CHARACTERISATION OF ALUMINIUM CARBON-NANO TUBE NANO COMPOSITE

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Abstract: In recent years, carbon nanotubes (CNTs) reinforced aluminium matrix composites have attracted increasing attention. The quality of dispersion, however, is a crucial factor which determines the homogeneity and final mechanical properties of these composites. Various amounts of well-dispersed multi-walled carbon nanotubes (MWCNTs) were used to reinforce an Al using powder metallurgy technique. The microstructures of the nanocomposites are observed in the optical metallurgical microscope. Pin-on-disk wear tests were performed under different loading conditions of 10N, 20N and 30N, to evaluate the wear and tribological properties of the different weight ratios of Al –MWCNT nanocomposites. In comparison with the Al, the addition of MWCNTs decreased the coefficient of friction in Al –MWCNT nanocomposites. The results show that additions of MWCNTs can upgrade the Al and convert it into a wear resistance material. The MWCNTs played dual roles in improving the tribological performance of the nanocomposites, indirectly by influencing the microstructure and mechanical properties of nanocomposites and directly by acting as a lubricating medium

Keywords: Carbon Nanotubes (CNTs), Aluminium, Microstructure, Nanocomposites, Powder Metallurgy, Wear.

1. Introduction

Composite materials (or composites for short) are engineering materials made from two or more constituent materials that remain separate and distinct on a macroscopic level while forming a single component. There are two categories of constituent materials: matrix and reinforcement. At least one portion of each type is required. The matrix material surrounds and supports the reinforcement materials by maintaining their relative positions. The reinforcements impart their special mechanical and physical properties to enhance the matrix properties. The primary functions of the matrix are to transfer stresses between the reinforcing fibers/particles and to protect them from mechanical and/or environmental damage whereas the presence of fibers/particles in a composite improves its mechanical properties such as strength, stiffness etc.

A composite is therefore a synergistic combination of two or more micro-constituents that differ in physical form and chemical composition and which are insoluble in each other. The objective is to take advantage of the superior properties of both materials. The synergism produces material properties unavailable from the individual constituent materials. Due to the wide variety of matrix and reinforcement materials available, the design potentials are incredible. Composite materials have successfully substituted the traditional materials in several light weight and high strength applications. The reasons why composites are selected for such applications are mainly their high strength-to weight ratio, high tensile strength at elevated temperatures, high creep resistance and high toughness.

Here the lightweight material, aluminium is taken as matrix and multi walled carbon nanotubes are taken as reinforcement. Aluminium is less wear resistant whereas MWCNTs are highly wear resistant. So in order to increase the wear resistance of the aluminium matrix, it is being reinforced with the MWCNTs. Pure aluminium powder is reinforced with different proportions of 0.5%, 1% and 2% MWCNTs using powder metallurgy technology. The microstructure of the different specimens were studied using optical metallurgical microscope. And the specimens were tested for the wear properties using pin on disc arrangement.

2. Experimental Details

2.1 Material selection

Aluminium**:** Aluminium is chosen as a base material. Aluminium is the world's third most abundant metal. Pure aluminium is soft, ductile, and corrosion resistant and has a high electrical conductivity. It is widely used for foil and conductor cables, but alloying with other elements is necessary to provide the higher strengths needed for other applications.

Multi-walled Nanotubes: MWCNTs are chosen as reinforcement material. MWCNTs have excellent properties and are being employed in a large number of commercial applications. MWNTs include several tubes in concentric cylinders. The number of these concentric walls may vary from 6 to 25 or more. The diameter of MWNTs may be 30 nm when compared to 0.7–2.0 nm for typical SWNTs.

