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Article

Experimental Approach for the Studies on Carbon Nano-tubes with Reinforced Aluminium-based Metal Matrix Composites - Part I (Ball Milling Process with Coating Process)

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I N F O

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A B S T R A C T

In this paper, some of the experimental approaches for the studies on carbon nano-tubes with reinforced aluminum based metal matrix composites - Part I is being presented. Experiments are being conducted and the results are obtained w.r.t. some of the material properties. The results show the efficiency of the methodology that is being presented by us in the form of experimental results. Here, we have presented the corrosion part of the experimental results.

Keywords: Composites, Corrosion, Mechanical, Test, Experiment

Introduction

The lightweight qualities of composite materials are the key motivator and advantage in their adoptions. Non corrosiveness, non conductiveness, flexiblity, no denting property, cheap maintenance, longer life and design freedom are some of the most essential advantages of composite mats. CNT Metal Matrix Composites (CNT MMCs) are a novel class of materials being researched to take use of carbon nanotube materials' good tensile strengths and electrical conductivities. Because of their low density and outstanding workability, aluminium alloys have a wide spectrum of uses in industry, although their yield strength is modest.[1]

- Can be produced economically
- Ensure a uniform distribution of nanotubes in the metallic matrices
- Result in significant inter-facial adhesions between the metallic matrices & the CNTs

Thin fibers can have very high strength and overall properties can be improved. Carbon nanotubes have a number of valuable and unique properties including high stiffness, high strength and which could be compared in a tenacity manner with the other fibre materials as it lacks few of these mentioned properties.[2]

In comparison to other conductive materials, thermal property & the electrical conductivity property is also relatively very high. Because carbon nanotubes are used to strengthen aluminium, the resulting composite can have a higher strength-to-weight ratio if they are mechanically well connected to the main substrates. Carbon nano tube reinforcing can considerably improve the composites' overall characteristics.[3]

Aluminum 6061 Alloy

Aluminium alloys 6061 is a particle mixed aluminium alloy with the main alloying components magnesium & the silicon.[4]

Properties of Aluminum 6061 Alloy

The pproperties of the aluminium alloy are:[5]

- Medium to high strength
- Good toughness
- Good surface finish
- Excellent corrosion resistance to atmospheric conditions
- Good corrosion resistance to sea water
- Can be anodized
- Good weldability and brazability
- Good workability
- Widely available

Physical Properties of Aluminum 6061 Alloy

- **Density:** 2.7 gm/cm^3
- **Modulus of Elasticity:** 70 GPa
- **Poisson's Ratio:** 0.33

Carbon Nanotubes

The CNT will be a tubic type material, which is made up of C material & has a dia which measures upto the nm scale level as it were discovered in 1991, the soot of arc discharge at NEC, by Japanese. The types of CNT are the single walled nano tubes & the multi walled nano tubes. A typical nanotube is shown in the Figure 1.[6]

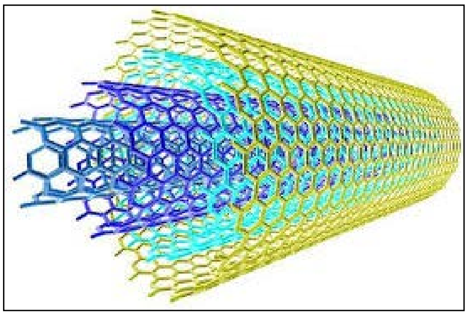

Figure 1.A Typical Nanotube

Properties of CNTs

- CNTs have High Electrical Conductivity
- CNTs have Very High Tensile Strength
- CNTs are Highly Flexible- can be bent considerably without damage
- CNTs are Very Elastic ~18% elongation to failure
- CNTs have High Thermal Conductivity
- CNTs have a Low Thermal Expansion Coefficient

Important benefits of Aluminium Composites

- Weight savings
- Non-corrosive
- Non-conductive
- Flexible
- Will not dent
- Low maintenance
- Long life and
- Design flexibility

Applications

- Automotive Industry- Gears, Break disc
- Aerospace Industry-most advanced type of CNTs which are very very attractive and could be used for a host of airspace structural materials, aircraft components, space systems and high-end or sports equipment, high-temperature shafting for the Comanche helicopter
- Ship building industry - Navy
- Military - Army & Airforce
- Powder metallurgy technique and can give a distinct application. The lightweight qualities of composites, as opposed to typical materials like metal and wood composites, are the key motivator and distinguishing advantage in their acceptance
- The applications of the CNTs in different fields are shown in the Figure 2

