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MULTIWALLED CARBON NANO TUBES REINFORCED WITH COPPER NANOCOMPOSITE BY POWDER METALLURGY TO ENHANCE TRIBOLOGICAL PROPERTIES

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Abstract— **Using powder metallurgy technology, carbon nanotubes are reinforced with metallic copper to investigate the tribological properties and microstructural characterization. The tribological properties were examined using a pin-to-disk test under various loading conditions. The influence of the weight fraction of CNTs on the tribological behavior of the nanocomposite was investigated. The nanocomposite with a high weight fraction of CNT and the sintering process showed high porosity and their wear resistance decreased under high load conditions. Good dispersion of CNTs and better interfacial bonding between CNT and copper were examined by scanning electron microscopy (SEM).**

Keywords— **multi-walled carbon nanotubes, powder processing, sintering, wear rate, nanocomposite, scanning electron microscopy (SEM)**

I. INTRODUCTION

Materials with properties such as a high strength-to-weight ratio, high specific stiffness, and excellent wear and corrosion resistance are a necessity in most modern aerospace and automotive applications today. It is difficult to obtain a single homogeneous material with all the desired properties. Although metals and alloys have very high strength and toughness, they have a limited modulus of elasticity. One of the strategies to increase the strength of the material has been to decrease the grain size. This has led to the development of nanocrystalline materials. [1]. Nanomaterials are interesting because they have unique optical, magnetic, electrical and other properties on this scale. These new properties can have a significant impact on electronics, medicine, and other areas. These nanomaterials are compounds Carbon nanotubes are one of the most frequently mentioned building blocks of nanotechnology. With a hundred times the tensile strength of steel, better thermal conductivity than any other than the purest diamond, and copper-like electrical conductivity, but with the ability to carry much higher currents, they appear to be a wonderful material [2]. Nanotubes come in a variety of flavors: long, short, single-walled, multi-walled and open, closed, with different types of spiral structures, etc. [3] Indeed, interest in MWCNT-reinforced copper composites has increased significantly. The common goal of the various groups is to produce composite materials with improved mechanical properties. Metal matrix composites (MMCs) with improved thermal conductivities have received considerable attention for packaging material applications such as microelectronics and optical communications [6]. The recent trend to improve the tribological and mechanical properties of copper-based composites is achieved through the use of multi-walled carbon nanotubes as a reinforcing element. Various methods have been proposed to synthesize the multi-walled carbon nanotube reinforced matrix (MWCNT), e.g. B. mechanical alloy (MA), thermal spraying, spark plasma sintering (SPS), semi-solid powder processing, flake powder metallurgy and friction stir processing [7].

II. EXPERIMENT

2.1 Material selection

The base material (copper) was purchased from Ace Rasayana, Bengalore, and had a mesh size of 325and its atomic number is 29. It is a ductile metal with high electrical and Thermal conductivity. Carbon nanotubes used as the reinforcement material were obtained from Redex Technology, Delhi. First, the carbon nanotubes are dispersed in a solvent and sonicated for 20 minutes and evaporated by heating the solvent. The solvent used is ethanol and the sonication is carried out by ultrasonic wave sonication equipment. In this process, the CNTs are dispersed and can be used as reinforcement. The matrix material (copper) and

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carbon reinforcing material (nanotubes) are made appropriately by precisely weighing them in an electronic balance and mixing them thoroughly to achieve successful densification and sintering results. Multi-walled nanotubes:

Table 1. Properties of copper

Atomic number	29
Copper density	8.96 g / cm³
Fusion point	1083 ° C.
boiling point	2595 ° C.
Elastic modulus	117 GPa
Thermal conductivity	391 Wm-k-1

Table: 2 weight percent for Cu / CNT

CNT in%	Copper in (g)	CNT in (g)	Total weight in (g)
0	30th	0	30th
0.5	29.85	0.15	30th
1	29.7	0.30	30th
1.5	29.55	0.45	30th

MWCNTs are chosen as reinforcement material. MWCNTs have excellent properties and are used in a variety of commercial applications. MWNTs comprise multiple tubes in concentric cylinders. The number of these concentric walls can vary from 6 to 25 or more. The diameter of MWNTs can be 30 nm, compared to 0.7-2.0 nm for typical SWNTs. The powder metallurgy process begins with the homogeneous mixing of the reinforcement (CNT) with the powder matrix (copper).

