

# Studies on Mechanical Characteristics of Carbon Nanotubes (CNT) Reinforced with 6061 Aluminium Metal Matrix Composites Coated With Nickel

Srinivasan R<sup>1</sup>, Dr P Vijaykumar<sup>2</sup>, Dr H K Shivanand<sup>3</sup>, Rakshith K S<sup>4</sup>

Ph.D. Scholar, Department of Mechanical Engineering, UVCE, Bangalore, India<sup>1</sup>

Professor, Department of Mechanical Engineering, UVCE, Bangalore, India<sup>2</sup>

Associate Professor, Department of Mechanical Engineering, UVCE, Bangalore, India<sup>3</sup>

ME Scholar, Department of Mechanical Engineering, UVCE, Bangalore, India<sup>4</sup>

**ABSTRACT:** In today's manufacturing scenarios material with good machinability and light weight are preferred, but most of them lack good machinability or the mechanical strength desired. In this paper, we presenting the fabrication of nickel coated AL6061 composite reinforced with carbon nanotubes (CNT) using stir casting using mass and volume fraction. Sample was prepared for four composition (i.e. 0.5 wt.%, 1 wt.%, 1.5 wt.%, 2 wt.% with 40micron nickel coating on the surface using electro-less plating process ) for investigation of mechanical properties such as tensile and compressive properties along with finding the hardness of the composite materials. The strength of materials is calculated and it found to be enhanced with good machinability and light weight material is obtained.

**KEYWORDS:** Composites. AL6061, CNT, MWCNT, Nickel Plating, Casting, MMC.

## I. INTRODUCTION

Al6061 alloys as matrix and multiwalled carbon nanotube (MWCNT) as reinforcement have been fabricated using stir casting process for the above experimental analysis. AL6061 is a precipitation-hardened aluminum alloy, containing magnesium and silicon as its major alloying elements. Annealed 6061 (6061-O temper) has maximum tensile strength no more than 120 MPa (18,000 psi), and maximum yield strength no more than 55 MPa (8,000 psi). The material has elongation (stretch before ultimate failure) of 25–30%. Carbon nanotubes have exceptionally small diameter as well as their high Young's modulus (~1 Tpa), Tensile strength (~200 Gpa) and high elongation in addition to high chemical stability act as suitable reinforcement. Electro less nickel plating is an auto-catalytic reaction used to deposit a coating of nickel on a substrate. This plating technique is to prevent corrosion and wear of the composite

The main objective of this research work is to develop carbon nanotubes (CNT) reinforced with Aluminum Al 6061 Metal matrix composite system with nickel coating. The Fabrication of this MWCNTs (Multi-walled Carbon nanotubes) based Aluminum matrix composites will be done by varying the weight percentage (0.5%, 1.0%, 1.5%, 2.0%, 3% weight percentage) of carbon nano tubes reinforcement with nickel coating on the surface electro less plating process and to develop the specimen as per ASTM standard and the Experiments will be conducted to determine the various mechanical tests on the developed composites like Tensile & Compression. Interface behavior and Damage / Mode of failure of the specimen and to determine the Hardness of the developed specimen using Vicker's Hardness testing method.

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 8, August 2016

It is clear that ultimate tensile strength increases with increase in Percentage composition of constituent material with Aluminum 6061. The increase in ultimate tensile strength is due to the addition of MWCNT which gives strength to the matrix alloy there by enhanced resistance to tensile stresses, there is a reduction in the inter-spatial distance between the particles this leads to restriction to plastic flow due to the random distribution of the particulate in the matrix above 1.5% of CNT addition

## II. MATERIAL USED

Aluminium alloy 2000, 6000 and 7000 series are used for fabrication of the automotive parts. MMC's under study consist of matrix material of aluminium alloy. An advantage of using aluminium as matrix material is casting technology is well established, and most important it is light weight material. Aluminium alloy is associated with some disadvantages such as bonding is more challenging than steel, low strength than steel and price is 200% of that of steel. But with proper reinforcement and treatment the strength can be increased to required level. 6061Al is quite a popular choice as a matrix material to prepare MMC's owing to its better formability characteristic.