Table1. Properties of Aluminium and MWCNTs

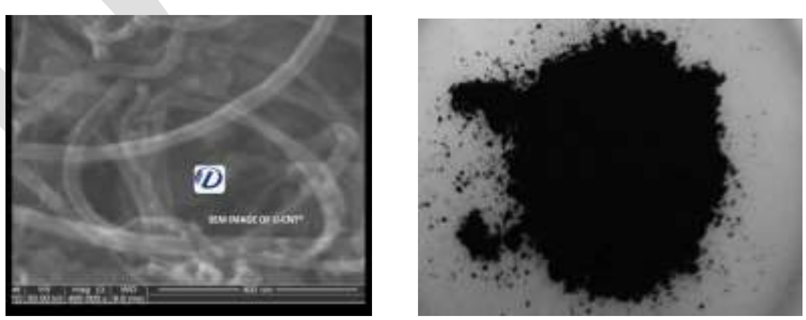
Properties	Aluminium	MWCNTs
Density	2.7 g/cm^3	1.6-2 g/cm^3
Young's modulus	70 GPa	1.7-2.4 Tpa
Thermal conductivity	204.3 W/m K	>3000 W/m K
Melting point	660^{o}C	35000^{o}C

2.2 Methodology

Fabrication of Nanocomposites:

Based on the ASTM standards the fabrication of nanocomposites was done at room temperature by powder metallurgy technique and a nanocomposite was sintered at 450^{o}C temperature for 1 hour and cooled to room temperature.

Synthesis of Carbon Nanotubes: The United Nanotech Innovations Pvt. LTD as produced the MWCNTs by Chemical Vapour Deposition Technique. CVD is the most widely used method for the production of carbon nanotubes. For this purpose, the metal nanoparticles are mixed with a catalyst support increase the surface area for higher yield of the catalytic reaction of the carbon feedstock with the metal particles. One issue in this synthesis route is the removal of the catalyst support via an acid treatment, which sometimes could destroy the original structure of the carbon nanotubes. However, alternative catalyst supports that are soluble in water have proven effective for nanotube growth. The packed carbon nanotubes are more than 20µm long and have a carbon purity of 98% or higher; they also retain the desirable alignment properties of the nanotubes.



(a) (b)

Fig 2.1(a) SEM image of U-MWCNT

(b) Powder form of U-MWCNT of outer diameter 20nm and length 20µm

2.3 Powder Metallurgy Technique

Powder metallurgy (PM) is a term covering a wide range of ways in which materials or components are made from metal powders. The PM press and sinter process generally consists of three basic steps: powder blending, Die compaction, and sintering. Compaction is generally performed at room temperature, and the elevated-temperature process of sintering is usually conducted at atmospheric pressure and under carefully controlled atmosphere. Optional secondary processing such as coining or heat treatment often follows to obtain special properties or enhanced precision. All PM processes avoid, or greatly reduce, the need to use metal removal processes, thereby drastically reducing yield losses in manufacture and often resulting in lower costs.

In the present work three variations of the reinforcement material Pure Al and MWCNT, 0.5 wt%, 1 wt%, and 3wt%, were added to the Aluminium and blended. The homogeneously blended powders with different variations of MWCNTs were compacted into cylindrical billets of 20mm diameter. Compacted specimens of Al and Al-MWCNT composites were sintered at 450 ° C for 1h in electrical sintering furnace. The sintered billets were machined in lathe and the pin specimens were prepared with flat ends, a diameter of 10 mm, and length of 25 mm.

Fig 2.2 Powder Metallurgy process for structural press and sintered process

2.4 Sintering Process: Sintering is a heat treatment applied to a powder compact in order to impart strength and integrity. The temperature used for sintering is below the melting point of the major constituent of the Powder Metallurgy material. After compaction, neighbouring powder particles are held together by cold welds, which give the compact sufficient "green strength" to be handled. At sintering temperature, diffusion processes cause necks to form and grow at these contact points.

In the present work the nanocomposites are sintered at temperature of 450°C for 1 hour in the electrical furnace. Upon sintering, the metallic bonding between the powder particles is formed mainly by diffusion.

