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Mechanical Behavior of Al7025-B_4C Particulate Reinforced Composites

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Abstract

In comparison to unreinforced alloy, Al7025 reinforced with hard ceramic particles possesses higher strength, hardness,wear resistance and low coefficient of thermal expansion. They can be used for automotive components and aircraft structures. The aim of the present work is to investigate the effects of adding micro size-B4C particales to Al7025 alloy on the mechanical properties of the composites.The Al7025 alloy reinforced with 6 wt. % of B_4C particulate composites were fabricated by stir casting method.Microstructure and mechanical properties such as hardness, ultimate tensile strength, yield strength, percentage elongation and density of the composites were examined. Microstructure of the samples has been investigated by using optical microscopy to know the uniform distribution of reinforcement particulates in the matrix. It was observed that the hardness, ultimate tensile strength and yield strength of Al7025 alloy increased with the addition of 6 wt. % B_4C particulates.From the study, it was revealed that the elongation and density of Al7025-6wt.% B_4C composite decreased in comparison to that of the base Al7025 alloy.

Keywords: Al7025 Alloy; B_4C Particulates; Hardness; Ultimate tensile strength; Yield strength; Stir casting

Introduction

Metal matrix composites (MMCs) offer designers requirements, they are particularly suited for applications requiring high strength to weight ratio at high temperature, good structural rigidity, dimensional stability, and light weight. The inadequacy of metals and alloys in providing both strength and stiffness to a structure has led to the development of various composites particularly metal matrix composites (MMCs) [1-3]. Composite materials are used extensively as their higher specific properties (properties per unit weight) of strength and stiffness, when compared to metals, offer interesting opportunities for new product design. MMCs are metals reinforced with other metal, ceramic or organic compounds. They are made by dispersing the reinforcements in the metal matrix [4]. Reinforcements are usually done to improve the properties of the base metal like strength, stiffness, conductivity, etc. The particle distribution plays a very vital role in the properties of the Al MMC and is improved by intensive shearing [5]. Addition of hard ceramic particles like SiO_3, SiC, Al_2O_3, TiB_2, B_4C etc. to Al matrix lead to strengthening of the matrix with improved properties. Ceramic particles such as Al_2O_3 and SiC are the most widely used materials for reinforcement with aluminium. Boron carbide (B_4C) could be an alternative to SiC and Al_2O_3 due to its high hardness (the third hardest material after diamond and boron nitride). Boron carbide has an attractive properties like high strength, low density (2.52 g/cm^3), extremely high hardness, good wear resistance and good chemical stability. Hence reinforcing the aluminium with boron carbide particles confers high specific strength, elastic modulus, good wear resistance and thermal stability [6]. From the Literaure survey it can be concluded that, most of the studies on aluminium based MMCs are devoted to SiC and Al_2O_3 particulate reinforcements; however, use of B_4C particulates as reinforcements in aluminium matrix is relatively limited. B_4C is considered to be the third hardest material and is an extremely promising material for a variety of applications like bullet proof vests, armor tanks and as neutron absorber material.

Cun-Zhu Nie et al., [7] studied the Boron carbide particulates reinforced 2024 Aluminum matrix composites were fabricated by mechanical alloying–hot extrusion technology successfully. A clean interface of B_4C between aluminum was obtained in their experiment, the yield strength and Young's modulus values were improved significantly over the monolithic 2024 alloy. Vijaya et al., [8] investigated the mechanical properties of aluminium alloy alumina boron carbide metal matrix composites

The present investigation focuses on fabrication and evaluation of mechanical behavior of Al7025 alloy matrix reinforced with B_4C particles.

Materials and Experimental Details

Matrix material

The matrix material used in the experimental investigation is aluminium 7025 alloy whose chemical composition is listed in Table 1. Al7025 alloy is one type wrought aluminium alloy, containing zinc as a major alloying element. The theoretical density of Al7025 is taken as 2.80 g/cm^3.

