Tensile Behavior of B_4C Particulate Reinforced Al2024 Alloy Metal Matrix Composites

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In the present investigation, microstructure study and tensile behavior of B_4C particulate reinforced Al2024 alloy composites have been reported. Al2024 matrix composites containing boron carbide were fabricated by conventional stir casting method.The composites containing 3 and 6 wt. % of B_4C (80 micron size)particulates were fabricated for the study. The micro–structure of the composite was examined by optical microscopy. Images were taken to identify the presence of B_4C particle in aluminum matrix. Further, tensile behavior of as cast Al2024 alloy and Al2024-3 wt. % B_4C and 6 wt. % B_4C composites were studied. Tensile properties like ultimate tensile strength, yield strength and percentage elongation were evaluated as per ASTM standards. Microstructural observation revealed the uniform distribution of particles in the Al2024 alloy matrix. It was found from the analysis, that the ultimate tensile strength of composite was increased due to increasing amount of boron carbide particle in the composite and the yield strength was increased due to the higher value of boron carbide. Also percentage elongation of the composites decreases with increase of the order of boron carbide. Finally, it was found that in the stress – strain curve, the boron carbide was the main factor in improving the tensile strength of composites because of its high hardness. The composites in the present study have great potential for application as structural materials.

Keywords: *Al2024 Alloy, B4C Particulates, Ultimate Tensile Strength, Yield Strength, Stir asting, Percentage Elongation.*

1. INTRODUCTION

Composite materials are a mixture or a combination of two or more constituents differing in form and/or material composition and are essentially insoluble in each other. Both constituents maintain their identity as they do not dissolve or melt in each other, and act in such a way that a new material results whose properties are better than the sum of their constituents. Due to advancement in technology, there is enlarged demand for an economical, light weight, harder, stronger and energy saving material in the area of space, aircraft, defence and automotive applications and aluminium matrix composites (AMCs) found applications in these areas. Aluminum is a corrosion resistance material widely used in aerospace applications doesn't have appropriate wear resistance by itself. Therefore, improvement of surface properties is required in practical applications [1-3]. The need for advanced engineering materials in the areas of aerospace and automotive industries had led to a rapid development of metal matrix composites. Metal matrix composites (MMCs), a metal/ alloy as matrix with ceramic reinforcements, are known for their high specific strength, modulus and hardness properties [4]. Nowadays boron carbide based aluminium composites are mainly used in nuclear and defence fields such as neutron absorber, armour plate materials and as substrate materials in computer hardware [5]. Al based MMCs can be fabricated via various casting techniques such as reactive squeeze casting and rapid solidification processing, exothermic dispersion, reactive hot pressing, and self propagating high temperature synthesis (SHS) and mechanical alloying (MA) [6].

Many researchers have reported the effect of ceramic particulates addition on mechanical and tribological properties of soft Al matrix. Dora Siva Prasad reported that the mechanical properties of low cost composites developed with the use of rise husk ash and SiC have been increased by increasing wt. % of reinforcement [7]. Baradeswaran et al. [8] investigated the effect of Al_2O_3 and graphite content on the mechanical and wear behaviour of Al7075 alloy composites. Suresh et al. [9] studied the mechanical behaviour and wear prediction of stir cast Al-TiB_2 composites and revealed that the ultimate tensile strength and hardness of the Al6061 increases with increase the amount of TiB_2.

From literature survey, it is seen that very scarce work has been done on combination of Al2024 alloy with B_4C particulate reinforced composites. In the present work, Al2024-B_4C composites have been fabricated by stir casting technique. Different weight % of B_4C particulates that is 0, 3 and 6 wt. % were used

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for synthesis of composites. The microstructure and tensile properties like ultimate tensile strength, yield strength and percentage elongation were investigated and discussed in details for both as cast Al2024 alloy and Al2024-B_4C composites.

2. EXPERIMENTAL DETAILS

2.1 Selection of materials

The matrix material used here is Al2024 alloy of theoretical density of 2.78 gm/cm^3. The chemical composition of Al2024 alloy is shown in Table 1. B_4C micro particles of average size 80 microns were used as the reinforcement particles with density of 2.52 gm/cm^3.

