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Influence of B_4C on Physical and Mechanical Properties of AA6061-B_4C-Gr Metal Matrix Composite

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Abstract

This paper reports an investigation of mechanical properties of ascast metal matrix composite of aluminium alloy reinforced with 5%, 8%, 10% of Boron carbide (B_4C) and 3% of graphite particles. The result reveals that as the reinforcement content increases, mechanical properties such as UTS (ultimate tensile strength), yield strength and hardness increases predominantly whereas the physical property ie density and Ductility of the composite decreases.

Keywords: aluminium alloy, boron carbide, graphite, Metal Matrix Composite (MMCs), mechanical properties, density.

Introduction

Aeronautical and automotive industries need to have light weight, high performance structural materials which provides necessary vehement for the development and emergence of metal matrix composites (MMC) to meet the requirement in construction industries, energy production and distribution lines etc. MMCs have proven advantages over conventional alloys like high specific strength, increased stiffness, better wear resistance, improved hardness etc. where the performance requirement becomes more demanding. Infact these materials have emerged as the most priority clause of advanced materials giving opportunity to engineers to map the needs with the material properties [1]. The reinforced metal matrix composites offer potential for improvement in mechanical properties and consistency over the new generation alloys [2,3]. These particulates are broadly grouped into two categories, namely hard particles like SiC, Al_2O3, B_4C, TiC_2 etc. and soft particles like talc, graphite etc. This paper describes experimental study of mechanical properties and physical properties of the MMCs. Objective of this study is to determine the influence of reinforcements on physical properties like density and mechanical properties such as hardness, elongation, ultimate tensile strength of AA6061, AA6061-B_4C-Gr hybrid composite.

Materials and experimental procedure:

Material:

Basic metal matrix composite material chosen for the present investigation being Al-Cu-Mg alloy designated by AA6061 because it gives excellent combination of strength and damage tolerance even at high level temperatures. Chemical composition of AA6061 is given in Table 1. Particulates were B_4C of size 80-120 µm and Gr. powders of size 150-200 µm.

TABLE 1 CHEMICAL COMPOSITION OF AA6061 MATRIX

Si	Fe	Cu	Mn	Mg	Ti	Cr	Ni	Pb	Sn	Co	Al
0.64	0.14	0.26	0.30	0.90	0.025	0.002	0.001	0.002	0.002	0.006	Balance

Composite fabrication:

For the present work, AA6061 MMCs were prepared to the required quantity as per Table 2. A two stage stir casting route was adopted to fabricate the composites [4]. Samples were fabricated in the size of 50 x 50 x 200 mm and dia.15 mm x 200 mm long. Fig. 1 depicts the melting equipment used for the fabrication of composite samples. It was decided to conduct 4 tests in each combination of weight fraction. This equipment was designed for pouring in **“ *bottom pouring* “** concept to fabricate sound castings.

TABLE 2 TESTING PLAN BY WEIGHT FRACTION

Sl#	Element	Trial 1	Trial 2	Trial 3	Trial 4
1	AA6061-alloy matrix	100%	92%	89%	87%
2	Boron carbide-B_4C	NIL	5%	8%	10%
3	Graphite	NIL	3%	3%	3%

Figure 1: Bottom pouring composite fabrication equipment

Test specimens preparation:
By Electric Discharge Machining, samples were machined and were manually polished by 1200g SiC emery with the help of diamond paste of 7 microns until achieving a mirror finish. Then etched by 2% nitric acid and alcohol 98% etching solution for 10 seconds. This was done for doing microstructure analysis. For doing hardness test composite specimens were prepared by Electric Discharge Machining to a rectangular plate of 40x40x10 mm. Three readings were taken on each specimen to eliminate possibility of segregation and mean value was considered. Hardness test was performed in Brinell hardness testing equipment with 2.5 mm steel ball dia. at a load of 187.5Kgf. The loading time was 30 seconds. For doing tensile tests, test specimen was turned as per ASTM-E8-95 standard in an Universal Testing Machine of 100T capacity. Fig.2 depicts Testing of a sample in this machine.