We use carbon nano tubes (Fig, 1) as reinforcement. CNT s are allotrope of carbon. They are composed of carbon atoms linked in hexagonal shapes, with each carbon atom covalently bonded to three other carbon atoms. They have diameters as small as 1 nm and lengths up to several centimetres. They can be bent and released to original shape.

CNTs have a Young's modulus of 1TPa, making them ideal reinforcements for composite materials. Carbon nanotubes (CNTs) have attracted much attention as an ideal reinforcement used in manufacturing of aircraft, automobiles and sports goods, due to high aspect ratio, strength, elastic modulus and low density. For the fabrication of high strength and elastic modulus, homogeneous dispersion of CNTs is necessary and the interfacial bonding between metal and CNTs should be strong enough to transfer load efficiently

## Methods

Al6061 and multiwall carbon nano tubes (20-30 nm) were properly mixed for composition using stir casting process Stirrer speed of 300rpm was used to mix the MWCNT added for casting process.

### A. Preparation of composite

The CNT powder was initially purified to remove the impurities like graphite, amorphous carbon etc. by adding concentrated Nitric acid, filtering and washing with de-ionized water followed by drying at 1200 C. In stir casting process, MWNT of 0 wt%.0.5 wt. %, 1 wt. %, 1.5 wt. %, 2 wt. % was mixed with Al6061 for 20 min at 300 rpm to get uniform mixing in the crucible. The mixture of a particular weight percentage of MWCNT and Al6061 was molded in the pattern Fig, 2, 3 and 4)



**Figure 1 CNT**



**Figure 2 Stir casting**



**Figure 3 moulding**



**Figure 4 final castings**

**B. Specimen preparation and Nickel Plating**

Using CNC lathe as cast specimen are machined to required dimensions for tensile, compression and hardness. ASTM E8: is a standard test method for tension testing of metallic materials and ASTM B557 is standard test methods of tension testing wrought and cast aluminium and magnesium alloy products.

Thus about specimen undergoes the process of nickel plating which takes in different stages which involves immersion in various alkaline bath to obtain clean surface, then they are dipped in nickel salt solution for the define amount of time as calculated based on the weight of the specimen dipped in it to obtain the uniform deposition of 40micron of nickel on the surface of the material.

The above graph 1 and table 1 represents the value of Maximum Tensile stress as a function of weight percentage of MWCNT's. The Tensile strength increases remarkably up to 1.5-2 % weight of CNT's and decreases gradually upon increase in weight percentage of MWCNT's. The increase in tensile strength up to an addition of 1.5% wt. MWCNT is due to the restriction of dislocation movement by the MWCNTs. The

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

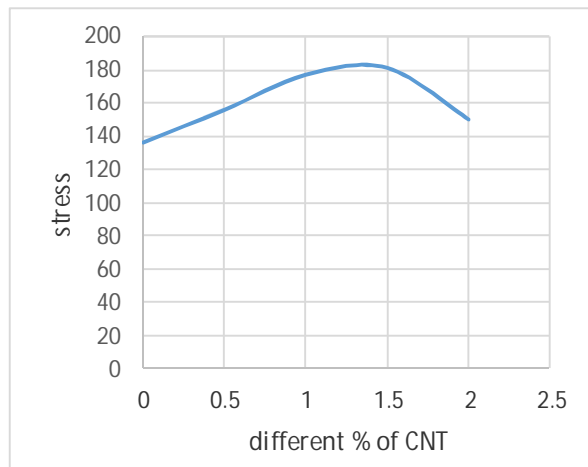
Vol. 5, Issue 8, August 2016

maximum tensile strength from the above graph is observed as 181.261Mpa against 1.5% weight of CNT.

