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Characterization of hybrid metal matrix aluminum with boron carbide and graphite

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Abstract

The importance of reinforced particle with aluminium metal matrix is to study and predict in the enhancement of mechanical properties like tensile and tribological property. Metal matrix composites (MMCs) constitute an important class of design and weight-efficient structural materials that are encouraging every sphere of engineering applications. There has been an increasing interest in composites containing low density and low cost reinforcements. With the increasing demand of light-weight materials in the emerging industrial applications, fabrication of aluminum-boron carbide with graphite composites is required. In this context aluminum - boron carbide with graphite composites were fabricated by stir casting with different particulate composition of B4C (5%, 10%).Microstructure analysis was done with scanning electron microscope. With the increase the amount of the boron carbide, the density of the composites decreased whereas the hardness is increased. The ultimate compressive strength of the composites was increased with increase in the weight percentage of the boron carbide in the composites.

Key words: Aluminum alloy, Boron carbide, graphite, stir casting, SEM, Mechanical properties.

Introduction

Metal Matrix Composites (MMCs) have emerged as an important class of materials and are increasingly utilized in various engineering applications, such as aerospace, marine, automobile and turbine compressor engineering, which require materials offering a combination of light weight with considerably accelerated mechanical and physical properties such as strength, toughness, stiffness and resistance to high temperature. Aluminum is the most frequently use matrix material due to its low density. Because of its extreme hardness and temperature resistant properties, B_4C, graphite are often used as reinforcement

S. Rama Rao.et.al (1) absorbed that the production of aluminium with boron carbide reinforcement material will improves the some mechanical properties like hardness, tensile strength.....etc. and the density is reduced. According to **Rohit Kumar et.al (2)**, the yield strength and tensile strength of the composites decrease with increasing the volume fraction of the B_4C particles, while the hardness of the composites increases with increasing the volume fraction of the B_4C particles so that impact strength increases with increase in volume fraction of reinforcement at a certain limit (upto10 %) after starts decreasing. **G.G. Sozhamannan et.al (3)** observed that production of Aluminium composite reinforced with discontinuous ceramic particulates by Stir casting route will have homogeneous mix and is cost effective process. The major problem in this technology is to obtain sufficient wetting of particle by the liquid metal and to get a homogeneous dispersion of the ceramic particles. **Neelima et.al (4)** has the maximum tensile strength has been obtained at 15% B_4C ratio. This indicates that the Aluminium Boron carbide composite material is having less weight and more strength. **Dunia Abdul Saheb et.al (5)** compared the micro and macro structural behavioural of Al-B_4C particulate composites by varing the weight fractions of B_4C. This study reveals that increasing trend of hardness with the increase in carbide up to 4 wt% weight fraction. Beyond this the hardness of composite decreases as graphite particles interact with each other leading to clustering of particles. **S. Naher et.al (6)** has simulated stir casting process using different blade designs and studied the effects of stirring speed, blade angles and number of blades on the uniform dispersion of B_4C particles into different liquid medium and time required for uniform dispersion of particles. They noticed the excessive vortex height is responsible for air entrapment into the liquid and is more in more viscous liquid. It was observed that settling times of particles only depends on the viscosity of the liquid metal and does not depend on the stirring speed and blade design. **M. Singh et al (7)** has conducted tribological tests on LM25 aluminium alloy reinforced with 10% Boron carbide particles. Samples were made by stir casting method in an oil fired furnace. Sliding wear tests were conducted on pin-on-disc machine at different applied loads. It was noticed that hardness and tribological properties were improved by the addition of Boron carbide particles to the matrix alloy and the seizure pressure of the composite is higher than the matrix alloy. **A.R. Riahi.et.al (8)** have focused on systemic tests of the role of tribal-layers which are formed on contact surfaces of hybrid composites with A356 aluminium base. Tests were done on Al/B_4C hybrid composite with A356 base, 10% B_4C with particle size of 16µm. Performed tribological tests determined dependence between wear and sliding speed and load. The tests were performed on block on ring tribometer for loads of 5–420 N and for sliding speeds of 0.2–3.0 m/s. **M.L. Ted Guo.et.al (9)** have studied tribological behaviour of Al-B_4C composites with different composition and found that friction coefficient decreases with the addition of graphite up to 5% and no considerable change noticed with further increase in graphite and also observed that hardness of the composite decreases with addition of Boron.**B.Mallick.et.al. (10)** explained that addition of magnesium to the liquid aluminium will reduce the surface tension of the melt facilitating the depression of ceramic particles in to the melt and also increases the wetting properties of metal-ceramic systems through reduction in solid-liquid interfacial energy.This paper aims to analyze the microstructure evolution of B_4C/Al composites during mechanical alloying bonding with graphite and the microstructure, mechanical property of the composites prepared by stir casting within the aluminum matrix. This type of composite is more frequently used in the automotive industry today, particularly in various engine components as well as brakes and rotors Boron Carbide (B4C) has many attractive properties, such as low specific gravity, high hardness value, high elastic modulus value and neutron absorption, which help B4C to be widely used as and armor materials. From limited information of B4C reinforced aluminum matrix composites, there are several research works mainly focused on the wettability and chemical reaction between aluminum and boron carbide with graphite. K. Madheswaran.et.al. (11) has studied mechanical characterization of aluminium-boron carbide composites with influence of calcium carbide particles. The objective of this work is to fabricate and testing the mechanical properties of aluminium metal matrix composites with boron carbide and calcium carbide reinforcements at different volume fractions. Mechanical properties like tensile strength, shear strength and toughness of newly developed MMCs is improved significantly by incorporating boron carbide and calcium carbide particles. The toughness of material is considerably reduced if the percentage of calcium carbide addition is increases. From this study, it is concluded that the ultimate tensile strength of aluminium metal matrix composite with 2% of calcium carbide and 8% boron carbide reinforcements compared with 1% calcium carbide and9% boron carbide reinforcements is increased by 8%. Ehsan Ghasali,Masoud Alizadeh : Has worked on investigation of microstructure and mechanical properties of B_4C-Aluminum matrix composites prepared by microwave sintering.B4C reinforced Aluminium composites were fabricated by microwave heating of the mixture of B4C (10, 15 and 20 wt. %) and aluminium powder at 650,750,850 and 9500c.The effect of different amounts of B4C on the microstructure and mechanical properties of aluminium matrix was examined. The maximum bending (238MPa) and compressive strength (330MPa) values were measured for composites sintered at 950 and 7500c respectively. The maximum hardness (112 Vickers) was measured for Al-20wt. % B4C composite sintered at 8500c.