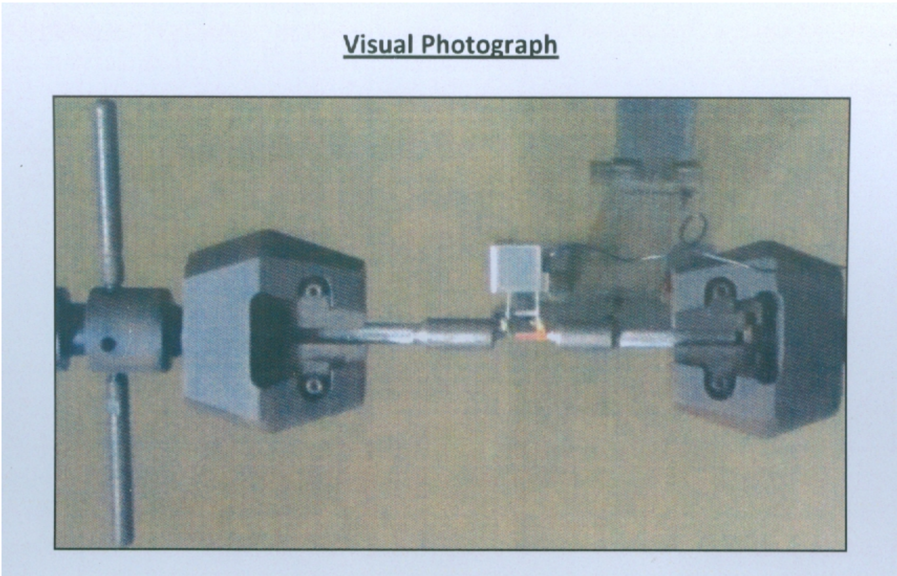

Figure 2: Universal testing machine for doing tests on mechanical properties

Results and Discussions:

Microstructure:

Microstructure analysis was carried on with the specimens of AA6061 alloy, AA6061-B_4C-Gr composite in optical microscope. Fig.3 depicts nearly uniform distribution of the particles B_4C and Gr in the AA6061-B_4C-Gr composite.

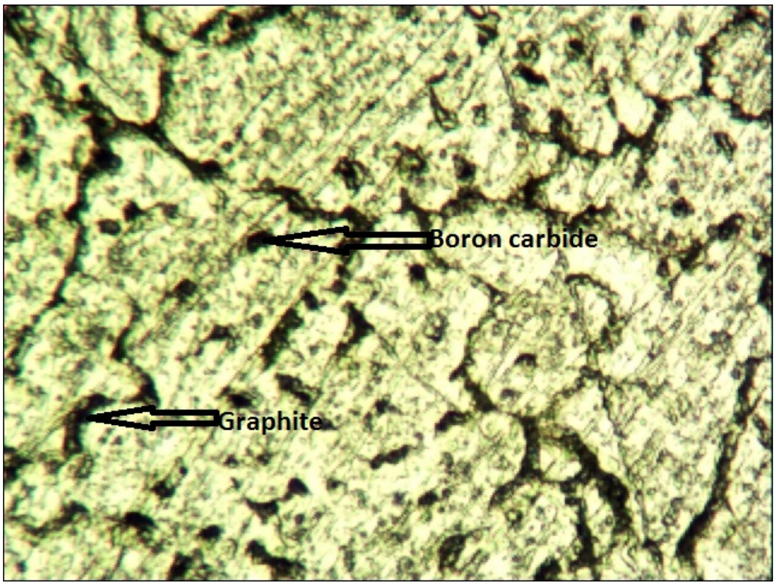

Figure 3: Microstructure of composite AA6061-B_4C-Gr

Mechanical properties

Table 3 shows the influence of B_4C and graphite reinforcements on the Ultimate Tensile Strength, yield strength, Hardness, Density and ductility. It shows that the tensile properties are increasing steadily as the wt.% of reinforcements increases in 4 different types of matrices. Whereas the ductility of composite and density decreases as the wt.% of reinforcement contents increases in the composite. These results are taken out of the experiments made as per the testing plan given in Table 2 and 3 at standard atmospheric conditions. These improvements in mechanical properties are due to the large differences in coefficient of thermal expansion between the aluminium alloy and the reinforcements. The same concept was attributed by the researcher Srivastan [5]. These experimental results are shown in Table 3 and plotted graph as shown in Figures 4a, 4b, 4c, 4d and 4e. ie Fig.4a shows increase in hardness through 70.8%, fig.4b shows increase in UTS through 48.5%, fig.4c shows decrease in density through 15.7%, fig.4d shows increase in yield strength through 59.0% and fig.4e shows decrease in elongation through 79.5%. These changes are due to fact that presence of hard particles B_4C increases hardness, increase in UTS due to the particles B_4C acting as a barrier to dislocations in the microstructure which lead to dislocation density causing a favourable contribution to the strength of AA6061-B_4C-Gr composite. Similar concept was discussed by S.Basavarajappa et al.,[6]. Decrease in density is due to the presence of soft particles of Gr. Quantitatively B_4C content increased from 0 to 10 wt% alongwith 3 wt.% of Gr shows reduction in ductility. There is also an imbrittlement effect due to the hard B_4C and Gr particles resists the passage of dislocation either by creating stress concentrations in the matrix or by including large difference in the plastic behavior between the matrix and the particulates [7].

