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NOVEL TECHNIQUE FOR FABRICATION OF ALUMINUM6061 - MWCNT (MULTI-WALLED CARBON NANO TUBE) METAL MATRIX COMPOSITES

Manjunatha L. H.[1] and P. Dinesh[2]
[1]Department of Mechanical Engineering, Reva Innatitute of Technology, Bangalore, India
[2]Department of Mechanical Engineering, MSRIT, Bangalore, India
E-Mail: lhmanju@gmail.com

ABSTRACT

Al6061 MMC’s are quiet popular in engineering applications because of low density and high stiffness. Carbon Nano tube of late, has emerged to be an excellent reinforcement material for aluminium based metal matrix composites. The present work attempts at developing Al6061 based MMC’s using MWCNT’s for reinforcement using powder metallurgy and stir casting techniques. In this study the details of the manufacturing techniques have been discussed. The SEM images and microstructure details from optical microscope are presented for the various compositions of the MMC’s that have been developed. From the SEM images and microstructure of the composites it is observed that there is uniform distribution of MWCNT and good bonding exists between the carbon nano tubes and the matrix, establishing the stir casting technique for production of Al6061-MWCNT metal matrix composites.

Keywords: Al6061alloy, multi-walled carbon nano tube (MWCNT), metal matrix composite, microstructure.

1. INTRODUCTION

The need to improve the mechanical properties in aluminum alloys has motivated the study of new materials and innovative routes to prepare them. Aluminum 6061-based Metal Matrix Composites (MMC) is becoming popular because of their low density and high specific stiffness. These materials can be produced by dispersing reinforcement particles (in form of oxide, carbide or nitride) into metallic matrix. There is continuous search for better reinforcement material among the scientific and engineering community’s. Research basically focuses on identifying reinforcement materials with better mechanical properties to satisfy various engineering applications. Multi-Walled Carbon Nanotubes are found to be one such excellent reinforcing material which can improve properties of Al6061 Metal Matrix Composites significantly. Many engineering applications in the field of aerospace engineering, automobiles, electronic equipment etc., require very light material with good mechanical properties. Al6061 based metal matrix composites with multi-walled carbonnonotube (MWCNT) reinforcement can be a solution for such applications. It can satisfy the requirement of light weight with good strength. This study focuses on preparing Al6061 Metal Matrix Composites with MWCNT reinforcements for various compositions and evaluating for their mechanical properties.

T. Laha [1] has proposed that CNT’s have remarkable mechanical, electrical and thermal properties. Depending on their length and diameter chirality and orientations CNT’s exhibit almost 5 times elastic modulus (equivalent to1TPa) and closely 100 times tensile strength (in the range of150TPa) than those of high strength steels. The unimaginable high strength of CNT’s makes them potential reinforcement for composite materials especially for Aluminium MMC’s. Deepak Srivatsava and Chenyu Wei [2] have investigated on nanomechanics of carbon nanotubes and composites. SWCNT’s have young’s modulus slightly larger than 1TPa and tubes can withstand about 5 to 10% axial strength before yielding which corresponding to stress of about 50Gpa before nanotube yield. Chunfeng Deng *et al*., [3] has found that carbon nanotube offers a kind of nanosize reinforcement that is light weight, a hollow core, has immense aspect ratio and has remarkable mechanical electrical and thermal properties. The investigators have used 2024Al matrix composites reinforced with 1 wt% CNT’s which was fabricated by cold isotactic pressing followed by hot extrusion techniques. The experimental results indicated that the CNT”s distributed homogeneously in the composites and the interface Al-CNT’s bonded well. The grain size of the matrix as fine as 200 nanometer and the elastic modulus and the tensile strength enchanced remarkable over those of 2024Al fabricated under same procedure.