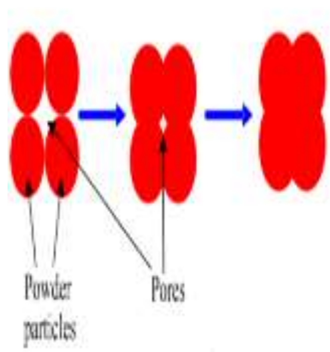


Fig 2.3 Sintering Process

Fig 2.4 Electrical Furnace

3. Microstructure of nanocomposites

In this present work the microstructure of the nanocomposites were tested at Raghavendra Spectro Metallurgical Laboratory.

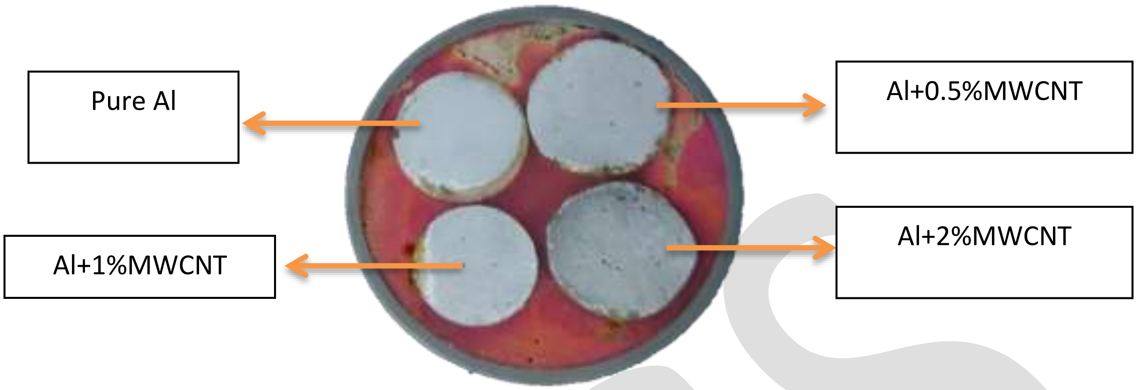


Fig 3.1: Microstructure Test specimens

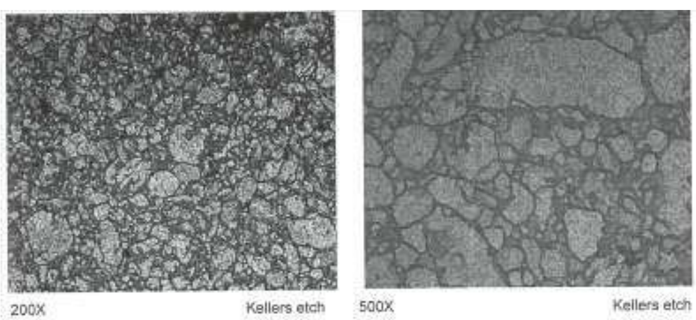


Fig 3.2: Microstructure of Pure Aluminium Specimen

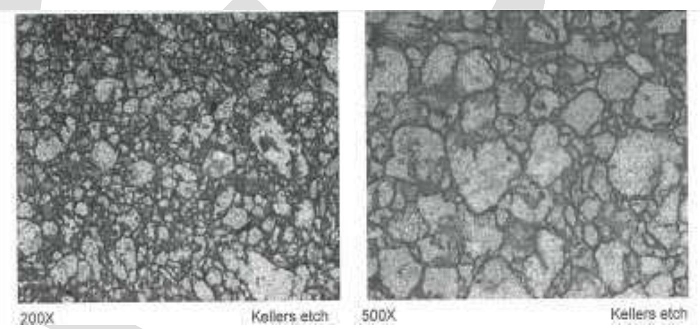


Fig 3.3: Microstructure of Al+0.5%MWCNT Specimen

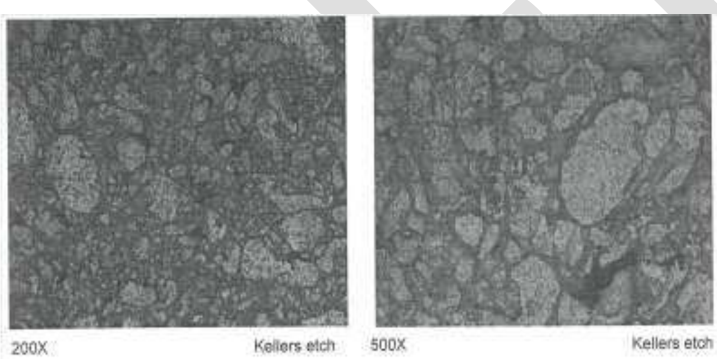


Fig 3.4: Microstructure of Al+1%MWCNT Specimen

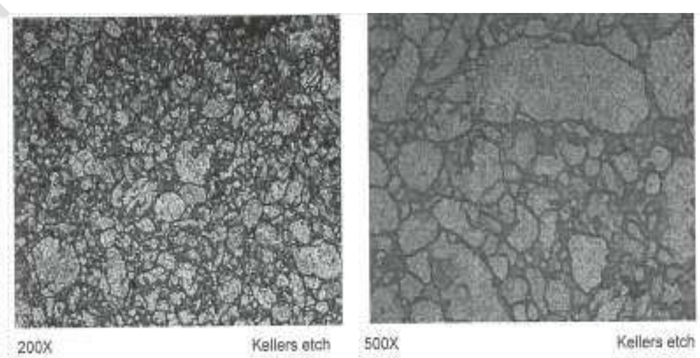


Fig 3.5: Microstructure of Al+2%MWCNT Specimen

4. Results and Discussion:

The following are the tabulated wear test results according to ASTM standard G99 obtained under varying load and speed conditions.

1. Sintering: 450^{o}C for 1 hour, air cooling in room temperature.
2. Specimen: dia. = 10mm and length = 25mm
3. Track diameter: 100mm

Table 2. wear test results

Specimen Type	Load (kg)	Speed (rpm)	Time (min)	Wear (µm)	Frictional Force (N)	Weight Loss (gm)	
Pure Al	1	150	10	. 19	6.7	Before	5.5100
						After	5.4900
						Diff. = 0.0200	
	2	150	10	20	9.5	Before	5.4900
						After	5.4400
						Diff. = 0.0500	
	3	150	10	22	15	Before	5.4400
						After	5.3700
						Diff. = 0.0700	
Al + 0.5%MWCNT	1	150	10	16	5.4	Before	4.7200
						After	4.7100
						Diff. = 0.0100	
	2	150	10	17	9.5	Before	4.7100
