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Fabrication and Characterisation of Cu-CNT Nanocomposites

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Abstract
Copper (Cu) and its alloys are used because of its high electrical and thermal conductivity coupled with strength. Carbon nanotubes (CNTs), since their appearance and for their unique properties such as exceptionally small diameters and high Young's modulus, tensile strength and high chemical stability, are considered to be an attractive reinforcement material for lightweight and high-strength nanocomposites. The powder metallurgy method allows nanocomposite materials to be produced by sintering a mixture of powders.

The powder metallurgy method is to fabricate a Cu/CNT nanocomposite. In this work, a nanocomposite material made of copper is reinforced by multi-walled carbon nanotubes by weight ratio. Sintering is the important process; it is the process where powder compacts are heated so that nearby particles fuse together. After this the mechanical properties of the nanocomposites are calculated for different mass percentage of carbon nanotubes.

This investigation deals with the study of the effect of CNT materials on the mechanical and its microstructure.

Keywords: Carbon nanotubes, MWCNT, Cu/CNT nanocomposite, powder metallurgy, Pin on Disc.

INTRODUCTION:

Composite materials are engineering materials constitute of two or more materials that remain separate and distinct on a macroscopic level while forming a single component. The reinforcements impart their special mechanical and physical properties to enhance the nanocomposite properties. A composite is a synergistic combination of two or more micro-constituents that vary in physical form and chemical composition. The objective is to take advantage of the superior material properties of both without compromising on the weakness of either.

The combination produces material properties varying from the individual constituent materials. The reasons for selection of composites in applications are mainly because of high strength-to weight ratio, high tensile strength at elevated temperatures, high creep resistance and high toughness. Basically, in a composite, the reinforcing materials are strong with low densities while the matrix is usually a ductile or tough material. If the composite is designed and fabricated precisely it combines the strength of the reinforcement.

Nanocomposite is a multiphase solid material where one of the phases has one, two or three dimensions of less than 100 nanometres (nm). The structure of nanocomposites are usually consists of the matrix material containing the nano-sized reinforcement components in the form of particles, whiskers, fibres, nanotubes. The mechanical, electrical, thermal, optical, electrochemical, catalytic properties of the nanocomposite will differ from their base component materials.

MATERIALS:

1)Copper: Copper has been used for thousands of years and its mechanical properties are well known. It is a ductile metal, having very high thermal and electrical conductivity. Pure copper is soft and malleable; a freshly exposed surface has a reddish-orange colour. (Figure1)

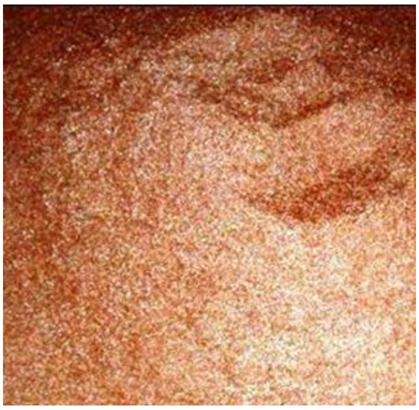

Figure 1: Copper powder of 1µm grain size

2) Carbon nanotubes:

Carbon Nano Tubes (CNTs) are gaining wide spread applications in several high technological areas because of its remarkable mechanical and electronic properties. Carbon nano tubes are the fourth form of carbon, discovered by the classic experiments of Ijima in 1991.

Carbon nanotubes (CNTs) are allotropes of carbon having cylindrical nano structure. Nanotubes have been constructed with length-to-diameter ratio. They have exceptional strength and unique electrical properties, and are efficient thermal conductors. Nanotubes are categorized as single-walled nanotubes (SWNTs) and multi-walled nanotubes (MWNTs) (Figure 2).