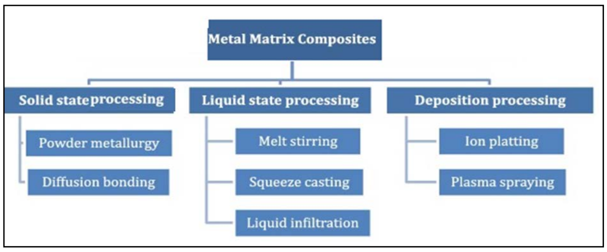

Figure 2.Applications of the CNTs

Literature Survey

Lot of researchers have worked on the topic of research that is being selected. To name a few of them are presented here. Lot of research work has been carried out in metal matrix composites through ingot metallurgy route using common reinforcement materials like SiC, Al_2O_3, TiO_2, TiB_2 etc. very less work on CNT reinforced Al MMC through powder metallurgy route. CNTs have a number of valuable and unique properties including stiffness, high strength and tenacity compared to other fibre materials which usually lack one or more of these properties. Due to the reinforcement of CNTs in Al can have high strength and greatly improve the composites overall properties. In ingot metallurgy route the suspended CNTs gets damaged and there is a tendency of formation of chemical products at the CNT/metal interface. The CNTs also form clusters. The use of powder metallurgy route overcomes these problems and the CNTs can be homogeneously dispersed and also reduces the cost of manufacturing.[7]

Qunqing Li et al., Nickel coating of CNT; Electroless plating process; The nickel tended to form as particles on the surface of carbon nanotubes and on the net of carbon nanotubes; By Electroless platting process CNTS can be coated properly.

D Jeyasimman et al., Ball milling process; Al-MWCNT; Ball milling process successfully prepared by high-energy ball milling; Samples were prepared and tested and got good results on mechanical properties.

ZY liu et al., Ball milling process Al-MWCNT, Ball milling process, Homogenous dispersion of CNTS in Al-MMC extended ball milling time(8-12 h) caused serious damage to the CNTs

Min-Feng yu et al., Strength and breaking mechanism of multiwalled CNT under tensile load; Multi Walled CNT; In-situ MWCNT tensile testing; Tensile strength of individual multi walled CNT has increased; Individual MWCNT stress-strain characteristic curves reveals that the outermost layer's E called as the Young's Modulus ranged from 270 to 950 GPA.

Shadakshari R et al., CNT reinforced with aluminium Matrix; CNT-Al; Powder Metallurgy(high energy ball mill, low energy ballmill, polyester binder-assisted); CNTs displayed great notch sensitivity & consistently shattered outside the gauge length, as depicted by the dispersion findings from various mixing techniques.

It was possible to achieve a proper mechanical connection b/w Al particles and Nickel in a P type CNT composite coating and also coating has increased the average size of the Al particles.

Objective of the Research Article

The main objective of the study is to realize carbon nanotube reinforced aluminum composite with relatively higher strength to weight ratio as compared to commercially available aluminum composite. As such the objectives include:[8]

- Advance coating for CNTs to prevent oxidation and undesirable products at the interface of matrix and reinforcement
- Synthesis of CNT aluminum composite
- Parametric experimental studies
- Characterization of synthesized composite in terms of mechanical properties
- Correlation of the effect of CNT on the mechanical properties of the synthesized composite

Coating of CNT

Figure 3.Coating Process-1

Figure 4.Coating Process-2

Process

Electroless plating method is used for coating the electroless plating, which is a two step process:[11]

- Sensitization, (0.1M $SnCl_2$/0.1M HCl) 30 minutes[9]
- Activation, (0.0014M $PdCl_2$/0.25M HCl) 30 minutes

After that, the activated C tubes was immersed in an electroless plating bath tub. The Table 1, shows the plating solution's composition as well as the chemical modification processes.[10]

Table 1.Specifications

S. No.	Chemical	Concentration
1	$NiCl_{2,}$ $6H_2O$	59.4 g/L
2	$NiSO_{4,}$ $6H_2O$	23.65 g/L
3	$Na_2HC_6H_5O_7$ $1.5H_2O$	12.74g/L
4	NaH_2 $PO_2 2H_2O$	104.16 g/L
5	NH_4Cl	100 g/L
6	$Pb(NO_3)_2$	2.848 g/L
7	pH at 25^{0}C(adjusted by NH_4OH)	8.75 pH
8	Bath temperature	25^{0}C