C. Srinivasan *et al*., [4] have investigated several methods available for production of CNT. Each method has its strength and weaknesses. The preparation methods include arc discharge, laser ablation, catalystic decomposition of hydrocarbons and electrolysis methods. Inspite of availability of variety of methods, for the production of CNT’s the cost of nano tube is high and hence there is a need for search of a low cost industrial method. Yanchen *et al*., [5] have used plasma assisted chemical vapour deposition method for producing well aligned graphitic nanofibers. Well aligned graphitic nanofibers on a large scale have been grown on Ni (100) wafers by plasma assisted hot filament chemical vapour deposition using a mixed gas of nitrogen and methane. Two stage control of the plasma intensity has been used in the nucleation and growth stages of the fibers. The growth direction of the fibres is perpendicular to the substrate surface and the plasma - induced Ni particles serve as catalyst. The growth mechanism of the fibres is described based on structural information provided by scanning electron microscopy and transmission electron microscopy. According to C.F. Deng *et al*., [6] the demand for high performance damping materials is rapidly and continuously growing in a variety of aerospace, mechanical and civil systems. Although metal matrix composites reinforced with traditional viscous or particle process high strength and stiffness they suffer from limitations like high weight, poor damping capacity and low plasticity. In recent years there is an increasing interest in CNT reinforced composites. A MWCNT's with 2024Al composites have produced by cold isotactic press and hot extrusion and this was tested for the damping characteristics. The experimental results showed that the damping capacity of the composites with the frequency of 0.5Hz reaches $975x10^{-3}$ and the storage modulus is 82.3GPa. CNT's have a promising reinforcement for MMC's to obtain high damping capabilities at elevated temperature without sacrifing mechanical properties. A.M.K. Esawi [7] has used powder metallurgy for fabrication of CNT's reinforced MMC's. A planetary ball mill was used to disperse 2 wt% MWCNT's in aluminium powder. Inspite the success of ball milling dispersing CNT's in the aluminium powder is often accompanies with consider strain hardening of aluminium powder which may have implication of final properties of the composites. It was found that the ball mill and extruded samples of Al-2 wt% CNT demonstrated high notch sensitivity and consitantly fractured outside gauge length during tensile testing. In contrast extruded samples annealed at 400^0C-500^0C for 10 hours, pre-heat to testing exhibited more ductile material under no notch sensitivity. R. George [8] has investigated strengthening in CNT/Al composites. Powder metallurgy technique was used for composite fabrication, Commercial purity Aluminium Powder was used as the matrix material. A mixture of CNT and aluminium powder (200 mesh) were ball milled at 200 rpm for 5 min. The short duration and slower milling speed ensures that the CNT are intact and can be validated from the transmission electron microscopy (TEM) images of the composite shown. The milled powder was compacted in a circular die with a load of 120KN; the billets thus obtained were sintered in an inert gas environment (nitrogen) for 45min at 580^0C and finally hot extruded at 560^0C. Some samples were tested and the results have indicated that the mechanical properties of CNT-Al composites including Young's modulus have significantly improved.

The study also involves preparation of CNT reinforced Aluminium Metal Matrix Composites by two different methods of manufacturing namely, Powder Metallurgy technique and Stir Casting method. Samples with various compositions produced from both the methods will be evaluated for their mechanical properties so that the best composition can be recommended for obtaining composites to suit various engineering applications.

It is also proposed to evaluate the mechanical properties of the MMC developed for various degree of heat treatment.

2. OBJECTIVES OF THE WORK

The literature survey has indicated that MWCNT's have emerged as excellent reinforcing material for Aluminium6061 MMC's. These composites can play a vital role in fulfilling the material requirement of various industries. Based on the literature survey, the following objectives have been identified for the present research topic. 1) To develop Al6061-MWCNT MMC's using Powder Metallurgy and Stir Casting techniques for various compositions of the reinforcement. 2) To evaluate the mechanical properties of the above MMC's. Mechanical properties for study include tensile, wear, thermal and corrosion behavior. 3) To make a comparative study of the mechanical properties for various composition to optimize the properties and the composition. In the present investigation, Al6061alloy with Carbon nano tube as particulates were successfully fabricated using the stir casting method and Powder metallurgy technique.