2.2 Sample preparation

2.2.1 Ball milling process

Copper powder and carbon nanotubes have different weight proportions. Both mixtures are fed into the rotating container together with hardened solid balls. The ball diameter is 10 to 12 mm at a speed of 200 rpm for a period of 5 minutes. The short duration and the slower grinding speed were chosen to ensure that the reinforcement remains intact without breaking during mixing.

Fig. 1: Ball milling machine

2.2.2 Green compaction

The compaction process involves pressing a calculated amount of powder into a circular shape as shown in FIG. 1 with a universal testing machine. to create a disc shape from solid green samples at room temperature. Green samples are samples that have not been fully processed when the load increases. The particles deform plastically, which leads to a reduction in the distances between the particles and the pore removal. The applied load is 147 kN or (15 tons).

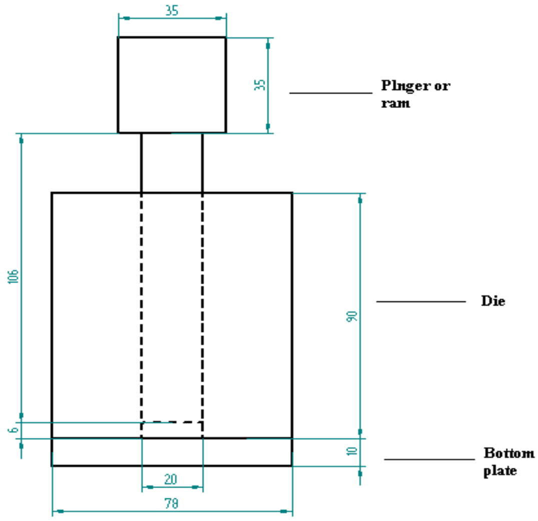

Fig: 2 assembling the die

2.2.3 Sintering process

Sintering is a heat treatment process in which densified samples or so-called green samples must be sintered in order to achieve the required mechanical properties (to increase strength and hardness). Green samples are heated in a controlled atmosphere. The temperature between 0.7 and 0.9 times the melting point of the service life of the base metal (copper) is 45 minutes. In tube furnace sintering process is carried out .

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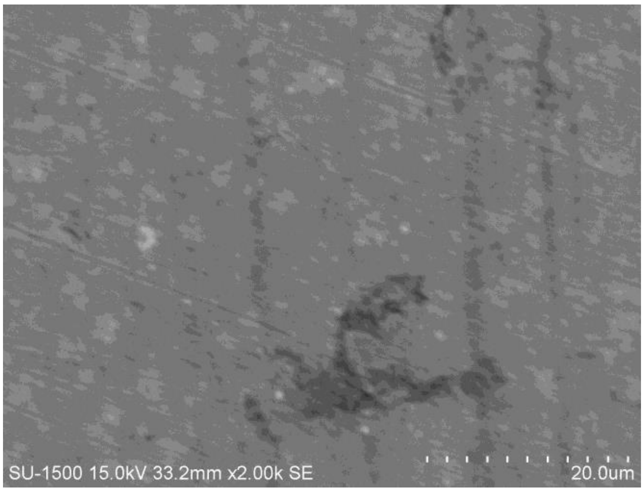
Fig: 3 sintered samples