Reinforcement material

The main advantage of introducing reinforcement material to

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Element	Symbol	Wt. Percentage
Zinc	Zn	5
Copper	Cu	0.1
Manganese	Mn	0.6
Magnesium	Mg	1.5
Ferrite	Fe	0.4
Chromium	Cr	0.35
Silicon	Si	0.3
Titanium	Ti	0.1
Aluminium	Al	Bal

Table 1: Chemical composition of Al7025 alloy.

base metal or alloy is to increase the properties there by enhancing the mechanical and tribological properties of composites. In the current research Boron Carbide particulates of size 70-80 microns (µm) were used as a reinforcement material, which was procured from Speedfam (India) Pvt. Ltd., Chennai. The density of B_4C is 2.52 g/cm^3 which is lower than the base Al matrix, contributes in weight saving.

Preparation of Al7025-B_4C composites

In the engineering materials, the MMC's can be manufactured by a unique technique such as casting, as it is inexpensive and suitable for mass production of components. The synthesis of metal matrix composite used in the study was carried out by liquid metallurgy route in particular stir casting technique. Initially B_4C particulates were preheated for 300-400°C. In the present work, an attempt has been made to study the mechanical properties of as cast Al7025 alloy and Al7025- B_4C particulate composites. The composites containing 6 wt.% of B_4C particulates were prepared. Initially required amount of charge or matrix material was placed in a graphite or silicon carbide crucible, which was placed in electric resistance furnace at a temperature of around 730 degree Celsius. After complete melting of Al7025 alloy matrix, degassing was carried out by using Solid Hexa Chloroethane [9], which helps to remove unwanted adsorbed gases from the melt. Once degassing is over, the preheated ceramic reinforcement particles were introduced into matrix in a novel way which involves two-stage additions of reinforcement during melt stirring. This novel two stage additions of reinforcement into matrix Al7025 will increase wettability of the matrix and ceramic reinforcement and further, which helps in uniform distribution of the particles. A continuous stirring process was carried out during addition of reinforcement into matrix. Normally for all composite preparation, stirring speed was maintained at 300rpm. After 10 minutes of continuous stirring, entire molten metal was poured into cast iron die. The prepared composites were machined and tested for micro structural studies. After revealing uniform distribution of B_4C particles in the matrix, tensile behaviour of as cast Al7025 alloy and its composites were evaluated as per ASTM standards. Figures 1 and 2 showing the cast iron die and stir casting set up and used to prepare the composites for the present study.

Specimen testing

The microstructure of the as cast Al7025 alloy and its composites reinforced with different wt.% of B_4C particulates were examined by using an optical microscope (Olympus made). The samples of as cast and Al7025-B_4C composites for microstructural study were cut from casted rods and ground by means of abrasive papers followed by rotating disc cloth polishing. Keller's reagent was used as an etching agent.

The composites and base Al7025 alloy were tested for their hardness using a Brinell hardness tester. The hardness testing was carried out in accordance with ASTM E10 standard at room temperature. A test load of 250 kg was applied to the specimens for 30s. The diameter of steel ball indenter was 5 mm. The size of the indent (d) was determined optically by measuring two diagonals of the round indent. The Brinell hardness number (BHN) was calculated for the unreinforced Al matrix and B_4C reinforced composite using equation (1). An average of ten readings was taken for each sample for hardness measurement.

$$BHN=\frac{2P}{\Pi D\left(D-\sqrt{D^2-d^2}\right)} \quad (1)$$

Where P is the applied load in kg, D is the diameter of the steel ball in mm and d is the size of the indent in mm. Each hardness value presented is an average of at least ten symmetrical indentations.

The experimental density of both unreinforced Al7025 alloy and Al7025-B_4C composites were measured by dividing the measured weight of test sample by its measured volume using an electronic weighing machine. The theoretical density of the composite was calculated by rule of mixture using formula:

$$\rho_{th}=\rho_m V_m + \rho_r V_r \quad (2)$$

Where ρ_m is the density of matrix, V_m is the volume fraction of the matrix, ρ_r is the density of reinforcement and V_r is the volume fraction of the reinforcement.