Table1. Chemical composition of Al2024 alloy

Elements	Wt. Percentage
Mg	0.02
Si	0.15
Cu	6.4
Zr	0.2
Fe	0.25
Mn	0.02
Ti	0.05
V	0.1
Zn	0.1
Al	Balance

2.2 Composite Fabrication

The Al2024 alloy containing 3 and 6 wt. % of B_4C particulate reinforced composites were fabricated by melt stirring method. Required amount of Al2024 alloy was charged into the graphite crucible and heated to 760^{0}C till the entire metal in the crucible was melted. The melted liquid agitated with the help of stirrer to form a fine vortex. 3gms of degassing tablet hexachloro-ethane (C_2Cl_6) [10-11] was added to the vortex to release all the absorbed gases and the slag was removed from the molten metal. The boron carbide particles were preheated to 700 ^{0}C for 1 hr before incorporation into the melt to make their surfaces oxidized. A stirrer made up of stainless steel coated with zirconium was lowered into the melt slowly to stir the molten metal at a speed of 300rpm. The speed of the stirrer can be controlled by means of a regulator provided on the furnace. The preheated B_4C particles were added into the vortex at a constant rate during the stirring. Stirring was continued for another 10 min even after completion of particle feeding [12]. Before, pouring the molten metal to mould, 2gms of cover flux was added to the molten metal to reduce the atmospheric contamination. The molten metal at a temperature of 730 ^{0}C poured into the mould which was preheated at 300 ^{0}C and allowed to solidify to obtain cast rods. The test specimens were prepared from these cast rods. The MMCs having different wt. % (0, 3, and 6%) of B_4C particulates were made by the same procedure.

2.3 Microstructural characterization and Tensile behaviour

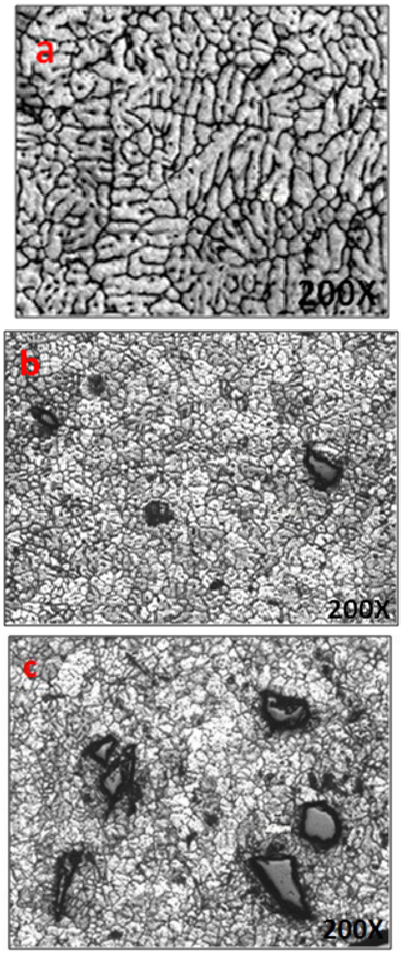
The microstructure of the cast Al2024 alloy and its composites reinforced with different wt. % of B_4C particulates were examined by using an optical microscope (Olympus made). The samples of cast and Al2024-B_4C composites for microstructural study were cut from casted rods and ground by means of abrasive papers followed by rotating disc cloth polishing. Keller's reagent was used as an etching agent.

Tensile testing of the prepared samples were conducted in accordance with the ASTM E8 standard on round tension test specimens of gauge diameter 9mm and gauge length 45mm. Figure 1 showing the tensile test specimen used in the study. Tension test was conducted by using Instron made servo-hydraulic machine, with cross head speed set at 0.280mm/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 Al2024 alloy composites.

Figure 1. Tensile test specimen

3. RESULTS AND DISCUSSION

The optical micrographs of as cast Al2024 alloy and Al2024 alloy reinforced with 3 wt. % of B_4C and 6 wt. % B_4C are shown in figure 2a, 2b and 2c respectively.