3. MATERIALS AND EXPERIMENTAL PROCEDURE

Reinforced Al6061-MWCNT composites were manufactured by using Powder metallurgy technique and Stir casting method. Al6061 powders of 200 mesh size as a matrix and Multiwalled Carbon Nano Tubes as reinforcement. The properties of as supplied MWCNT s (Nanoshel LLC USA) are given in Table-1 and Al6061 alloy composition given in Table-2.

Table-1. Typical properties of mutiwalled carbon nano tube.

Properties	Values
Purity	Carbon > 95% (trace metal basis)
OD × ID × L	10-30 nm×2-6 nm×15-30 μm
Total impurities	Amorphous carbon<3% (TEM))
Melting point	3652-3697 °C
Density	1~2 g/cm^3

Table-2. Typical chemical composition of Al6061.

Component	**Amount** (Wt. %)
Aluminium	Balance
Magnesium	0.8-1.2
Silicon	0.4 – 0.8
Iron	Max. 0.7
Copper	0.15-0.40
Zinc	Max. 0.25
Titanium	Max. 0.15
Manganese	Max. 0.15
Chromium	0.04-0.35
Others	0.05

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3.1. Development of aluminium-CNT metal matrix composites by powder metallurgy technique

Aluminium 6061 powder (200 mesh) and multiwalled carbon nano tubes (Nanoshell., USA) were procured from different sources available in the market. The two materials were properly mixed for different composition by using ball mill and magnetic stirrer, to mix uniformly CNT's with aluminium 6061 powder. Compacting die was used to compact the powder by using universal testing machine, after compacting the powder in to solid billet. Different samples of aluminium powder with 0 wt%, 0.1wt %, 0.2 wt%, 0.3wt%, 0.4 wt %, 5wt% of carbon nano tubes have been prepared. Ball mill was used to mix the aluminium6061 powder with CNT's. A magnetic stirrer was used to mix uniformily CNT's with Al6061 powder.

Figure-3(a). Low cost sintering furnace with nitrogen gas cylinder.

The above Figure-3(a) shows the low cost sintering furnace was designed and fabricated for current research work. Samples were prepared for various compositions and the samples were investigated for microstructure, using optical microscope and SEM apparatus.

3.2. Development of aluminium-MWCNT metal matrix composites using stir casting method

The procured MWCNT's and Aluminium 6061Alloy were taken in a graphite crucible and melted in electric furnace. The temperature was slowly raised to 800-850^{0}C. The melt was degassed at 800^{0}C using a solid dry hexachloroethane degasser. The molten metal was stirred to create a vortex and the particulate were introduced. The preheated carbon nanotubes were slowly added in to the melt. The percentage of CNT added was 0.1wt%, 0.2wt%, 0.3 wt%, 0.4 wt%, 0.5 wt %. The stirred dispersed molten metal was poured in to preheated iron moulds 22mm diameter and 120mm height and cooled to room temperature. The microstructure of the MMC's was observed under a optical microscope and scanning electron microscope at various locations across the specimen to examine the distribution of multi-walled carbon nano tubes in the matrix.

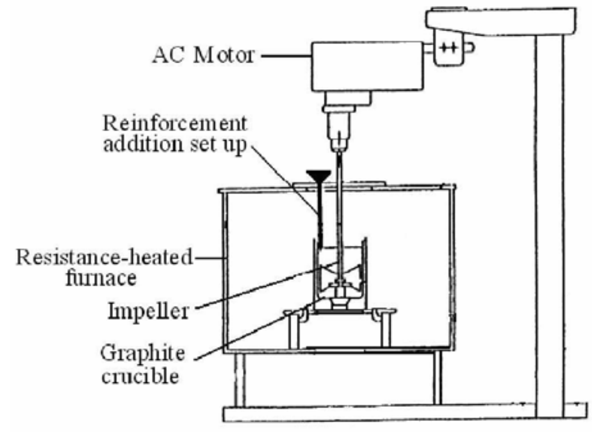

Figure-3(b). Schematic of stirring device.