The entire process was carried out at a temperature of 25°C. After each stage, the carbon nanotubes were cleaned using distilled water and then roasted in an oven at 150°C to eliminate any moisture from the coated CNT's. Ball milling, compaction, sintering operations were performed on the dried CNTs. Figure 5, gives the process of powdered metallurgy that is being carried out in the laboratory of the college.[12]

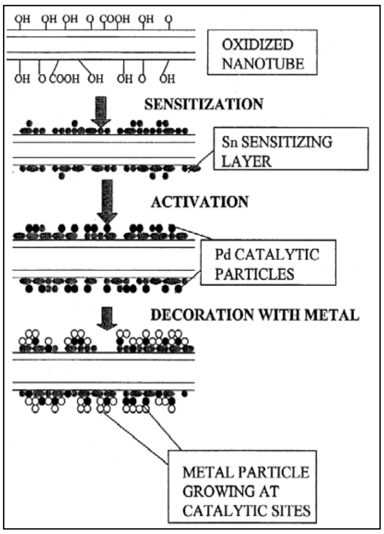

Figure 5.Process of Powdered Metallurgy Carried Out

Ball Milling

The mixing and blending is done in a four jar planetary ball milling. Before being put into the milling jar, the Al type CNT powders were stirred together. Stearic acid (1-wt%) was added to the reaction mixture to prevent severe cold type of rollings. The ball to the powder weight ratio was taken as 5:1 with a 150 RPM revolutional speed. The ball milling process took approx four hrs. The Figure 6, gives the ball milling mechanism approach, whereas the Figure 7, gives the ball mill jar with stainless steel balls. The Figure 8, gives the planetary ball milling process, whereas the Figure 9, gives an idea of how the compaction process is carried out in the laboratory.[13]

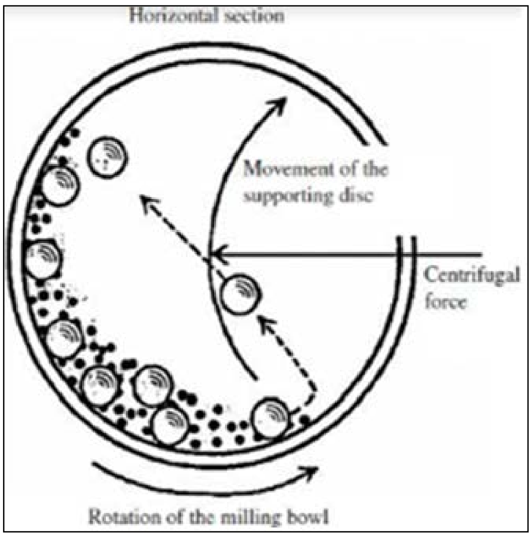

Figure 6.Ball Milling Mechanism

Figure 7.Ball Mill Jar with Stainless Steel Balls

Figure 8.Planetary Ball Milling

The XRD patterns of purchased Aluminium 6061 as shown in figure is matched with the standard Patterns of the Al-6061 material and also by wet method Chemical composition of the Procured Aluminium6061 powder is evaluated and it is matched with Standard table.[14]