TABLE 3 Mechanical /Physical properties of AA6061 matrix and MMC of AA6061-B_4C-Gr

% of AA6061	% of B_4C	% of Gr	Hardness (BHN)	Density (g/cc)	UTS (MPa)	Yield strength (MPa)	Ductility (% elongation)
100	Nil	Nil	48	2.68	103	83	14.6
92	5	3	60	2.49	132	101	4.6
89	8	3	75	2.33	140	115	3.9
87	10	3	82	2.26	153	132	3

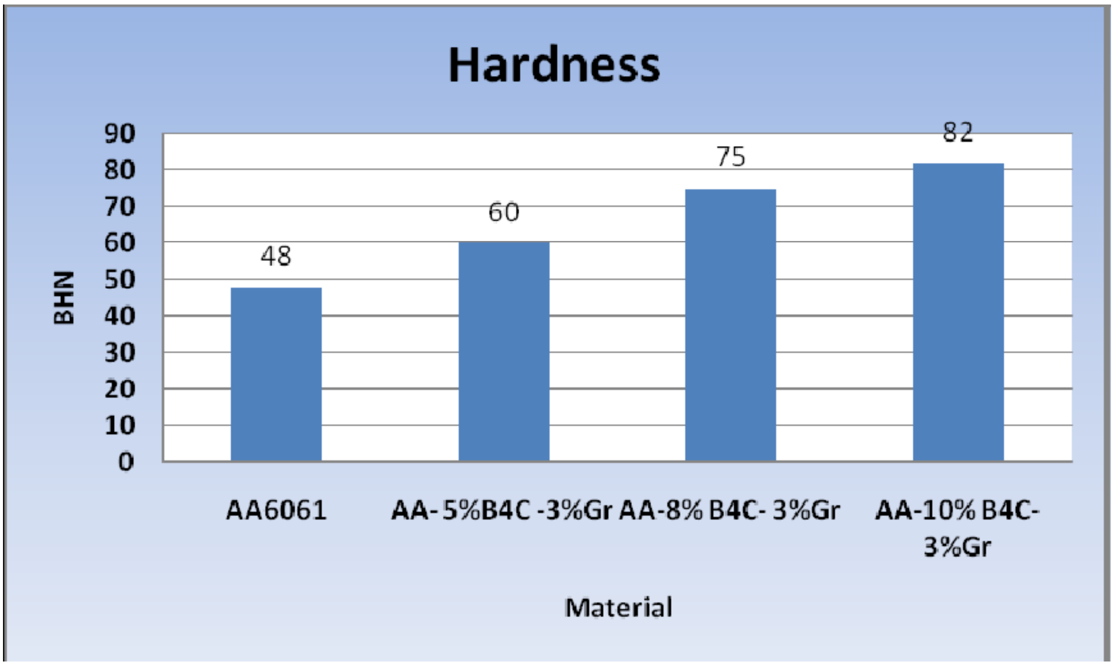

Figure 4a: Hardness improvement

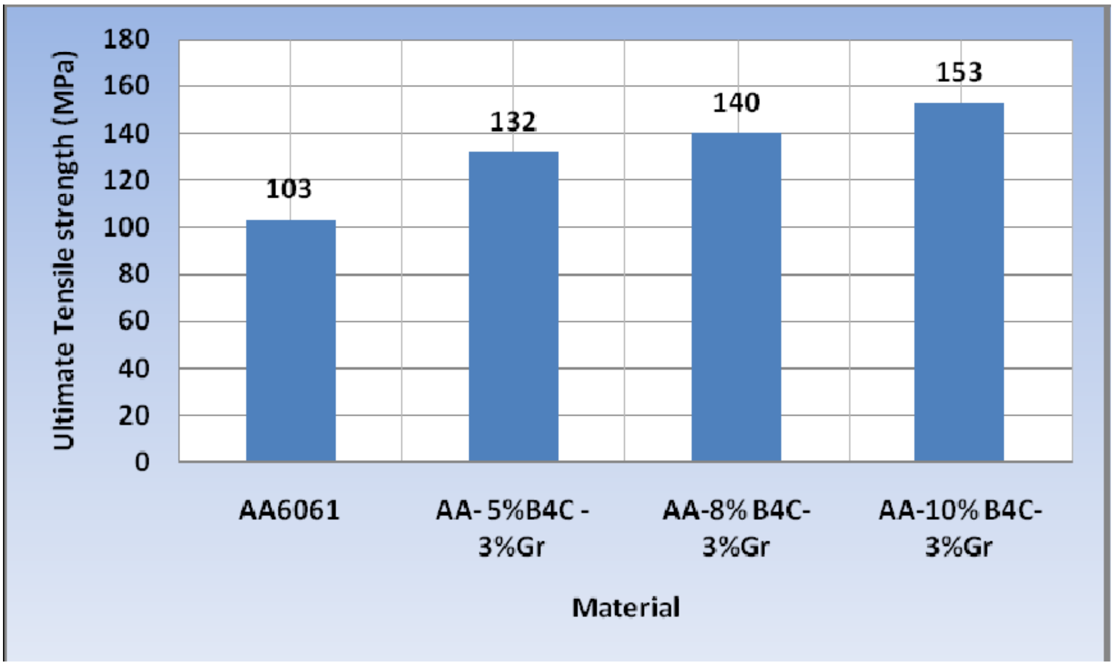

Figure 4b: UTS improvement

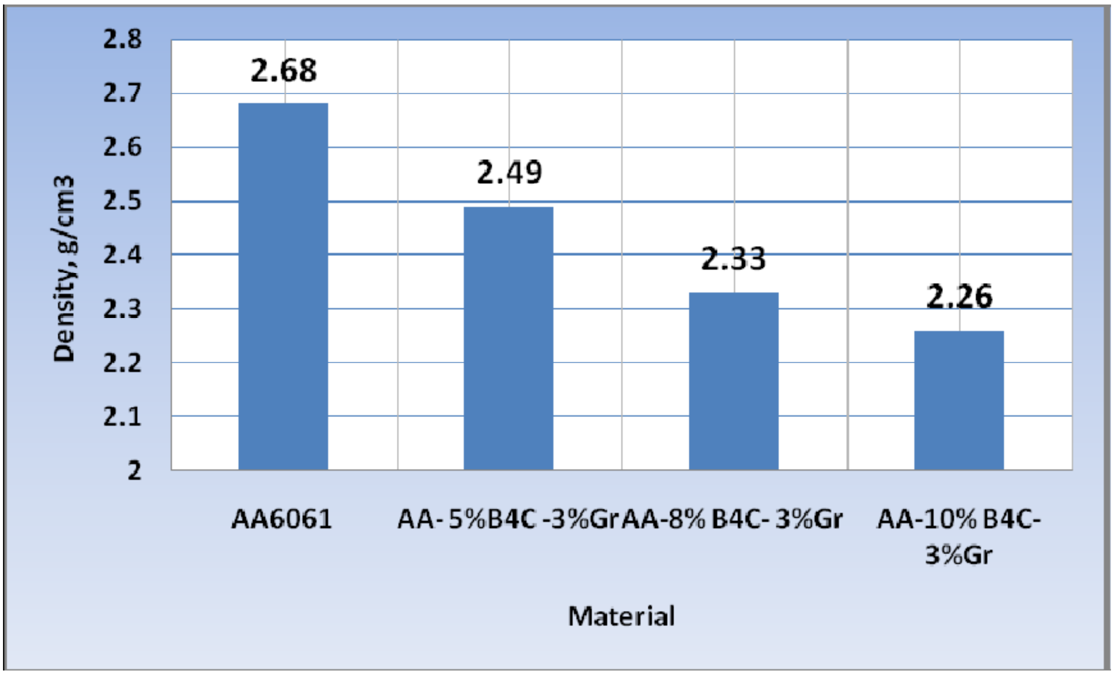

Figure 4c: Density reduction