4. RESULTS AND DISCUSSIONS

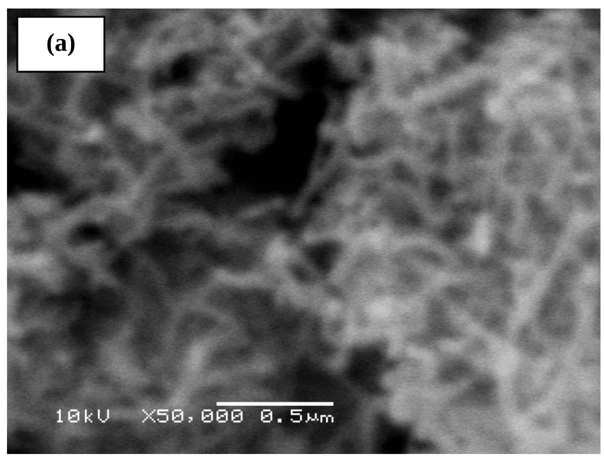

Figure-4(a). SEM image of carbon nano tubes(X50, 000).

(a). Metal matrix composite through powder metallurgy technique

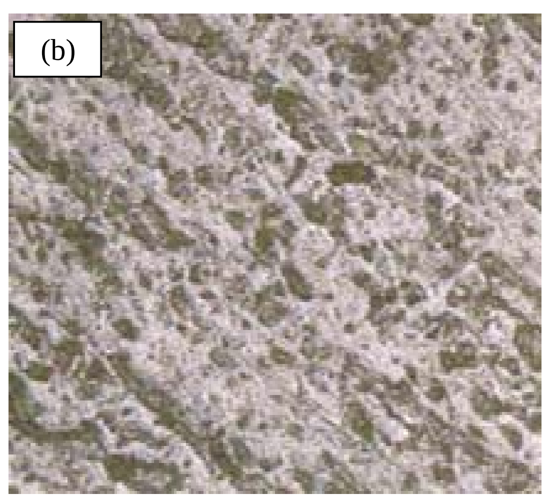

Figure-4(b). Before sintering (Al6061-0 wt %)

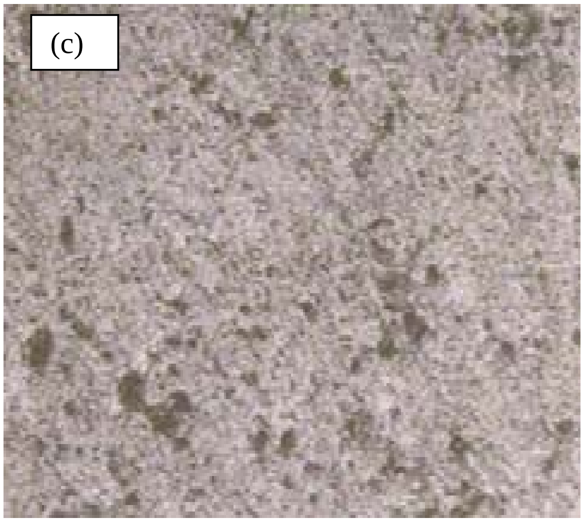

Figure-4(c). After sintering ((Al6061-0 wt %).

Compacting die was used to compact the aluminium powder by using universal testing machine, after compacting the powder in to solid billet. The microstructure of the MMCs was observed under a optical microscope at various locations across the specimen to examine the structure after Compaction as shown in Figure-4(b) and After Sintering as shown in Figure-4(c).

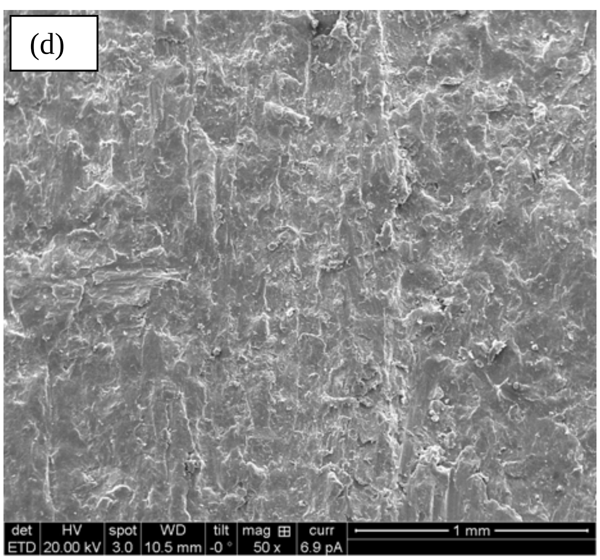

Figure-4(d). Shows SEM image of Al6061 -wt % MWCNT (magnification X100).