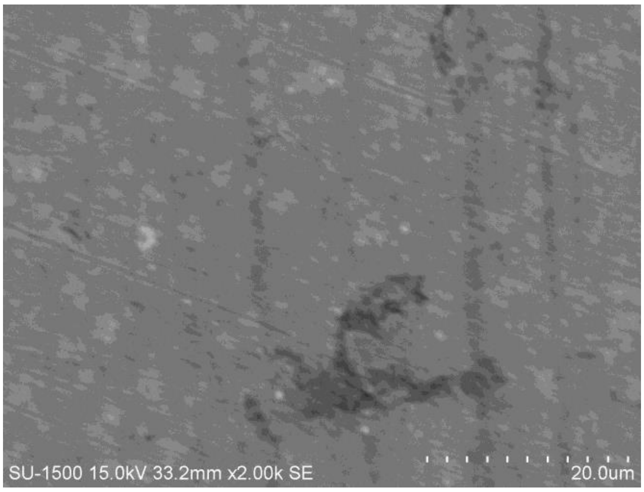
III. MICROSTRUCTURAL STUDY

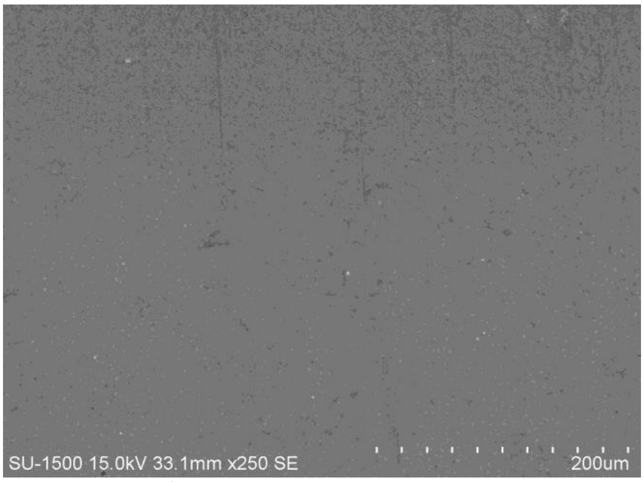
It is an investigation of the crystal structure of a material, its size, composition, orientation, formation, interaction and ultimately its effect on the macroscopic behavior in relation to physical properties such as strength, toughness, ductility, hardness, durability. to corrosion.

3.1 Scanning electron microscope

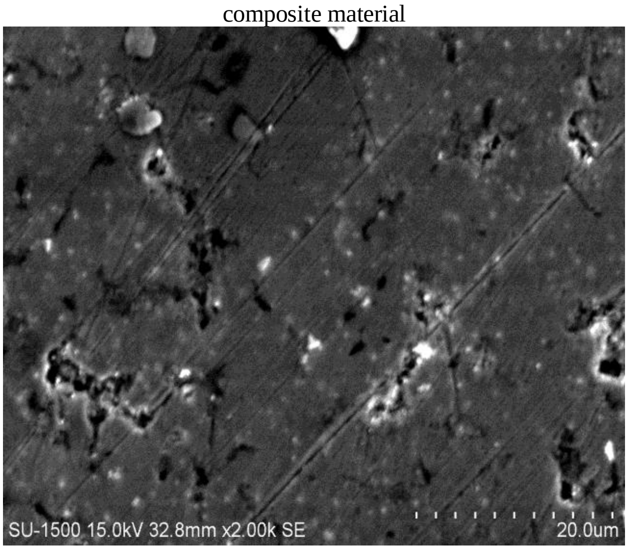
It is a type of scanning electron microscope that creates images of a sample by scanning it with a focused electron beam. Electrons interact with atoms in the sample, generating various signals that can be detected and contain information about the topography and composition of the sample surface
The CNT / copper nanocomposite powder has the morphology of the CNTs implanted in the copper particle with dimensions between about 20 µm and 200 µm. The microstructure of the sintered nanocomposite is examined with SEM.