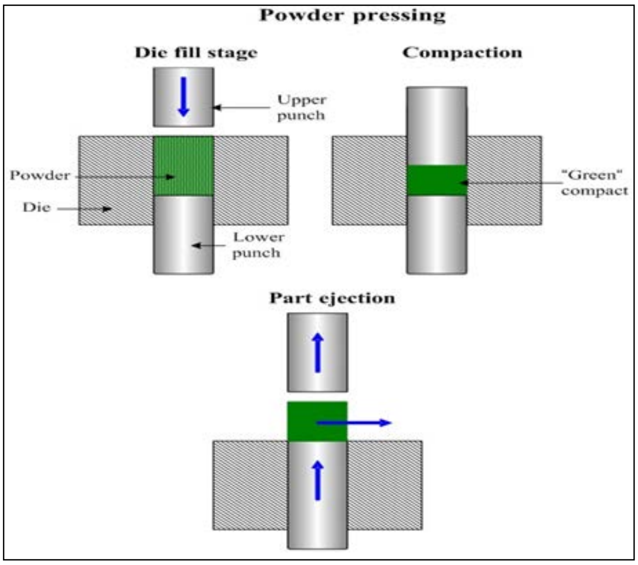

Figure 9.Compaction Process

Compaction

The Al type of CNT mixed powder is poured b/w the bottom punches and the upper punches in a die at this stage, with the bottom punch acting as a supporter during compacting process, as an extractor at the conclusion part of the material.[17] The powders are compressed by the upper punch & the die cavity.[16] Blended powders are pressed in dies under high pressure to form them into the required shape.[15] By trial and error, the optimum pressure to apply on the punch for successful compaction was discovered to be 50 KN. Samarth Computerized Universal Testing Machine[18] was used to complete the process. A green compact, or simply a green, is the work portion that has been compacted but has not yet been entirely completed.[19] The Figures 10-13, gives the quantitative & the qualitative results of the experimentation that is being carried out.[20]

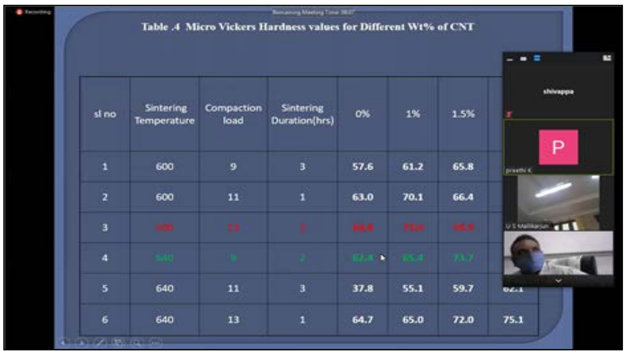

Figure 10.Quantitative Results -1

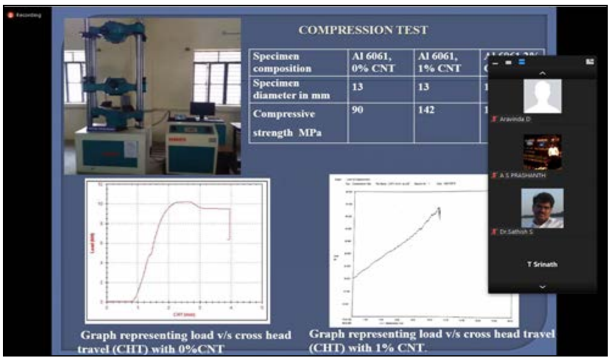

Figure 11.Quantitative Results -2

Figure 12.Quantitative Results -3

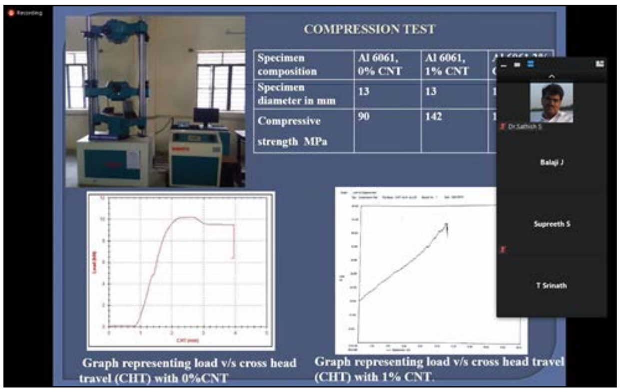

Figure 13.Quantitative Results-4

Conclusion

In this research article some of the experimentation that had been carried out in the field of composite materials w.r.t. the ball milling process of compaction has been presented in a nutshell. From the above Figures, we can conclude that The effect of temperature on micro Vickers hardness value results for 600 and 640°C from the graphs for 9 to 3 hrs showing highest hardness value and also linear increase in the hardness value for varying CNT%. The Effect of Load on micro-Vickers hardness value results for 9 and 13 ton load we got good results for all the samples but only 1.5% CNT samples the hardness value has got decreased. The effect of time on micro Vickers hardness value results comparatively got good hardness value as the curing time increases for 2 and 3 Hrs curing we got better hardness values. So, we can conclude from the experiment conducted that 600degree 9 ton 3 hrs curing we got highest hardness value. The aluminium powdered grain sizes was reduced by the ball milling method, allowing for uniform dispersion of CNT without agglomerations. Micro-structure analysis reveals good matrix-reinforcement bonding and grain boundaries that are easily discernible.

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