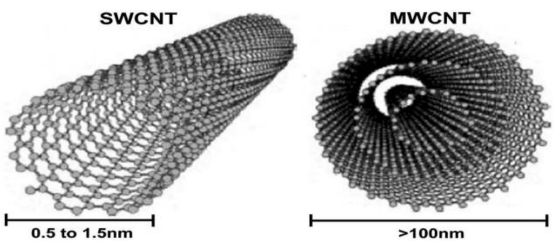

Figure 2: Nanotube structure

Table1: Properties of Copper and Carbon nanotubes

Properties	Copper	MWCNT
Density	8.9 g/cc	1.6-2 g/cc
Young's modulus	120 Gpa	1.7-2.4 TPa
Thermal conductivity	385 W/mK	>3000 W/mK
Melting point	1083^{o}C	35000^{o}C

OBJECTIVE:

1. To fabricate the Copper based nanocomposites using Multiwall Carbon nanotubes (MWCNT) as reinforcement material.
2. To investigate the effect of MWCNT on the metallic dry sliding adhesive wear of the composites.

METHODOLOGY:

1.Design and Fabrication of CNT Reinforced Nanocomposites:

Based on ASTM standards the nanocomposites are to be made using powder metallurgy (P/M) technique using MWCNT as filler materials.

Powder Metallurgy Technique:

Powder metallurgy is the process of blending fine powdered materials, compressing them into a desired shape or form, and then heating the compressed material in a controlled atmosphere at particular temperature to bond the material (Figure 3).

Figure 3: Representation of Powder Metallurgy Process

The conventional process is having three main steps: powder preparation, cold compression in rigid dies and sintering. The dimensions and geometrical features are mainly controlled by the compaction step, and their precision depends on the compaction tools and other parameters. Upon sintering, the metallic bonding between the powder particles is formed by diffusion. Sintering is often observed as there is decrease in volume. Here, we have utilized the powder metallurgy method to fabricate a Cu/CNT nanocomposite.

Figure:4 shows a schematic view of the synthesis process based on the powder metallurgy method. The purpose of this work is to study the effect of the sintering temperature on the density and hardness of the Cu/CNT nanocomposite.

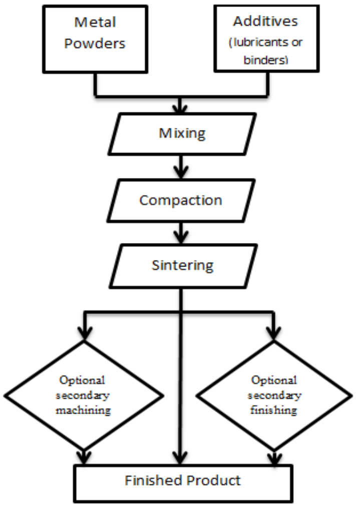

Figure 4 Schematic representation of the Cu/CNT nanocomposite fabrication process using powder metallurgy

2) Testing:

Table: 2 Specimen prepared for test

Specimen	Material Designation	Weight%
1	Copper	7
2	Cu + MWCNT 0.5%	6.25
3	Cu + MWCNT 1%	5.70
4	Cu + MWCNT 1.5%	5.27

Table:3 ASTM STANDARDS

Test	ASTM Standards
Wear	ASTM G99-05

Properties Tested:

1) Microstructure of Nanocomposites:

Microstructure of any metal or composites mainly depends on how the product is manufactured and finishing process is done. Hence to improve microstructure further heat treatment is carried out and the tribological properties and mechanical properties such as fatigue strength and hardness and chemical properties such as corrosion factor also depends on the microstructure.

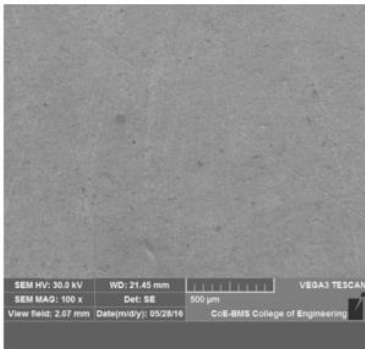

Figure: 5 SEM image of Pure Copper

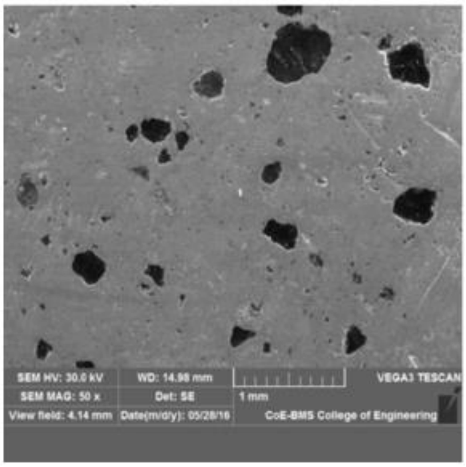

Figure: 6 SEM image of Cu + MWCNT 1.5%

2) Wear Test:

The wear property of the composites is measured at room temperature in accordance with ASTM G99-05. The test is carried out using Pin-on-Disk Apparatus **(**Figure 7).