4: SEM image of sintered copper (45 min) -0.5% by weight CNT composite material



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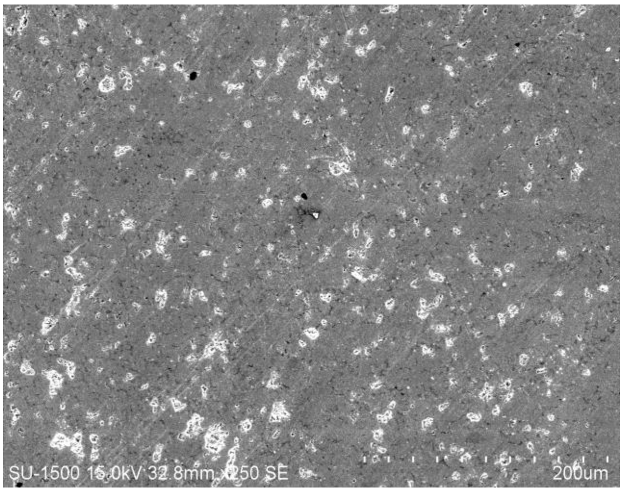
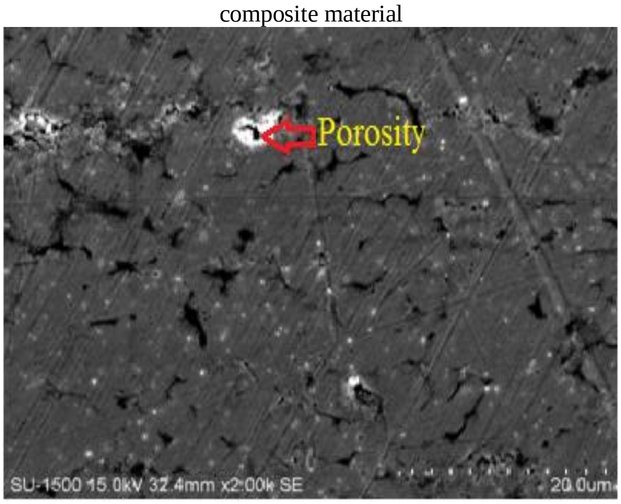
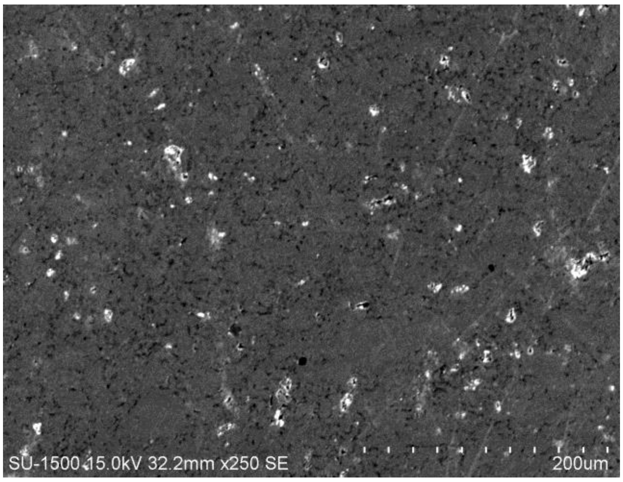


5: SEM image of sintered copper (45 min) -1.0% by weight of CNT composite material





6: SEM image of sintered copper (45 min) -1.5% by weight CNT composite material

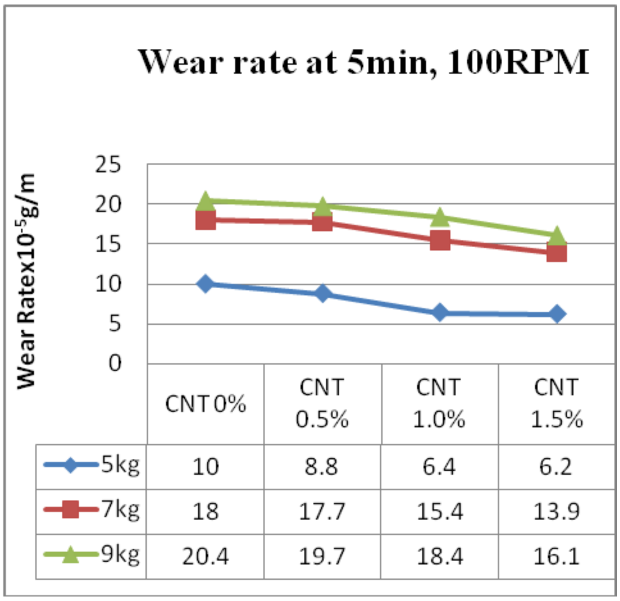
The green compacts were sintered in argon at 7500 ° C. for 45 minutes, and the sintered samples were produced by mechanical polishing using emery paper of various qualities. 4, 5 and 6 show microscopic photographs of 0.5, 1 and 1.5% by weight of sintered MWCNT-reinforced copper matrix nanocomposite. Scanning electron microscope (SEM) images show the surface of the sample and the inner surface of smoothed and engraved samples. In Figures 5 and 6, a defect occurs on the surface which helps to empty out the contents during the compaction process where the copper powders are not perfectly compacted. The microscopic images in the figures show the distribution of CNTs in the copper matrix for CNT / Cu nanocomposites that were produced with different CNT proportions by weight. It was observed that with increasing weight fraction of CNT, the homogeneous distribution of CNTs in the copper matrix decreased and the density of the sintered composite decreased. As shown by the SEM image in Fig. For the CNT / Cu nanocomposites produced.