Tensile testing of the prepared samples were conducted in accordance with the ASTM E8 standard on round tension test specimens of gauge diameter 9 mm and gauge length 45 mm. Tension test was conducted by using Instron made servo-hydraulic machine,

Figure 1: Cast Iron Die.

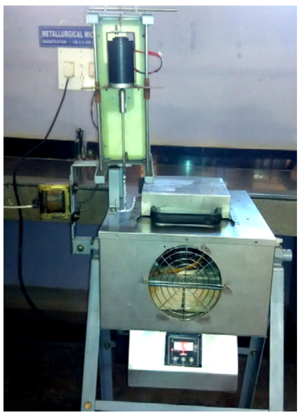


Figure 2: Stir casting set up.

with cross head speed set at 0.280 mm/min. The experiments were conducted at room temperature. Stress versus strain graph was plotted to know the effect of B_4C particulates on tensile behaviour of Al7025 alloy composites.

Results and Discussion

Microstructural study

Figures 3a and 3b shows the optical micrographs of as cast Al7025 alloy and Al7025-6 wt.% B4C composite respectively. The grain size of the composite was much smaller than that of the alloy because particles act as nucleation sites. Figure 3b reveals good distribution of reinforcements and there is no agglomeration in the composite. From the optical microphotograph, it is clear that a good crack free bonding was formed at discrete locations between the reinforcement and the matrix alloy.

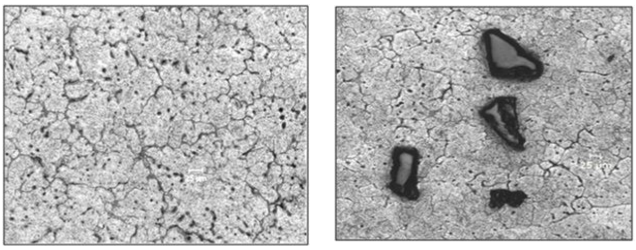
Density measurements

In the present research work, the measured densities of as cast Al7025 alloy and Al7025-6 wt.% B_4C composites are presented in the Figure 4.

It is observed that, by the addition of B_4C particles the density of the composite is slightly decreased. This decrease in density is mainly due to lower density of B_4C particles as compared to the base Al7025 alloy. Further, from Figure 4, the experimental densities for both alloy and composites are in line with the theoretical densities but slightly lesser than the theoretical densities.

Hardness

In the present work, hardness values of the Al7025 alloy and



(a) (b)

Figure 3: Optical micrographs of (a) as cast Al7025 alloy (b) Al7025-6 wt. % B_4C composite.

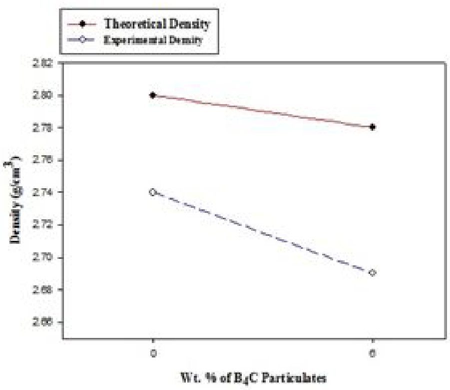


Figure 4: Comparison of theoretical and experimental densities of Al7025 alloy and its composites.

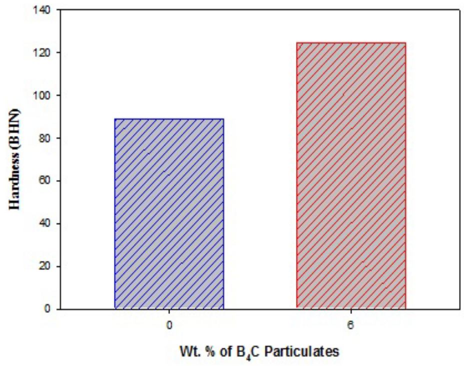


Figure 5: Variation in hardness with wt. % of B_4C particulates.