(a)

(b)

(c)

Figure 2. Optical micrographs of (a) as cast Al2024 alloy (b) Al2024-3 wt. % B_4C composite and (c) Al2024-6 wt. % B_4C composite

Optical micrographs of Al2024 alloy composites revealed the uniform distribution of B4C particulates in the matrix, and no void and discontinuities were observed. Common casting defects such as porosity and shrinkages were not found in the micrographs. There was a good interfacial bonding between the B_4C particles and Al2024 alloy matrix.

The results of the tensile tests at room temperature are shown in figures 3, 4 and 5 with the different weight % of B_4C particulates. From the figures 3 and 4 it is observed that the ultimate tensile strength (UTS) and yield strength (YS) increase with an increase in the percent weight fraction of reinforcement particles. Variation of percentage elongation is shown in figure 5. The corresponding values of UTS, YS and percentage elongation are presented in the Table 2.

Table2. Mechanical properties of Al2024 alloy matrix and composites

Sl. No.	Sample	UTS MPa	YS MPa	% Elongation
1	Al2024 Alloy	157.4	136.1	14.1
2	Al2024 Alloy + 3 wt. % B_4C	173.2	151.2	11.3
3	Al2024 Alloy + 6 wt. % B_4C	191.9	183.1	9.8

The variation of ultimate tensile strength and yield strength with varying wt.% of B_4C is shown in figure 3 and 4 respectively. The ultimate tensile strength and yield strength were increased with increasing B_4C content. The B_4C particles in the matrix alloy provide protection to the softer matrix. The addition of hard ceramic particle improves the mechanical properties mainly by stress transference from the Al2024 alloy matrix to the B_4C reinforced particles. This is because of dislocation mechanism by which a dislocation bypasses impenetrable obstacles where a dislocation bows out considerably to leave a dislocation loop around a particle [13]. This interaction between the dislocations and B_4C results in an improved strength.

In the present study, the increase in UTS and YS is mainly through an increased dislocation density arising from a thermal mismatch between the matrix and reinforcement. Metal matrix composites are characterized by a large difference in the thermal expansion coefficient of the matrix and reinforcement. Even small temperature changes generate thermal stresses in the Al2024 alloy matrix. These stresses can be partially released by dislocation generation in the vicinity of the particle matrix interface [14].

From figure 2b and c, it can be found that B_4C particle distribution significantly affected the mechanical properties of the composites. The uniform particle distribution often results in good mechanical properties like ultimate tensile strength and yield strength.

From figure 5, it can be seen that the elongation of the composites decrease as the increase of B_4C content in the Al2024 alloy matrix. Under tensile loading, the unformed B_4C particle could cause stress concentration around particles. Thus, particles aggregated at grain boundaries intensified the stress concentrations. So, the addition of B_4C particles reduced the elongation of the matrix. As the ceramic particle contents increased in the soft Al2024 alloy matrix, the stress concentrations increased. Thus, the elongation decreased with the increase of wt.% of B_4C particulates.

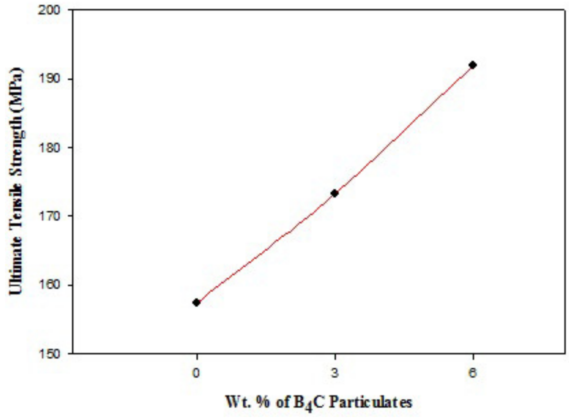


Figure 3. Variation in ultimate tensile strength with wt.% of B_4C particulates.