IV. RESULTS AND DISCUSSION

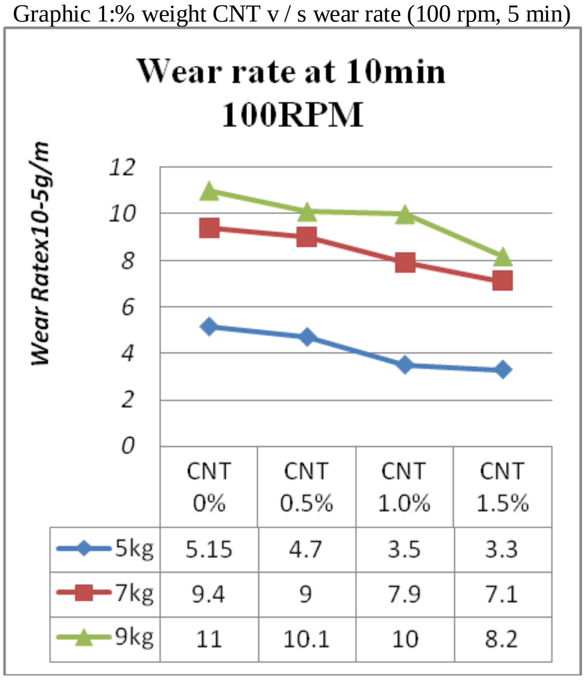
4.1 Wear test

The study of wear is defined as the loss of material due to abrasion, adhesion, erosion or other types of wear mechanisms. This is a fundamental phenomenon that occurs between two surfaces that move relative to one another. The wear test is carried out with the pen on the disk wear testing machine. A typical pen is cylindrical in shape with a diameter of 8 mm and a length of 20 mm. A typical disk is 180 mm in diameter and 12 mm in thickness. The disc is ground to give a surface roughness of 0.8 micrometers. The disc is made of highly polished EN-25 steel. During the wear test, the pin sample's wear loss is measured in micrometers.

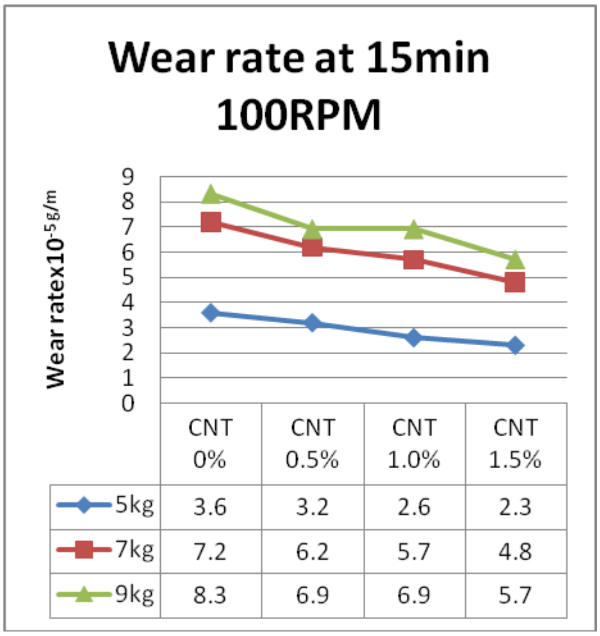
Fig. 7 testing machine for pin wear



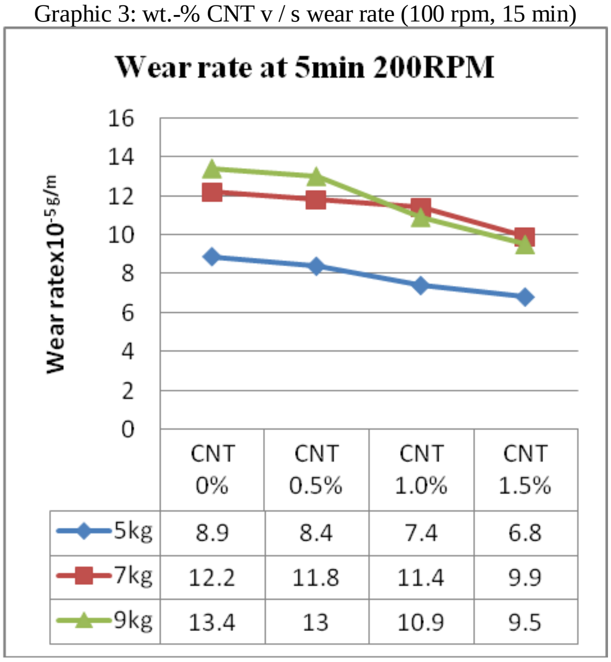
Graphic 1:% weight CNT v / s wear rate (100 rpm, 5 min)