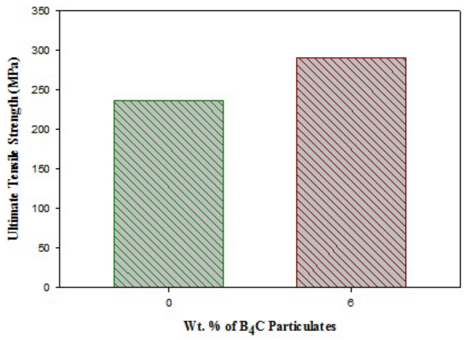


Figure 6: Variation in ultimate tensile strength with wt. % of B_4C particulates.

Al7025-B_4C composites have been obtained by Brinell hardness tester. The variation of hardness with Al alloy and its composite is shown in Figure 5. It is noticed that the hardness of Al7025-6 wt.% B_4C composite is more than Al7025 alloy. A notable rise in the hardness of the alloy matrix can be seen with the addition of B_4C particles. This is mainly due to the presence of B_4C particles in the matrix Al7025 alloy. Whenever a hard reinforcement is incorporated into a soft ductile matrix, the hardness of the matrix material is enhanced [10].

Figure 6 shows variation of ultimate tensile strength (UTS) with 6 wt.% of B_4C particulates. The ultimate tensile strength of Al7025-6 wt.% B_4C composite material increases by an amount of 22.42% as compared to as cast Al7025 alloy matrix. The microstructure and properties of hard ceramic B_4C particulates control the mechanical properties of the composites. Due to the strong interface bonding load from the matrix transfers to the reinforcement exhibiting increased ultimate tensile strength [11].

This increase in UTS mainly be due to B_4C particles acting as barrier to dislocations in the microstructure. The improvement in UTS may be due to the matrix strengthening following a reduction in Al7025-B_4C grain size, and the generation of a high dislocation density in the Al7025 alloy matrix a result of the difference in the thermal expansion between the metal matrix and the B_4C reinforcement.

Yield strength

Figure 7 shows variation of yield strength (YS) of Al7025 alloy

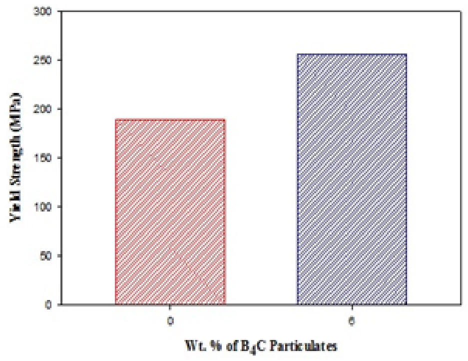


Figure 7: Variation in yield strength with wt.% of B_4C particulates.

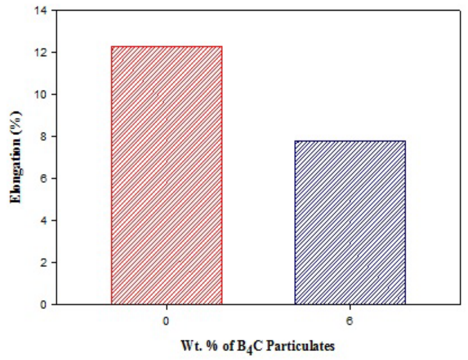


Figure 8: Variation in percentage elongation with wt.% of B_4C particulates.

matrix with 6 wt.% of B_4C particulate reinforced composite. It can be seen that by adding 6 wt.% of B_4C particulates yield strength of the Al7025 alloy increased from 189.6 MPa to 256.3 MPa. This increase in yield strength is in agreement with the results obtained by several researchers [12], who reported that the strength of the particle reinforced composites is more strongly dependent on the volume fraction of the reinforcement. The increase in YS of the composite is obviously due to presence of hard B_4C particles which impart strength to the soft aluminium matrix resulting in greater resistance of the composite against the tensile stress. In the case of particle reinforced composites, there is a restriction to the plastic flow due to the dispersion of the hard particles in the matrix, thereby providing enhanced strength to the composite.