(b). Metal matrix composite through stir casting technique

i). Microstructure of the MMC developed obtained by a Scanning Electron Microscope.

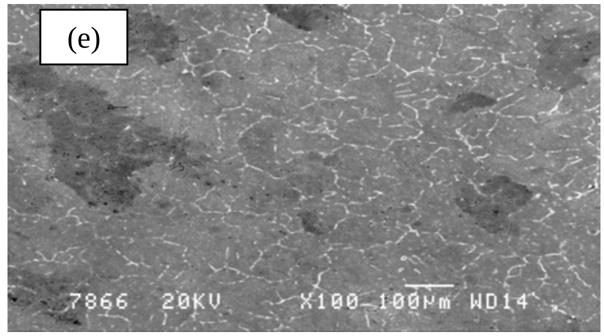

Figure-4(e). Al6061 + 0 wt %CNT (X100).

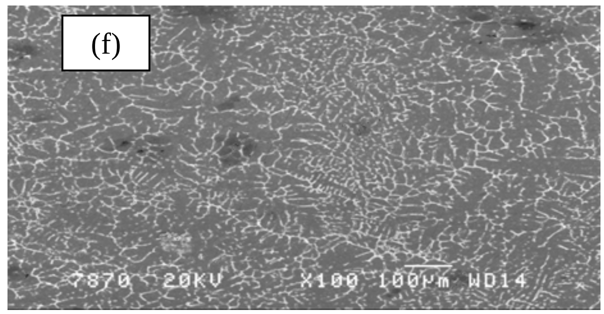

Figure-4(f). Al6061+ 0.1 wt % CNT (X100).

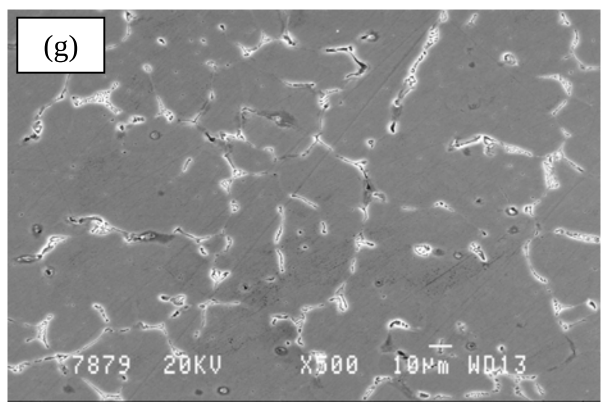

Figure-4(g). Al6061+ 0.2wt % CNT (X100).

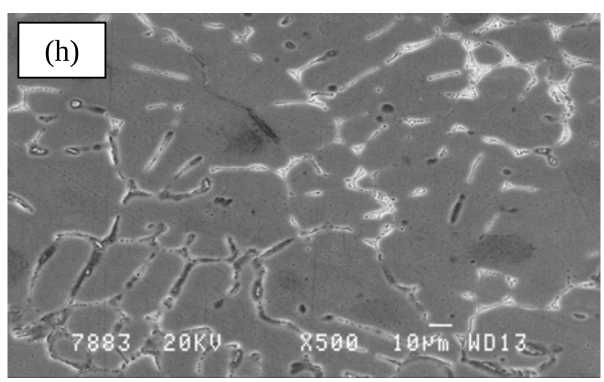

Figure-4(h). Al6061+ 0.3 wt % CNT (X500).