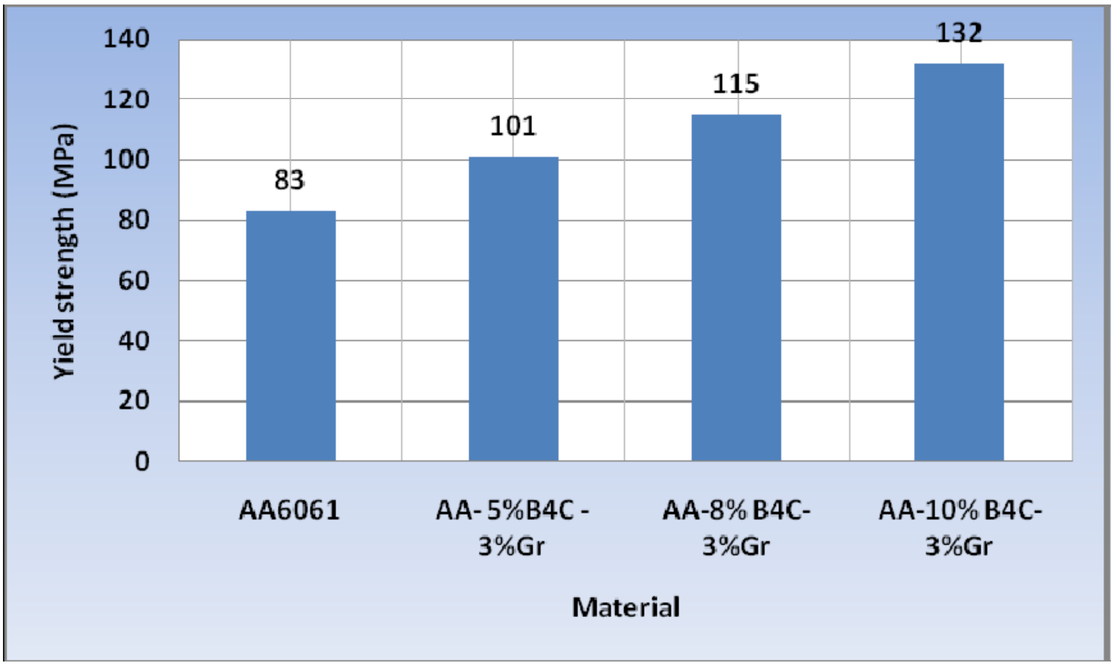

Figure 4d : Yield strength improvement

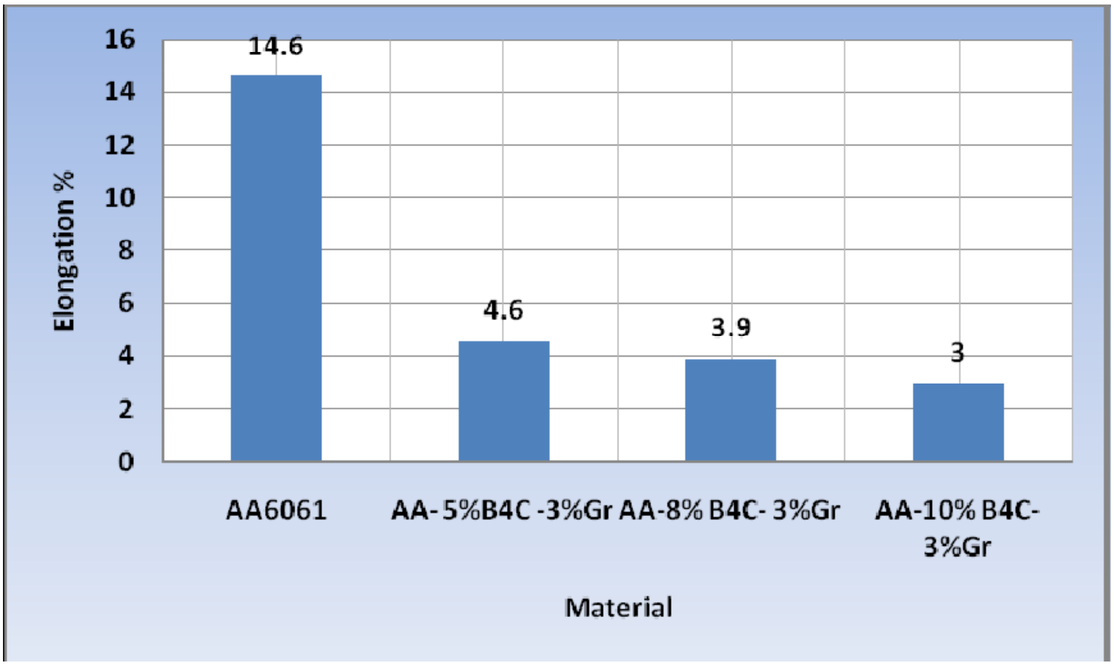

Figure 4e: Elongation reduction

Conclusions:

Outcome of these investigations made on the influence of B_4C and graphite reinforcement content mechanical and physical properties of the AA6061 aluminum alloy composite, results the following conclusions.

- It was proven successfully to fabricate metal matrix composites having relatively improving mechanical and physical properties by the inclusion of B_4C and graphite particles into the molten aluminium alloy using stir casting method.
- By the addition of B_4C and graphite particulate reinforcements and increase in their wt.% improves the mechanical properties of MMCs like UTS, hardness, and yield strength at the cost of ductility.
- Ductility (Elongation %) reduces as the reinforcement wt. % increases.
- Physical property-density reduces by the inclusions of these reinforcement which is a favorable aspect in automotive and aerospace engineering applications.

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