Percentage elongation

Figure 8 is a graph showing the effect of B_4C content on the percentage elongation (ductility) of the composites. It can be seen from the graph that the ductility of the composites decrease significantly with the 6 wt.% B_4C reinforced composites. This decrease in percentage elongation in comparison with the base alloys is a most commonly occurring disadvantage in particulate reinforced metal matrix composites. The reduced ductility in Al7025-6 wt.% composites can be attributed to the presence of B_4C particulates which may get fractured and have sharp corners that make the composites prone to localised crack initiation and propagation. The embrittlement effect that occurs due to the presence of the hard ceramic particles causing increased local stress concentration sites may also be the reason.

Conclusion

The results of the study of microscopic structure and mechanical properties of the Al7025-6 wt.% of B_4C composites materials produced by stir casting are remarked as below:

- The liquid metallurgy technique was successfully adopted in the preparation of Al7025-6 wt.% B_4C composites.
- The microstructural studies revealed the uniform distribution of the B_4C particulates in the Al7025 alloy matrix.
- Density of the Al7025-B_4C composites decreased as compared to that of base alloy 7025 matrix. Further, experimental densities of base alloy and composites are in line with the theoretical densities, which show good casting procedure adopted for fabrication of composites.
- Hardness of the Al7025-B_4C composite was found to be more than base Al matrix.
- The ultimate tensile strength and yield strength properties of the composites found to be higher than that of base matrix. The improvements in UTS and YS by adding 6 wt. % of B_4C was increased by 22.46% and 34% respectively.

It was observed that the percentage elongation decreased for Al7025-6 wt.% B_4C composite as compared to base Al7025 alloy matrix.

References

1. Dora Siva P, Chintada S (2014) Hybrid composites a better choice for high wear resistant materials. Journal of Materials Research and Technology 3: 172-178.
2. Rama Rao G (2012) Padmanabhan Fabrication and mechanical properties of aluminium-boron carbide composites. International Journal of Materials and Biomaterials Applications 2: 15-18.
3. Rajmohan T, Palanikumar K, Arumugam S (2014) Synthesis and characterization of sintered hybrid aluminium matrix composites reinforced with nano-copper oxide particles and micro-silicon carbide particles Composites: Part B 59: 43-49.
4. Hamid RE, Seyed AS, Mohsen HS, Yizhong H (2014) Investigation of microstructure and mechanical properties of Al6061-nanocomposite fabricated by stir casting Materials and Design 55: 921-928.
5. Zadra M, Girardini L (2014) High performance low cost titanium metal matrix composites. Materials Science & Engineering A 608: 155-163.
6. Attar S, Nagaral M, Reddappa HN, Auradi V (2015) A review on particulate reinforced aluminum metal matrix composites 2: 225-229.
7. Cun-Zhu N, Jia-Jun G, Jun-Liang L, Di Zhang (2007) Production of boron carbide reinforced 2024 aluminum matrix composites by mechanical Alloying Materials Transactions 48: 990-995
8. Vijay R, Elanchezhian C, Jaivignesh M, Rajesh S, Parswajinan C (2014) Evaluation of mechanical properties of aluminium alloy alumina boron carbide metal matrix composites. Materials and Design 58: 332-338.
9. Nagaral M, Auradi V, Kori SA (2014) Dry sliding wear behaviour of graphite particulate reinforced Al6061 alloy composite materials 170-174; 592-594.
10. Halverson DC, Snowden WE, Aleksander J (1989) A Processing of boron carbide-aluminum composites. J Am Cerum 72: 775-780.
11. Saikeerthi SP, Vijayaramnath B, Elanchezhian C (2014) Experimental evaluation of the mechanical properties of aluminium 6061-B_4C-SiC composite. International Journal of Engineering Research 3: 70-73.
12. Shorowordi KM, Laoui T (2001) Microstructure and interface characteristics of B_4C, SiC and Al_2O_3 reinforced Al matrix composites: A comparative study 4th International Conference on Mechanical Engineering Dhaka Bangladesh 175-181.