 Hardness

Figure-6 shows the hardness of AA7050 built up with B_4C reinforcement. The hardness test was performed on Brinell hardness testing equipment using a 5 mm ball indenter and a load of 250 kgf. Figure-6 shows the average values of hardness for each specimen, which were taken at three distinct areas of the composites. It shows that adding of B_4C particles to an aluminum 7050 alloy improves the hardness of the composites. The hardness increases from 71 BHN to 84 BHN, which is 18.3% higher than the matrix alloy. Multi reinforcing particles contribute to the reduction of particle porosity and fine grain structure. This is due to the support of B_4C particles in the aluminum matrix alloy.

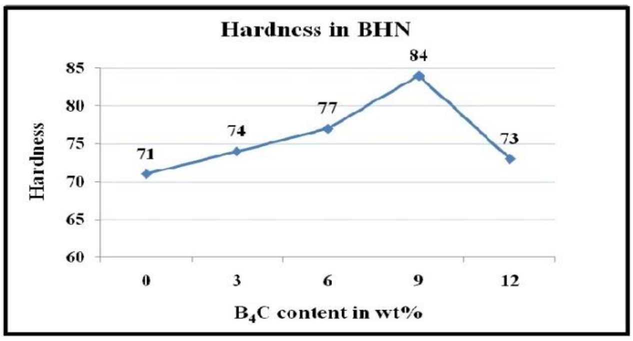
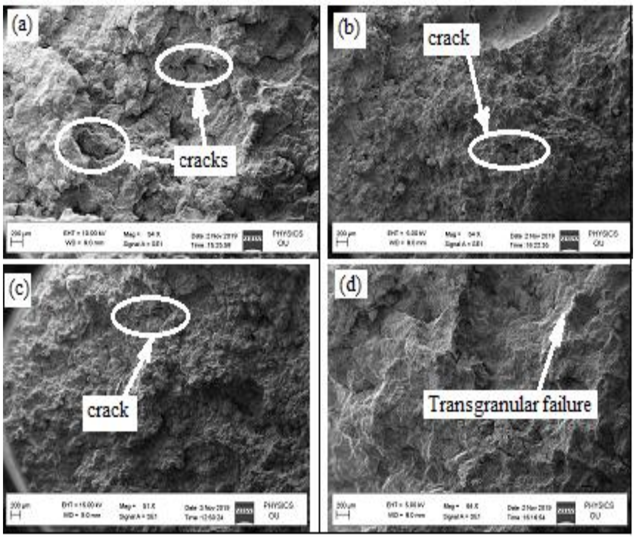


Figure-6. Hardness variation in composites.

3.3 SEM Analysis



Figuere-7. SEM images showing surface of tensile fracture AA7050 alloy with B_4C wt. % of reinforcements: (a) 0wt.% (b) 3wt.% (c) 6wt. % (d) 9wt. %.

SEM images of fractured as cast AA7050 alloy and AA7050-B_4C metal matrix composites are showed up in Figure 7(a) to (d). The strength of a metal matrix depends on initial crack and its growth. The presence of dimple structure exhibits ductile fracture and the presence of intergranular and transgranular disillusionment shows brittle fracture. The ductile fracture initiation and progression was appeared in Figure-7(a) due to small voids. Composite specimens that failed as a result of a combination of ductile and brittle fracture were shown in Figures 7(b) to (d). SEM images of the fracture surfaces showed that tiny voids created the initial cracks, causing ductile failure in the composites. Due to the B_4C reinforcement particles cleavage planes emerged at grain boundaries of the composites resulting in brittle fracture in the specimens.

4. CONCLUSIONS

The mechanical characteristics of AA7050/B_4C MMC's are prepared by the stir casting process with different B_4C reinforcement proportions. The experimental results led to the following conclusions.

- The incorporation of B_4C reinforcement particles in the aluminum 7050 alloy increases the tensile strength of the composites.
- The highest tensile strength is achieved with a 9wt. % B_4C composite (189 N/mm^2), which is 30.3% greater than the unreinforced aluminum7050 alloy.
- The inclusion of boron carbide reinforcements within the aluminum 7050 alloy reduces the percentage elongation of the composites.
- The hardness of the composites increases as the amount of B_4C reinforcement in the matrix alloy increases. The highest hardness is found in a 9wt. % B_4C composite (84 BHN), which is 18.3% greater than the base alloy.
- Scanning electron microscopy analysis revealed that the ductile and brittle failures are appeared in the composites. The cracks, dimples, transgranular cleavages have been noticed in the composites.

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