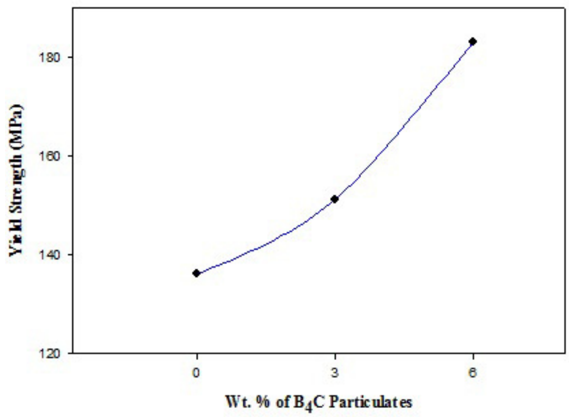


Figure 4. Variation in yield strength with wt.% of B_4C particulates.

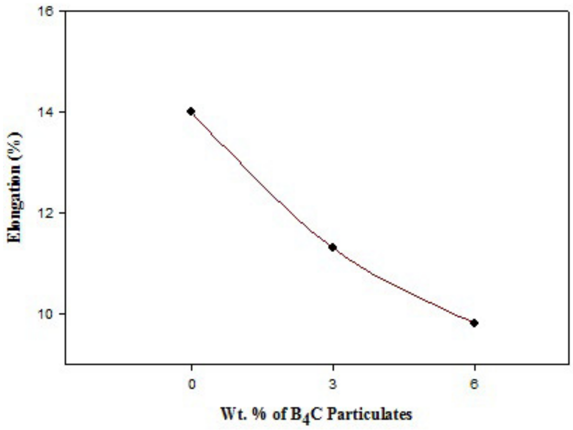


Figure 5. Variation in percentage elongation with wt.% of B_4C particulates

4. CONCLUSIONS

In this study, the microstructure and tensile behavior of B_4C particulate reinforced Al2024 alloy composites has been determined. The following conclusions are drawn:

1. Stir casting technique is successfully adopted in the preparation of Al2024-B_4C composites.

2. The micro structural study revealed the uniform distribution of the particles in the matrix system.
3. The ultimate tensile strength and yield strength increased with the increase in B_4C content. The strength improvement of composites can be attributed to the good bonding between the matrix and reinforcement material.
4. It has been noted that the percentage elongation decreased with increase in wt.% of B_4C particulates in the Al2024 alloy matrix.
5. Also, it was found that stress value is more for 3 and 6 wt. % of B_4C reinforced composites compared to as cast Al2024 alloy matrix.

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ПОНАШАЊЕ ПРИ ЗАТЕЗАЊУ Al2024 КОМПОЗИТА СА МАТРИЦОМ НА БАЗИ ЛЕГУРЕ ОЈАЧАНИХ B_4C ЧЕСТИЦАМА

М. Нагарал, Паван Р., Шилпа П. С, В. Ауради

Приказани су резултати истраживања микроструктуре и понашања при затезању Al2014 композита на бази легуре ојачаних са B_4C честицама. Композити са садржајем боркарбида су произведени конвенционалним СТИР процесом ливења. За сврхе проучавања направљени су композити са 3 и 6 тежинских % B_4C (80 микрона) честица. Микроструктура композита је испитана помоћу оптичког микроскопа, и направљене су слике да би се одредило присуство B_4C честица у композиту алуминијума. Даље, понашање при затезању је испитано код Al2024 легуре и Al2024-3 тежинских % B_4C и 6 тежинских % B_4C композита. Евалуација особина затезања као што су затезна чврстоћа, напон течења и проценат издужења је извршена према АСТМ стандардима. Испитивања микроструктуре су показала да постоји равномерна дистрибуција честица код Al2024 композита са матрицом на бази легуре. Утврђено је да се затезна чврстоћа композита повећава са количином честица боркарбида и да се напон течења повећава са порастом вредности боркарбида. Проценат издужења композита се смањује са повећањем редног броја боркарбида. Најзад, утврђено је да је на кривој напона боркарбид главни фактор побољшања затезне чврстоће композита због велике чврстоће. Сви испитани композити имају велики потенцијал примене као структурни материјали.