### III. RESULTS AND DISCUSSION

Sly No	% of AL6061	% of CNT	Tensile strength (N/mm <sup>2</sup> )
1	100	0	136.276
2	99.5	0.5	155.899
3	99	1	176.975
4	98.5	1.5	181.261
5	97	2	150.130

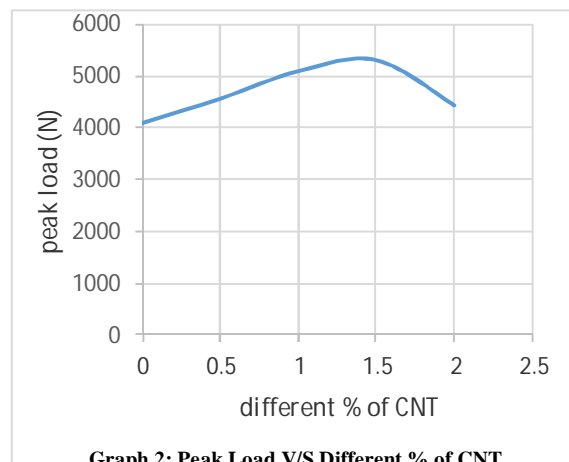
**TABLE: 1** Comparison between Tensile Strength of AL6061 with Different %CNT



**Graph 1:** Stress V/S Different % of CNT

Sly No	% of AL6061	% of CNT	Peak load(N)
1	100	0	4089.400
2	99.5	0.5	4562.800
3	99	1	5089.600
4	98.5	1.5	5305.500
5	97	2	4432.600

**TABLE: 2** Comparison between Peak Loads of AL6061 with On Different % CNT



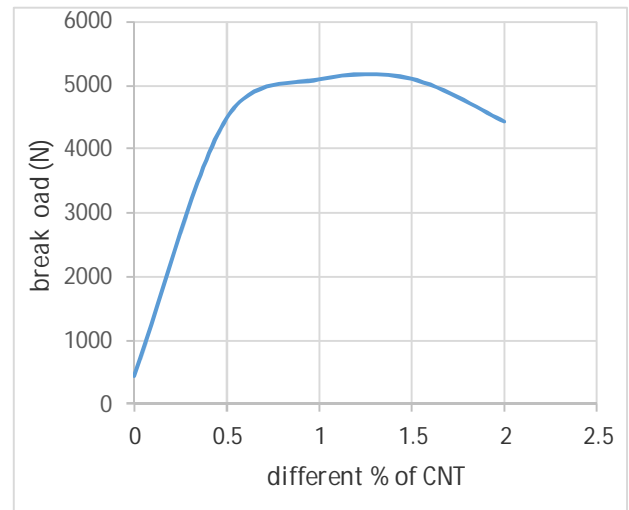
**Graph 2:** Peak Load V/S Different % of CNT

## International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 8, August 2016

Sly No	% of AL6061	% of CNT	breaking load(N)
1	100	0	441.298
2	99.5	0.5	4483.499
3	99	1	5089.631
4	98.5	1.5	5100.86
5	98	2	4432.588



Graph 3: Breaking V/S Different % of CNT

**TABLE: 3 Comparison between Break Loads of AL6061 with On Different % CNT**

The above graph 2 and table 2 represents the different values of peak load as a function of weight percentage of MWCNT's. The value of peak load or peak stress is the function of Ultimate tensile strength and it is the point where maximum elastic deformation and region of plastic deformation initiation (0-1.5%). After passing the Peak load the specimen tends to failure deforming the material further.