2. Experimental Details

2.1 Materials

Metal matrix composites containing 5 and 10 weight percentages of B4C and 4 weight percentages of graphite particles were produced by liquid metallurgy route. For the production of MMCs, an Al LM25 alloy was used as the matrix material while B4C, graphite particles with an average size of 80-90µm were used as the reinforcements. Al LM25 alloy having chemical composition as per the ASTM ingot specification is given below

Mechanical Properties	**Values**
Tensile Stress (N/mm^2)	130-150
Hardness (BHN)	55-65
Modulus of Elasticity ($x10^3$ N/mm^2)	71
Elongation (%)	2

Table 1 Mechanical properties of (LM25)

2.2 Preparation of composites

In stir casting method before the casting reinforcements, stirrer, permanent mould preheated to 300^0C to remove moisture and gases from the surface of the reinforcements, and equipment's before casting. Now the required amount of Al LM25 is weighed and placed in the graphite crucible and heated to 730^oC using resistance furnace then the degassing tablet is added to minimize the coating film defects by expelling the volatile components present in the melt during casting. The tablet helps in the removal of entrapped air in the melt and thus prevents casting defects like porosity and blow holes. Then the matrix Al LM25 is reinforced with B4C particulates with different weight percentages (5&10). The micro particle of B_4C, Graphite was added at the temperature of 710^oC and constant rigorous stirring was done for 15mins until a clear vortex is formed. The melt was then superheated above the liquids temperature and finally poured into a cast iron permanent mould to obtain cylindrical samples of 15 mm diameter and 75 mm length. Unreinforced matrix alloy specimens were also cast for comparison purpose.

Figure 1. Composites specimen

3. Testing of Composites

Micro Structure Analysis.

Micro structural characterization studies were conducted on unreinforced and reinforced samples. This is accomplished by using scanning electron microscope. The composite samples were metallographically polished prior to examination. Characterization is done in etched conditions. Etching was accomplished using Keller‘s reagent. The MM micrographs of composite and wear debris were obtained using the metallurgical microscope –Dewinter Tech. The images were taken in both secondary electron (SE) and back scattered electron (BSE) mode according to requirement.

Particle Size Analysis

Particle size of the milled powder was measured by Malvern particle size analyzer (Model Micro-P, range 0.05- 550 micron). Firstly, the liquid dispersant containing 500 ml of distilled water was kept in the sample holder. Then the 15 instrument was run keeping ultrasonic displacement at 10.00 micron and pump speed 1800 rpm. Electrolytic Etchtant:1%HF

Tensile Tests

Tensile tests were conducted at room temperature using a universal testing machine (UTM) in accordance with ASTM standard. The tensile test specimens of diameter 9mm and gauge length 45mm were machined from the cast composites with the gauge length of the specimens parallel to the longitudinal axis of the castings. For each composite, two tensile test specimens were tested and the average values of the ultimate tensile strength and yield strength were measured.

Wear Resistance Test

The wear resistance test is conducted on wear test machine in accordance with ISTM. The wear test specimens of diameter 150mm and gauge length 500mm were machined from the cast composites.

For every composite, one wear resistance test specimens were tested. The wear resistance values of the samples were measured on the machined samples with a load of 1000gms,40 RPM and 60 grade coarser abrasive sheet.

4. Results and Discussion

It is well known stir casting process, the following figures shows the distribution of aluminium- boron carbide with graphite particles through in metal matrix composite. The result indicates the reinforcement of particles as distributed in good manner the bonding between aluminium- boron carbide with was graphite achieved through stir casting method. Addition of graphite added with aluminium, increases the ultimate tensile strength and wear resistance, reduce the co efficient of friction.

