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Study on Properties of Multi Walled Carbon Nanotube Reinforced Aluminum Matrix Composite through Casting Technique

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***Abstract*—Multi walled Carbon Nanotube (MWCNT)/aluminum composites were fabricated by stir casting process. Commercial purity aluminum is used as matrix and multi walled carbon Nanotubes as reinforcements with 0.5, 1, 1.5& 2 weight percentage. Scanning electron microscope (SEM) method is used to analyze the dispersion of reinforcement in the matrix. The mechanical properties of the composite were tested. The effects of relative density, the hardness, strength were investigated. 80% of hardness is increased by smaller addition of MWCNT. The strength, hardness and elastic modulus of the composite were improved.**

Keywords— Stir casting, composites, Multi walled Carbon Nanotube, hardness, strength.

I. INTRODUCTION

Carbon Nanotubes were first invented by Ijima[1]. Since then carbon Nanotubes has been very much interest and significant research in the field of carbon fiber materials and their composites. Carbon Nanotubes were emerged as ideal nano reinforcements for composites due to their one dimensional carbon structures with its superior mechanical properties[2-3]. Aluminum metal matrix composites has high ratio of strength to weight ratio of rigidity to weight in comparison with any other metal matrix composite. Additionally, the composite has many other excellent properties, such as damping, high temperature creep deformation resistance, size stability and easy hot working. It is an ideal material used in aviation, military engineering, automobile and other industrial fields. Studies on employing carbon nanotube into reinforcing aluminum metal matrix composite through stir casting are not reported.

Under temperature lower than 700^0 C, CNTs takes no changes in air and has better thermal stability than carbon fiber. The Young's modulus of CNTs is 1.8 TPa, tensile strength about 100 times that of steel, and more than 20 times that of high strength carbon fiber. It is also possess low expansion rate and density of about 1.35gm/cc. for all above reasons, CNTs are the ideal material to use as reinforcement in aluminum matrix composite[4-7]. Powder metallurgy technique has evolved into the most widely used technology for fabrication of CNT / Al composites[8]. Stir casting technique method[9] is used and seen that the reinforcement effect in the magnesium matrix is fairly effective and mechanical properties improved greatly. The aim of this paper is to come up with study on properties of MWCNTs reinforcing Aluminum by stir casting technique and to study effects of CNTs on mechanical property and microstructure of the composite.

II. EXPERIMENTAL METHOD

A. Material for experiment

Aluminum commercial purity ingot and Multi walled carbon nanotubes (MWCNTs) are used in the study. Multi walled carbon nanotubes, are an one dimensional multi pipe wall provided by Nnaoshell, Haryana India, with Carbon > 95% (trace metal basis), outer diameter of 10-30nm, inner diameter of 2-6nm and length is of 15-30µm. Melting point is $3652\text{-}3697^0$C and the density is 1~2gm/cc. The properties of commercial purity aluminum ingot 99.99% Aluminum balance, 2.70gm/cc density, with a melting temperature of 660.32^0C is been used for the experiments.

B. Purification of MWCNTs

Multi walled carbon nanotubes (MWCNTs) were initially dispersed in a solvent (Ethanol) and sonicated for 20 min and decanted to obtain pure MWCNTs.

By using ultra soncation equipment the nanotubes will be dispersed for 20 min, then dried completely by heating to its melting temperature[10]. The dried MWCNTs can be used as reinforcement. It is done to remove the impurities present in the MWCNTs. This process id done for all the reinforcement weight percentages.

C. Preparation of composites

Aluminum ingot was melted in the furnace, then carbon nanotubes is added into melts and mixed with the help of stirring bar. MWCNTs of 0.5 wt%, 1 wt%, 1.5 wt% and 2 wt% of carbon nanotubes weight percentages was added into melt aluminum to get the composites. The Aluminum / multi walled carbon nanotubes is poured into die and solidified. Fig.1 shows the Aluminum / MWCNTs reinforced samples produced by casting method.

(a)

(b)

Fig.1: The composite samples a) 0 wt % & b) 1 wt %

D. Performance test of composites

The distribution of MWCNTs in Aluminum matrix was characterized by Scanning electron microscope (SEM). Brinell hardness tester was used to evaluate the hardness of the samples with various volume percentages.

E. Strength

Tensile test was carried out on a universal testing machine. The test samples were prepared as per the ASTM 8 standard. Tensile test specimen gauge length of 40mm, diameter is 13mm and reduced diameter of the diameter is 8mm. Under static loading conditions the test was conducted for yield strength & tensile strength.

