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Evaluation of Mechanical Properties of CNT and Boron Fibers Reinforced Al6061 Metal Matrix Composites

Thippeswamy D G[1], Shivarudraiah[2], H K Shivananda[3]
[1]*Research Scholar, Department of Mechanical Engineering, UVCE, Bangalore.*
[2, 3]*Professor, Department of Mechanical Engineering, UVCE, Bangalore.*

Abstract: Aluminium based metal matrix composites have properties such as high ductility, light weight, high strength to weight ratio and hence used in various applications. MWCNT have low density, high strength and stiffness due to which it is used as reinforcement. Boron fiber is an amorphous elemental boron product which has a combination of high strength and high elastic modulus. In this present work Al 6061 is used as metal matrix, various weight percentages of MWCNT's (0.5, 1, 1.5, 2) and Boron fibers (1, 3, 5, 7) are used as reinforcements. Stir casting method is used to fabricate the metal matrix composites. The fabricated composites were machined to prepare the test specimens according to the ASTM Standards. Tensile and compression tests was conducted on the prepared specimens in order to find their mechanical behaviour. From the results obtained and graphs plotted, it was found that weight percentage of 1.5% MWCNT specimen yielded good results for tensile and compression as compared to base material.
Keywords: Composites, Al 6061, MWCNT, Boron fiber, Stir Casting

I. INTRODUCTION

Composite material is a material system composed of a suitably arranged mixture or combination of two or more nano, micro, or macro constituents with an interface separating them that differ in form and chemical composition and are essentially insoluable in each other.

The discrete constituent is called the reinforcement and the continuous phase is called the matrix. Composites are classified as metal matrix (MMC), polymer matrix (PMC) and ceramic matrix composites (CMC). In MMC , Aluminium, Titanium and Magnesium are some of the lighter metals which are used as matrix metals. Aluminium alloys such as Al 6061 and other series are widely used as metal matrix as they are light weight and have other good physical properties. The reinforcing materials can be in different forms such as particulates, whiskers or fibers. Single and Multiwall carbon nanotubes having excellent chemical stability due to their seamless cylindrical graphite structure are an exceptional candidate for the reinforcement in aluminium matrix.

II. MATERIALS AND METHOD

A. Aluminium 6061

Al 6061 in the form of ingots is used in this study. It is best suited for mass production of light weight metal castings. It has a melting temperature of 660^0 C. The elastic modulus of Al 6061 ranges from 70 to 80 Gpa and has density of 2.7 gm/cc. It has better properties such ductility, machinability , weldability etc compared to other alloys. It forms a clear interface when mixed with other different materials.

B. Multiwall Carbon Nanotubes (MWCNT)

Multi Wall Carbon Nanotubes (MWCNT) are used as reinforcement which are one dimensional pipe wall, with carbon content greater than 98% with outer diameter of 20nm and inner diameter of 16nm .It has a length of 20µm, The bulk density is 0.10 gm/cm^3.

C. Boron Fibers

There are limited number of studies on properties of Boron fibers reinforced metal matrix composites. Boron fibers are not only strong in tension but also facilitate strong compression in composites. Boron fibers manifests a combination of high strength and elastic modulus. Boron fibers in the form of Chopped strands having diameter 12.5µm and density of 2.4g/cc is used in this study.

D. Method for preparation of Composites

Metal Matrix composites was prepared by stir casting method. In this method, Al 6061 in the form of ingots were placed in the crucible and kept in furnace. The ingots were melted at a temperature of more than 700^0 C. Predetermined weight percentage of MWCNT(0.5, 1, 1.5, 2) and weight percentage of Boron fibers (1, 3, 5, 7) were added to the melt aluminium and stirred to get the composites. After mixing of reinforcement and base metal, the crucible is taken out from the furnace and the molten metal is poured into die and allowed to solidify. After solidification, the casted composite is removed from the die and machined to prepare the specimen as per ASTM standards for various testings.

III. EXPERIMENTAL PROCEDURE

A. Tensile Test

Tensile test was carried out on Universal testing machine. The test specimens were prepared as per ASTM E8 standard as Shown in Fig 1. Tensile test specimen has gauge length of 60mm and diameter of 12mm. The test was conducted under static load condition for tensile strength.

Fig 1: Tensile Test Specimen

B. Compression Test

Compression test was carried out on Universal testing machine in accordance with ASTM E9 standard at room temperature. The specimen is as shown in Fig 2. The height of specimen is 20mm and diameter 20mm.