						After	4.6900
						Diff. = 0.0200	
	3	150	10	19	16	Before	4.6900
						After	4.6600
						Diff. = 0.0300	

Table 3. Wear Coefficient results

Specimen Type	Load (N)	Speed (rpm)	Time (min)	Wear coefficient, K (x 10^{-4})
Pure Al	9.81	150	10	3.397
	19.62	150	10	2.548
	29.43	150	10	2.265

Al+0.5%MWCNT	9.81	150	10	1.698
	19.62	150	10	1.698
	29.43	150	10	1.698

$$\textbf{Wear coefficient, K=} \frac{\text{volume} \quad (mm^3)}{\text{load} \times \text{sliding distance} \quad (\text{Nm})}$$

Where,

Volume = $\frac{\pi d^2}{4} \times L$

d- Diameter of the specimen

L- Wear out length of the specimen

Sliding distance = Speed of disc × time

Speed of disc = $\frac{\pi DNT}{60000}$

Where, D – diameter of the track, mm

N – Speed in rpm

T – Time in seconds

5.Conclusion:

It is concluded that the homogeneous distribution of CNTs with sound interface in Al matrix is an important technological issue to enhance the mechanical behaviour and wear resistance of CNT/Al nanocomposite. Oxidation wear is the main wear mechanism for the CNT/Al composite under dry sliding conditions. The formation of carbon film can reduce the friction and wear rate. Compared with pure Al composite, the CNT/Al nanocomposite has a lower coefficient of friction and reduced weight loss. Increasing the nanotube volume fraction can significantly decrease both the coefficient of friction and wear rate of the composite.

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