III. RESULTS AND DISCUSSIONS

A. Microstructure

The multi walled carbon nanotubes were examined firstly by scanning electron microscope (SEM) and by XRD. Fig.2 shows the SEM images and clearly indicates that the particles are of carbon [5] and Fig. 3 shows the XRD patterns of multi walled carbon nanotubes the image reveals that the peak points are of carbon. Fig. 4 shows the pure aluminum Scanning electron microscope images. The Casted composite samples were analyzed through SEM, and the reinforcement distribution over the matrix is uniform which can be seen in fig. 5 The effect of MWCNTs on

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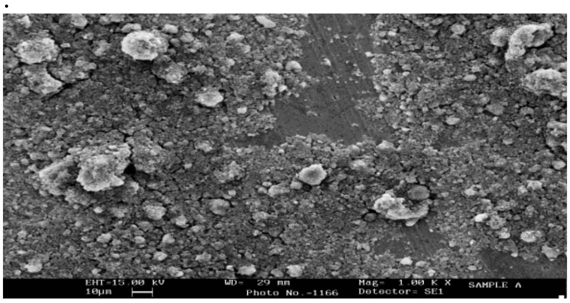
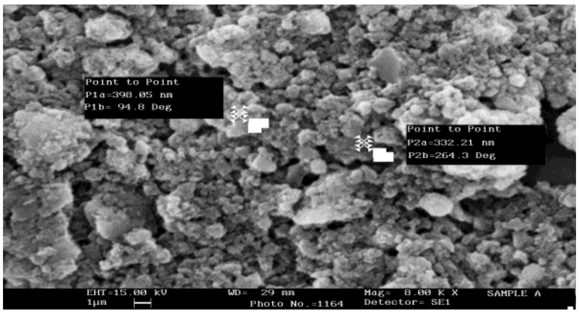


(a)



(b)

Fig. 2. SEM images of MWCNT

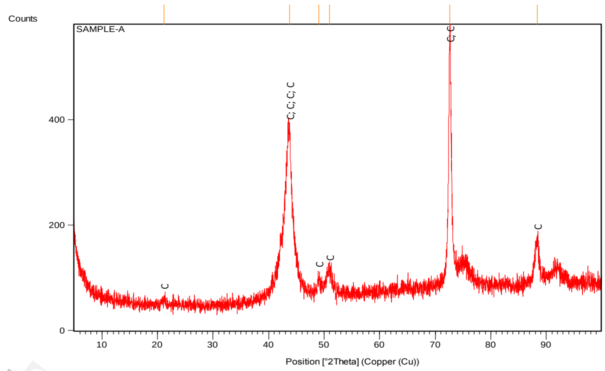


Fig.3: XRD images of MWCNTS

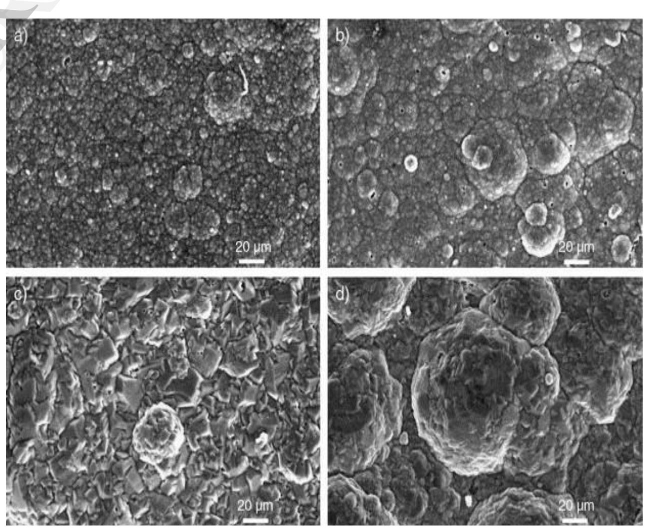


Fig. 4: SEM images of Commercial purity Aluminum ingot

microstructure of composite, the crystal grains of composite with 0.5% and 1.5% MWCNTs content is more coarse than those with 2% MWCNTs content. On the other hand, a large number of MWCNTs exist in melt can temper the growth of crystal and result in fine crystal.

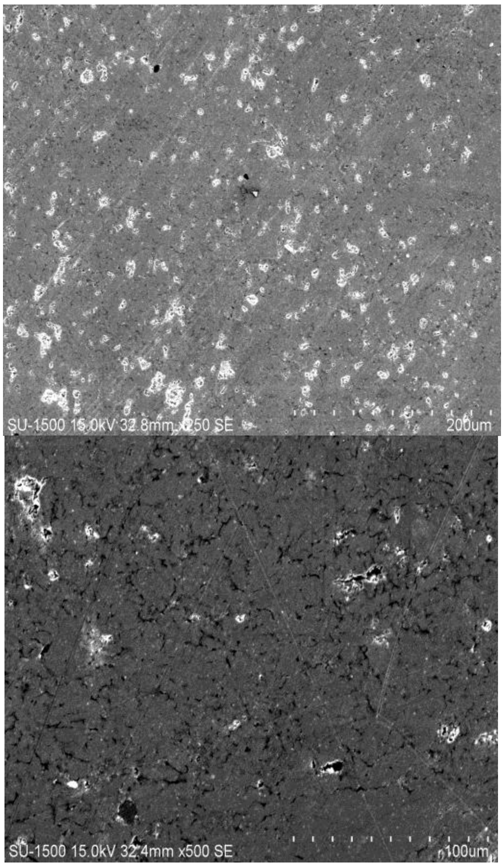


Fig. 5: SEM images of Al/MWCNT Composite with 1Wt %

B. Hardness

Table 1: Hardness of Al/MWCNT samples

Wt % of MWCNTs	Hardness (BHN)
Aluminum + 0 Wt % of MWCNT	38
Aluminum + 0.5 Wt % of MWCNT	55
Aluminum + 1 Wt % of MWCNT	59
Aluminum + 1.5 Wt % of MWCNT	66
Aluminum + 2 Wt % of MWCNT	69