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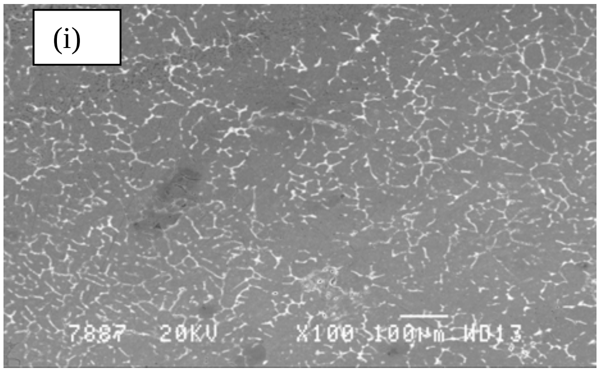

Figure-4(i). Al6061+ 0.4 wt % CNT (X100).

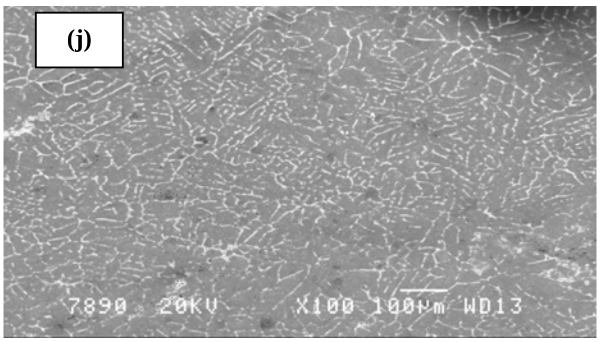

Figure-4(j). Al6061+ 0.5 wt % CNT (X100).

The microstructure of the MMCs was observed under a scanning electron microscope (SEM) at various locations across the specimen to examine the distribution of Carbon Nano tubes in the matrix. The microstructure examination of the as-cast composites generally revealed that Carbon Nano tube particles were not distributed evenly in the matrix, regional clusters of particles exist and some pores are resolvable in the as-cast samples. The Figure-4(e) to Figure-4(j) show the SEM image of Al6061-wt % MWCNT structure, with no void and discontinuities observed. There was good interfacial bonding between the carbon nano tubes and metal matrix composites.

ii). Microstructure of the MMC developed obtained by an Optical Microscope

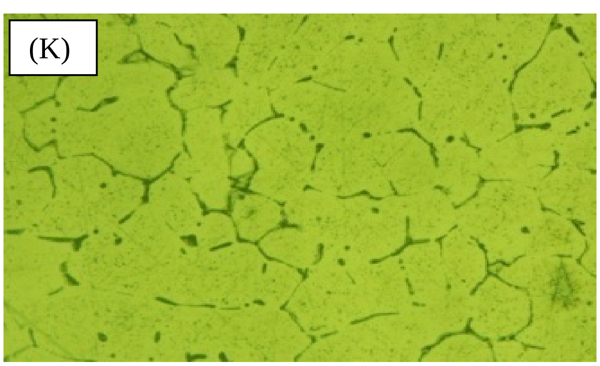

Figure-4(k). Al6061+ 0 wt % CNT (X200).

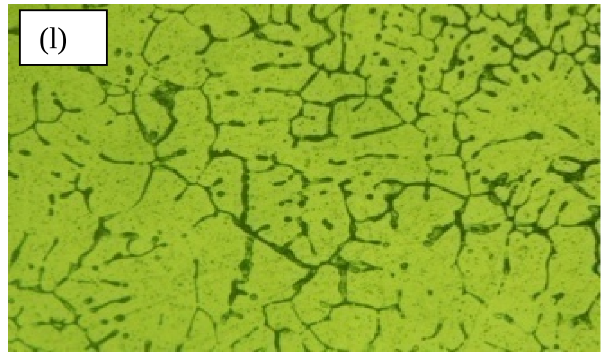

Figure-4(l). Al6061+ 0.1 wt % CNT(X200).