Sl No	% of AL6061	% of CNT	Compressive strength (N/mm <sup>2</sup> )
1	100	0	615.50
2	99.5	0.5	810.22
3	99	1	894.11
4	98.5	1.5	880.21
5	97	2	815.64

**TABLE: 4 Table showing comparison between compressive strength of Al6061 with different % CNT**

The peak load values for different weight % of CNTs shown in the graph above. The peak load is maximum indicated for the composition as 5305.5N at 1.5%. The above graph 3 and table 3 represents the value of breaking loads as a function of weight percentage of MWCNT's. The breaking load is the point of maximum load required to fracture the specimen which is the results from larger amount of plastic deformation. Their exhibit the nature of necking phenomenon and results in

## International Journal of Innovative Research in Science, Engineering and Technology

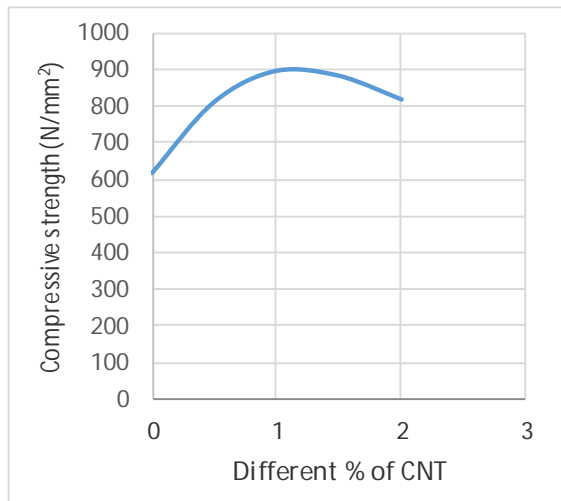
(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 8, August 2016

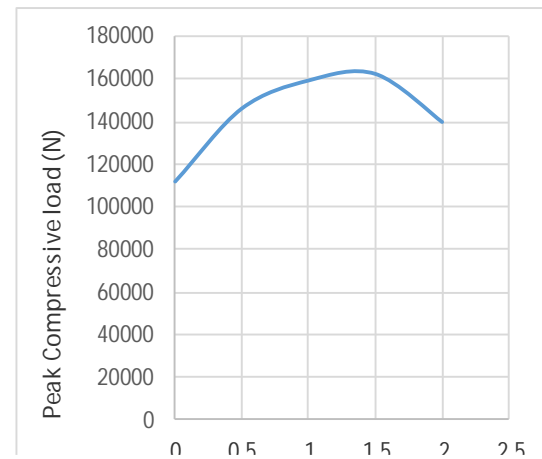
the reduction of cross sectional area of the specimen. From the above graph, the Breaking load for the specimen is minimum at 2% weight of CNT and maximum between 1.5-2% CNT. The lower weight % of CNT determines the larger breaking load of the material

The Compression test were carried out on different composition of 6061 AL with CNT's on UTS and the compressive strength results are validated under different

loading conditions of samples test



**Graph 4: Compressive Strength V/S Different % of CNT**



**Graph 5: Peak Compressive Load V/S Different % of CNT**

The graph 4 and table 4 show the relationship between compressive strength and different

Sl No	% of AL6061	% of CNT	Peak Compressive load (N)
1	100	0	111540.00
2	99.5	0.5	146026.80
3	99	1	159480.00
4	98.5	1.5	162261.00
5	97	2	139560.00

**TABLE: 5 Comparison between Peaks Compressive Loads of Al6061 with On Different % CNT.**

weight % MWCNT's reinforced 6061AL. The compressive strength values remarkably increases with the decrease weight% of MWCNT's and gradually decreases the strength with the increased weight percentage of reinforcements. Maximum compressive strength is found to be 894.11 at 1% of reinforcements (MWCNT) and Minimum compressive strength is 615.50 at 0% weight of reinforcement.

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 8, August 2016

The above graph 5 and table 5 represents the relationship between Peak compressive loads as a function of different weight percentage of CNT composition. The peak compressive load is the value of ultimate load required to determine the initial failure mode of the specimen and further causes the material to deform elastically which is the function of compressive strength. From the above graph. The strength is proportional to the elastic strain rate of the sample which is the function of compressive stiffness.

The Ultimate compressive load is found to be 162261.00 N against the weight % of composition having 98.5% 6061 aluminium with 1.5% of MWCNT. The Minimum peak compressive load tends to impose the failure is 111540.00 at 0% CNT's.