Fig 2: Compression Test Specimen

IV. RESULTS AND DISCUSSIONS

A. Strength Properties

The results obtained from all the specimens after testing were tabulated as in Table 1 and graphs were plotted as in Fig 3. From the plotted graph it is found that as the weight percentage of reinforcement increased the tensile strength has also increased i,e for 0.5 % of MWCNT combined with 1%, 3%, 5% and 7% of Boron fiber specimen from 117.6 to 132 N/mm^2. But for 1 % MWCNT and 1% Boron fiber specimen, there is a decrease in tensile strength to 106.6 N/mm^2 and as the Boron fiber content increased from 3% to 7% , there is an increase in tensile strength. The maximum tensile strength was 158 N/mm^2 for specimen with Al + 1.5% MWCNT +7% B content as compared to base material. For 2 % of MWCNT combined with 1%, 3%, 5% and 7% of Boron fiber specimen the tensile strength decreased from 140 to 100 N/mm^2. This increase and decrease trend may be due to distribution for fibers, bonding between the reinforcement and the matix and manufacturing process. The increase in strength can be attributed to addition of MWCNT and Boron fibers, since CNT have greater load bearing capacity in unidirectional axis and boron fibers along with the matix can withstand higher loads.

Table 1: Tensile Strength Of Specimen

Composition	Tensile Strength in N/mm^2	Composition	Tensile Strength in N/mm^2
Al	105.2	Al + 1.5% MWCNT +1% B	108
Al + 0.5% MWCNT +1% B	117.6	Al + 1.5% MWCNT +3% B	128
Al + 0.5% MWCNT +3% B	120	Al + 1.5% MWCNT +5% B	138
Al + 0.5% MWCNT +5% B	125	Al + 1.5% MWCNT +7% B	158
Al + 0.5% MWCNT +7% B	132	Al + 2 % MWCNT +1% B	140
Al + 1 % MWCNT +1% B	106.6	Al + 2 % MWCNT +3% B	143
Al + 1 % MWCNT +3% B	130	Al + 2 % MWCNT +5% B	110
Al + 1 % MWCNT +5% B	140	Al + 2 % MWCNT +7% B	100
Al + 1 % MWCNT +7% B	152		

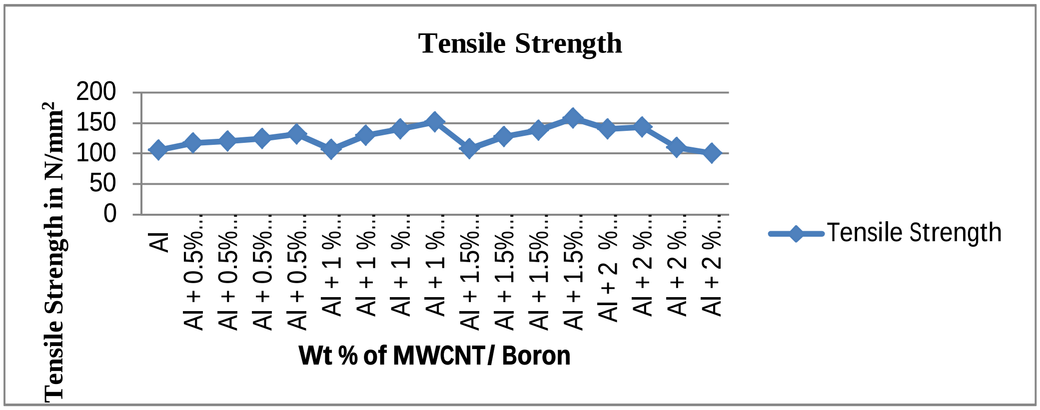

Fig 3: Tensile Strength Graph

Compression test was conducted and the results was tabulated as in Table 2 and graph was plotted as shown in Fig 4. It is seen from the graph that the compressive strength of the specimens increases as the Weight percentage of MWCNT and Boron fiber increases. This is due to the interface and effective transfer of applied load to the reinforcement which are uniformly distributed. The specimen with weight percentage of 1.5% MWCNT and 5% boron fiber had maximum compressive strength of 645 N/mm^2 as compared to base material

Table 2: Compression Strength Of Specimen

Composition	Compression Strength in N/mm^2	Composition	Compression Strength in N/mm^2
Al	580	Al + 1.5% MWCNT +1% B	585
Al + 0.5% MWCNT+1% B	583	Al + 1.5% MWCNT +3% B	610
Al + 0.5% MWCNT +3% B	593	Al + 1.5% MWCNT +5% B	645
Al + 0.5% MWCNT +5% B	605	Al + 1.5% MWCNT +7% B	633
Al + 0.5% MWCNT +7% B	614	Al + 2 % MWCNT +1% B	530
Al + 1 % MWCNT +1% B	590	Al + 2 % MWCNT +3% B	533
Al + 1 % MWCNT +3% B	610	Al + 2 % MWCNT +5% B	539
Al + 1 % MWCNT +5% B	625	Al + 2 % MWCNT +7% B	558
Al + 1 % MWCNT +7% B	635		