Micro Structure Of Al-B_4c With Addition Of Graphite

91% of Al and 5% of B4C,4% of Graphite

B4C-Al with graphite showing different microstructures obtained after initially subsequently cooled in the furnace for 24 h (initial composition: 5 % B4C-91% Al, 4%graphite),then obtaining the microstructure shows figure

86% of Al and 10% of B4C,4% of Graphite

B4C-Al with graphite showing different microstructures obtained after initially heating to 700°C for one and half hour and subsequently cooled in the furnace for **24** h (initial composition: 10% B4C-86% Al, 4%graphite),then obtaining the microstructure shows figure.

Figure 2 91% of Al and 5% of B4C,4% of Graphite

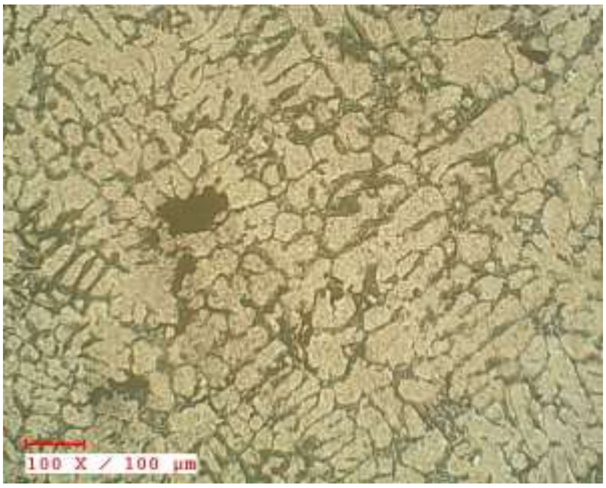
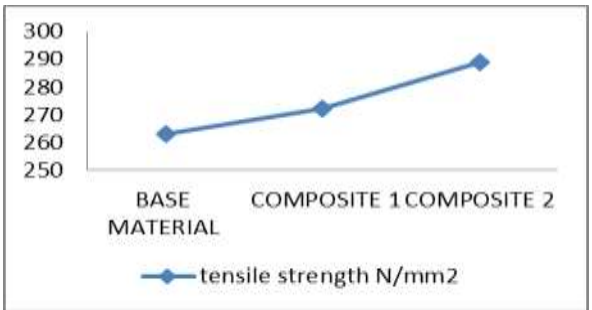


Figure 3 86% of Al and 10% of B4C,4% of Graphite

The microstructure shows network of interdentric Al-Si Eutectic particle in the matrix of Al solid solution.in this matrix, some porosity also observed

TENSILE TEST

we can see that the tensile strength was increased in the composites and have comparable variation. Weak interfacial bonds may result in decrease in tensile strength of the composite, but here the increase of tensile strength shows that there was good interfacial strength. From this result we can expect good interfacial strength when we heat the reinforcements at



higher temperatures which will facilitate uniform distribution of more amount of composite without losing the strength.

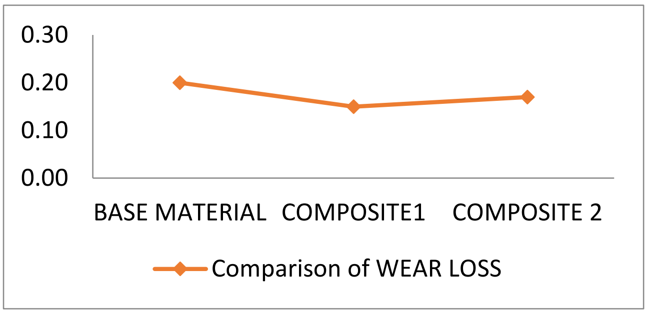
s.no	Composition material	Tensile strength(N/mm)
1.	AL LM25	263
2.	AL LM25,5% B_4C,4% GRAPHITE	278
3.	AL LM25,10% B_4C,4% GRAPHITE	287

Table 2. Specimen tensile strength

Figure 4. Comparison of tensile strength

Wear test

When the friction is the predominant factor causing deterioration of materials, abrasion and wear testing will give data to compare materials or coatings and can help you predict of life time of material or coating.



s.no	Composition material	Wear loss
1.	AL LM25	0.20
2.	AL LM25,5% B_4C,4% GRAPHITE	0.15
3.	AL LM25,10% B_4C,4% GRAPHITE	0.17

Figure 4. Comparison of tensile strength

Table 3. Wear strength

Conclusion

The Al–B_4C–Gr hybrid composites were prepared successfully by stir casting method and reinforcement of boron carbide increased the strength of composites. Optimal per cent reinforcement can be of 12% for any value of sliding distance, speed and load within the range considered in this investigation. Al–B_4C–Gr hybrid composites are better substitutes the Al alloy owing to improved hardness and wear resistance as a result of the addition B_4C–Gr particulates to Al. Analysis shows that, increase in per cent reinforcement reduces the wear up to 12%. The hardness of the composites increased and density was decreased with increasing the amount of the boron carbide in the matrix phase. Increasing the amount of boron carbide particles in composites caused the ultimate compression strength to increase.

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