The sample is loaded at a constant rate and the wear is recorded. The standard dimensions of the specimens are Ø8mm×25mm.

Figure:7 Wear testing machine

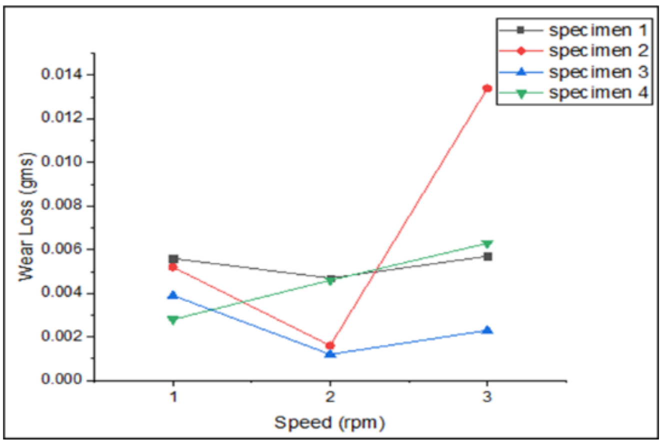

Figure: 8 wear loss vs speed for constant load of 2kg

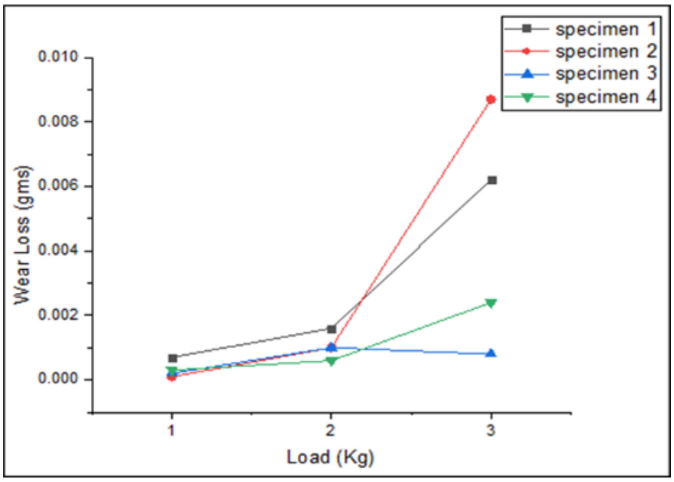

Figure: 9 wear loss vs load for constant speed of 150rpm

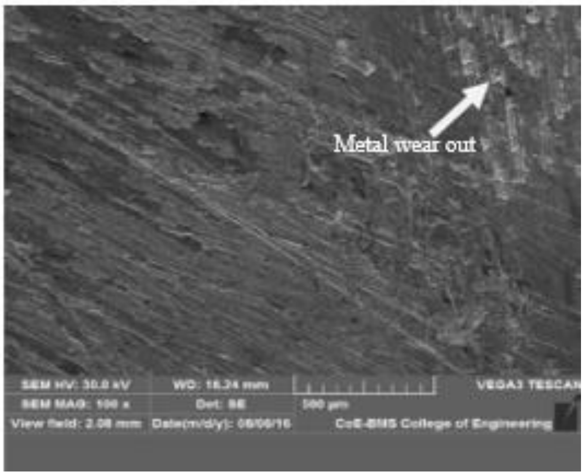

Figure: 10 SEM images of wear tested Pure Copper

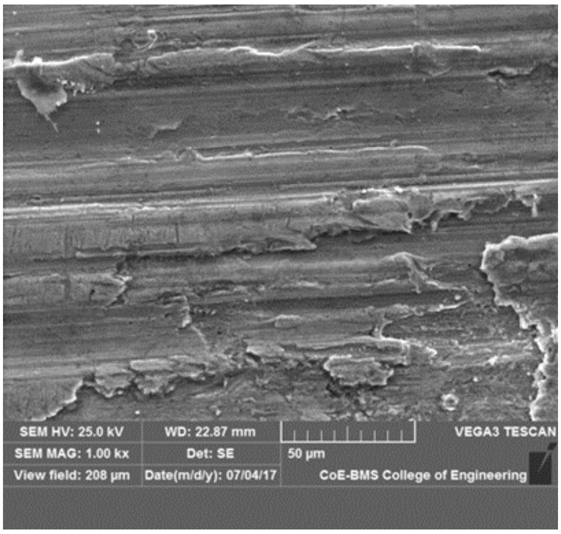

Figure: 11 SEM images of wear tested with Cu + MWCNTs 1.5%

3. Wear Coefficients of friction

Wear Coefficient of all wear tested specimen is determined and each specimen is compared to pure copper.

Wear Coefficients formulae

Wear coefficient (K) = Volume / (Load × Sliding distance)

Where, Volume = $(\pi d^2 / 4) \times L$

d = Diameter of specimen

L = Wear out length of the specimen

Sliding distance =Speed × time (T)

Linear speed of disc = $\pi DN / 60$

Where D=diameter of the track in mm