The compressive load for the indication of compressive stress increases significantly with the decrease in weight percentage and decreases invariably with increase in weight percentage of MWCNT.

## IV. CONCLUSION

Al6061 alloy as matrix mixed with MWCNT in weight percentages of 0.5% wt., 1% wt., 1.5% wt., and 2% wt. as reinforcement were produced through Stir casting route. The specimens were moulded successfully with nickel surface coating of uniform thickness of 40 microns and subjected to evaluate the behaviour of mechanical properties of MMC's. From the investigation, following points are arrived.

- Al6061-MWCNT composite showed ductile property where as Al6061 were brittle.
- Young's Modulus increases remarkably with the increase in Reinforced particulate MWCNT and the higher value is observed at 1.5% wt.

Tensile strength as well as compressive strength increases with the addition of MWCNT but hardness decreases with the addition of MWCNT, is it the direct result of nickel coating as it impart more toughness rather higher yield value.

## REFERENCES

1. R. Pérez-Bustamante, I. Estrada-Guel, W. Antúnez-Flores, M. Miki-Yoshida, P.J. Ferreira, R. Martínez-Sánchez, "Novel Al matrix nanocomposite reinforced with multiwall carbon nanotubes, Journal of Alloys and compounds 450 (2008) 323–326,
2. Deng et al. Preparation and characterization of carbon nanotubes/aluminium matrix Composites Materials Letters 61(2007) pp.1725- 1728.
3. Yufeng Wu et.al. Carbon nanotube reinforced aluminum composite fabricated by semi-solid powder processing| Journal of Materials Processing Technology 211 (2011) 1341–1347.
4. A.M.K. Esawi et.al, "Fabrication and properties of dispersed carbon nanotube–aluminium Composites" Materials Science and Engineering a 508 (2009) pp.167–173.
5. Sridhar Æ Karthic R. Narayanan —Processing and characterization of MWCNT reinforced aluminum matrix composites Mater Sci (2009) 44:1750–1756.
6. Jinzhi Liao et.al, "Mixing of carbon nanotubes (CNTs) and aluminum powder for powder Metallurgy use| Powder Technology" 208 (2011) 42–48.
7. Torralba et al, P/M aluminum matrix composite: an overview, Journal of Materials Processing Technology 133 (2003) 203–206."
8. Aniruddha V. Muley,\*, S. Aravindan, and I.P. Singh, " Nano and hybrid aluminum based metal matrix composites: an overview "Manufacturing Rev. 2015, 2, 15 \_ A.V. Muley et al., Published by EDP Sciences, 2015
9. Hansang Kwon, Mehdi Estili, Kenta Takagi, Takamichi Miyazaki, Akira Kawasaki, "Discussion on the mechanical behaviour of carbon nanotube/C60 composite based on observation of interfacial structure" Materials Transactions, JIM, Vol39, No 5(1998)pp.578-581.
10. M.M.J Treacy, T.W.Ebbesen & J.M.Gibson "exceptionally high young's modulus observed for Individual carbon nanotubes" Nature, Vol381 (1996) pp.678- 680.
11. C. S. Goh, J. Wei, L. C. Lee and M. Gupta: Nanotechnology, 2006, 17, 7–12.
12. G. Cao, H. Konishi, X. Li, Recent developments on ultrasonic cavitation based solidification processing of bulk magnesium nanocomposites, International Journal of Metal casting, American Foundry Society 2 (2008) 57–68.
13. JinzhiLio, Ming-Jen Tan, (2011), "Mixing of carbon nanotubes (CNTs) and aluminum powder for powder metallurgy use, Powder Technology 208, (2011), PP42-48
14. JinzhiLio, Ming-Jen Tan, (2011), "Mixing of carbon nanotubes (CNTs) and aluminum powder for powder metallurgy use, Powder Technology 208, (2011), PP42-48