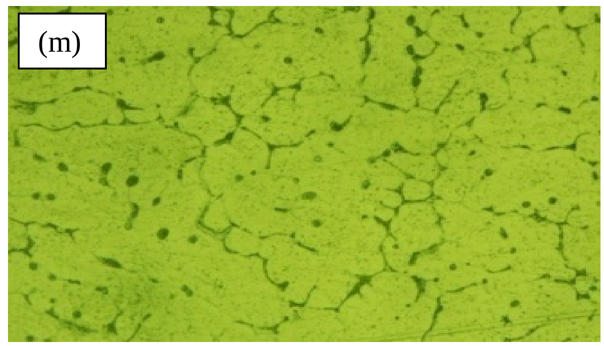

Figure-4(m). Al6061+ 0.2 wt % CNT(X200).

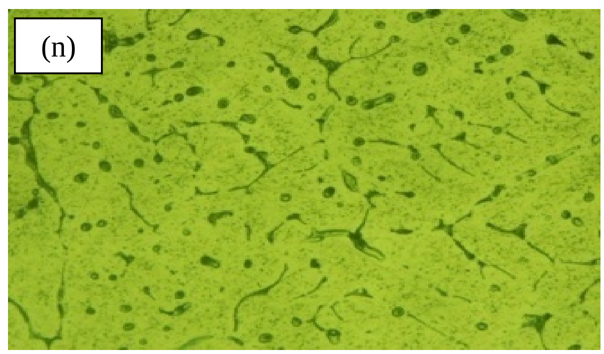

Figure-4(n). Al6061+ 0.3 wt % CNT(X200).

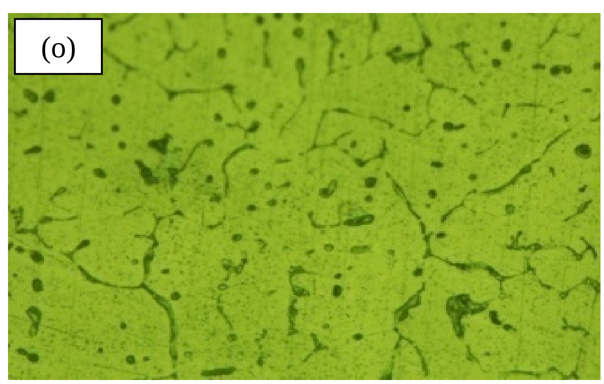

Figure-4(0). Al6061+ 0.4 wt % CNT(X200).

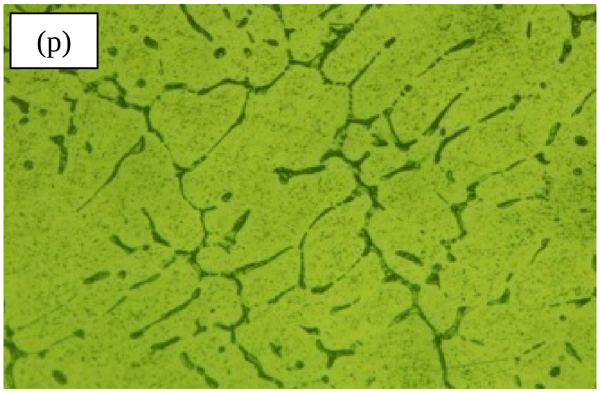

Figure-4(p). Al6061+ 0.5 wt % CNT(X200).

The microstructure of the MMCs was observed under an optical microscope at various locations across the specimen to examine the distribution of Carbon Nano tubes in the matrix. The microstructure examination of the as-cast composites generally revealed that Carbon Nano tube particles were not distributed evenly in the matrix, regional clusters of particles exist and some pores are resolvable in the as-cast samples. The Figure-4(k) to Figure-4(p) show the microstructure image of Al6061-wt % MWCNT structure, with no void and discontinuities observed. There was good interfacial bonding between the Multi-walled carbon nano tubes and metal matrix composites.

5. CONCLUSIONS

The present study has highlighted the need for developing Al-CNT metal matrix composites.

The Metal Matrix Composites have been developed successfully using powder metallurgy technique and stir casting methods. Microstructure images and SEM images of various compositions have been obtained. Micrographs of Al6061-wt % MWCNT structure, with no void and discontinuities observed. It is observed that there was good interfacial bonding between the Multi-walled carbon nano tubes and metal matrix composites.

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