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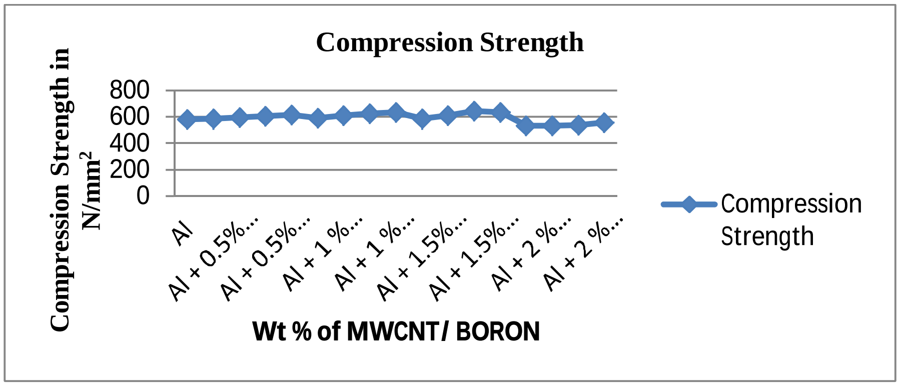

Fig 4: Compression Strength graph.

V. CONCLUSION

Al 6061 composite material containing weight percentages of 0.5, 1, 1.5, 2 % MWCNT and 1, 3, 5, 7% Boron fiber were fabricated using Stir cast method. Tensile strength of prepared composite is higher when compared to base Al 6061 composite. By addition of MWCNT and Boron fiber the compressive strength was also increased when compared to base material.

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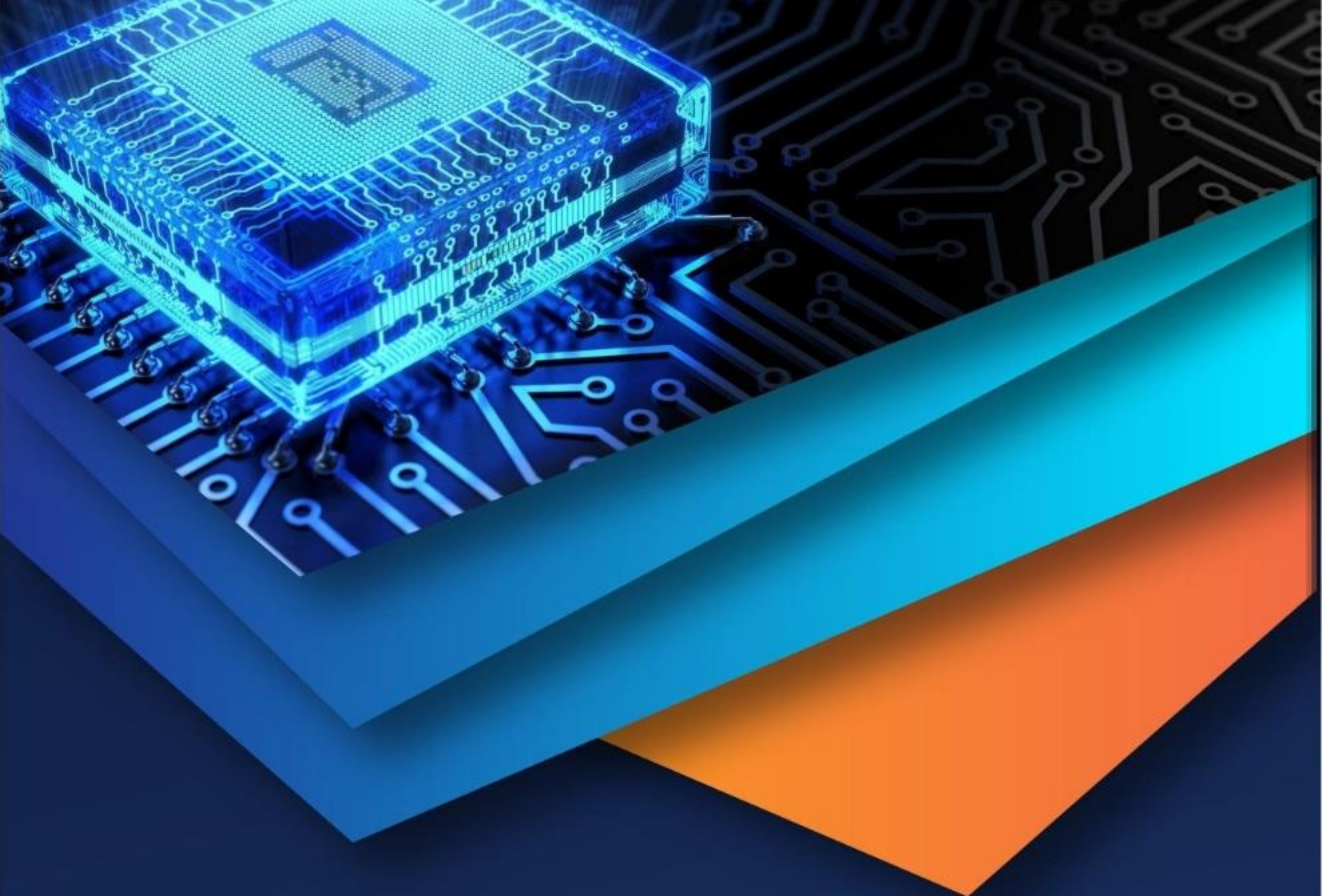

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