Hardness of the multiwalled carbon nanotube reinforced commercial purity aluminum composited processed by stir casting samples were determined by using Brinell hardness testing machine. Table.1. shows, hardness which increases with increase in Wt % of MWCNT.

The large number of fine MWCNTs distributed in composite contributes fair deformation resistance to the movement of dislocation. But if the MWCNTs content is high, uniform distribution of reinforcement is hard and MWCNTs may get together to form micro-split source which results reduction of elastic modulus and hardness. Hardness results show that, 2% weight of MWCNTs is high. In Fig. 6 the bar chart of Al/MWCNT composites plotted. The composition found to be harder than the matrix i.e., commercial purity aluminum due to the uniform dispersion of particals, therein hardness of composite increases with increase in percentage of multiwalled carbon nanotubes(MWCNTs).

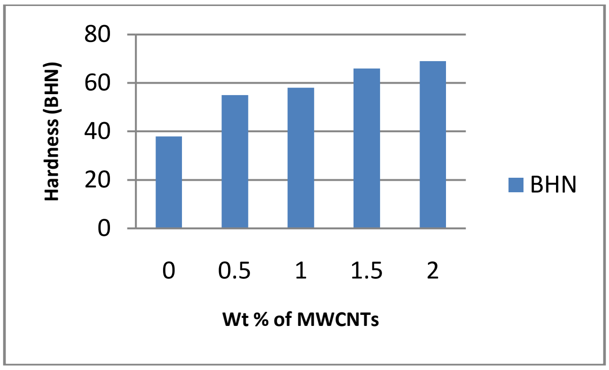


Fig. 6: Bar chart of Hardness (BHN) of Al/MWCNT Composite

C. Strength Properties

The experimental density increases with an increase in weight percentage of MWCNTs in the composites because of the agglomeration of reinforcements in the matrix. An addition of MWCNTs composites samples indicates densities were low.

Table 2: Strength properties

Composition	Experimental Density (g/cc)	Young's modulus (GPa)	Tensile strength (MPa)
Al + 0 Wt % of MWCNT	2.70	70.12	123
Al + 0.5 Wt % of MWCNT	2.58	74.53	147
Al + 1 Wt % of MWCNT	2.61	79.5	151
Al + 1.5 Wt % of MWCNT	2.63	83.72	152
Al + 2 Wt % of MWCNT	2.68	85.67	150

The strength properties were evaluated by preparing the standard tensile test specimen as per the ASTM 8 standard. The effect of MWCNTs on Tensile and Young's modulus is shown in table 2, which indicates the tensile strength and young's modulus of casted MWCNT/Al composites increases as the weight percentage of MWCNTs increased, which confirmed that the reinforced effect of the MWCNTs achieved by stir casting route.

Many metals exhibit a continuous transition from the elastic region to the plastic region. In such cases, the precise determination of the yield strength is difficult. Yield strength is calculated using proof stress which is 0.02% of strain.

Table 3: Yield Strength & % of elongation properties

Composition	Yield Stress (MPa)	% of Elongation
Al + 0 Wt % of MWCNT	86	13
Al + 0.5 Wt % of MWCNT	97	10.575
Al + 1 Wt % of MWCNT	95.95	9.1
Al + 1.5 Wt % of MWCNT	98.6	8.43
Al + 2 Wt % of MWCNT	98.2	7.92

In table 3 the results of Yield strength and ductility were shown. The yield strength is increasing by increase in wt % of MWCNTs and the ductility measures the elongation is decreasing as the wt % of MWCNTs increases in the matrix and seen to be brittle in nature.

IV. CONCLUSION

Commercial purity aluminum as matrix reinforced with multi walled carbon nanotubes in weight percentages of 0.5, 1, 1.5 and 2% were produced through stir casting technique. It can be seen that the reinforcement effect of MWCNTs to the commercial purity aluminum matrix is fairly effective. Mechanical properties improved significantly with smaller addition of reinforcement, consequently elongation decreases. This can be explained in terms of getting together of MWCNTs caused by uneven distribution of reinforcement in matrix. The hardness is increasing in increasing the reinforcement. On the other hand, it can be explained like a large number of MWCNTs exist in melt can tamper the growth of crystal and result in fine crystal.

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