N=Speed in rpm

T=Time in seconds

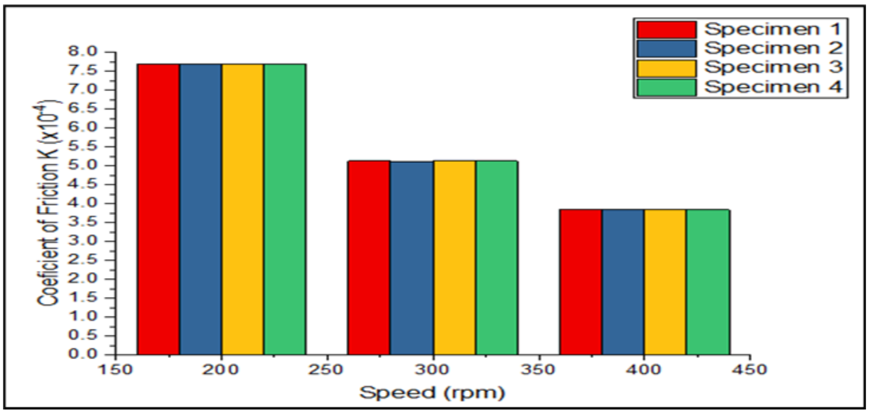

Figure: 12 Coefficient of friction v/s speed of Constant load with varying speed

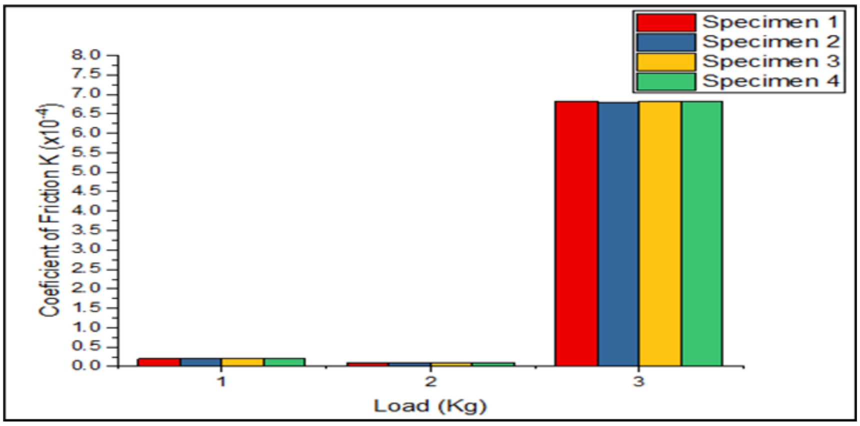

Figure: 13 Coefficient of friction v/s Load of Constant speed with varying load

Conclusion:

It may be concluded that the homogeneous distribution of CNTs with sound interface in Cu matrix is an important technological issue will enhance the mechanical behaviour and wear resistance of CNT/Cu nano composite. Oxidation wear is the main wear mechanism for the CNT/Cu composite under dry sliding conditions. Hence from test conducted and graph plotted it is indicated that as the percentage of carbon nanotubes increased as reinforcement in composites there is decrease in both friction and wear rate. Increasing the nanotube volume fraction can significantly decrease both the coefficient of friction and wear rate of the composite

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