Graphic 2: wt.-% CNT v / s wear rate (100 rpm, 10 min)



Graphic 3: wt.-% CNT v / s wear rate (100 rpm, 15 min)



Graphic 4:% by weight CNT v / s wear rate (200 rpm, 5 min)

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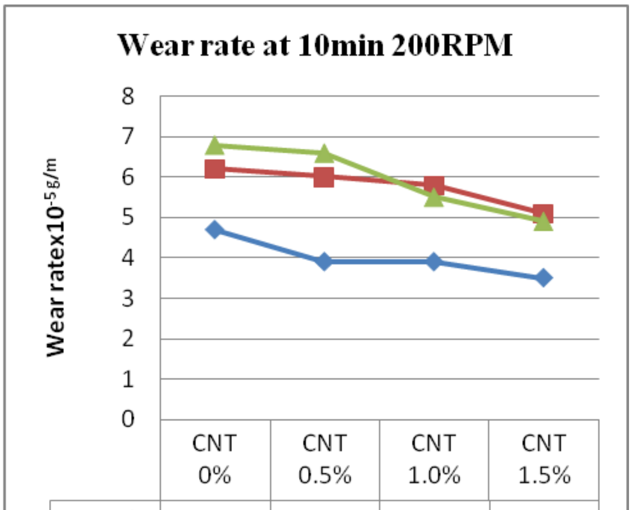
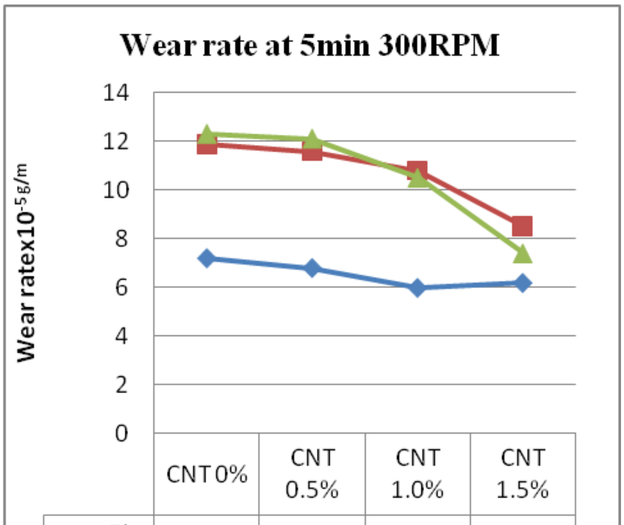


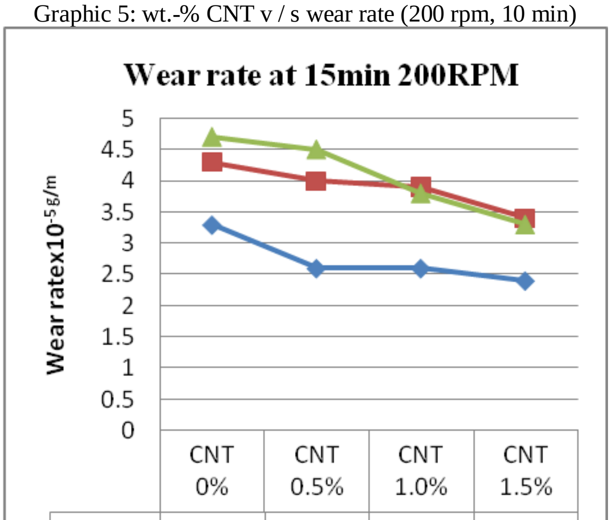
	CNT 0%	CNT 0.5%	CNT 1.0%	CNT 1.5%
5kg	4.7	3.9	3.9	3.5
7kg	6.2	6	5.8	5.1
9kg	6.8	6.6	5.5	4.9

Graphic 5: wt.-% CNT v / s wear rate (200 rpm, 10 min)



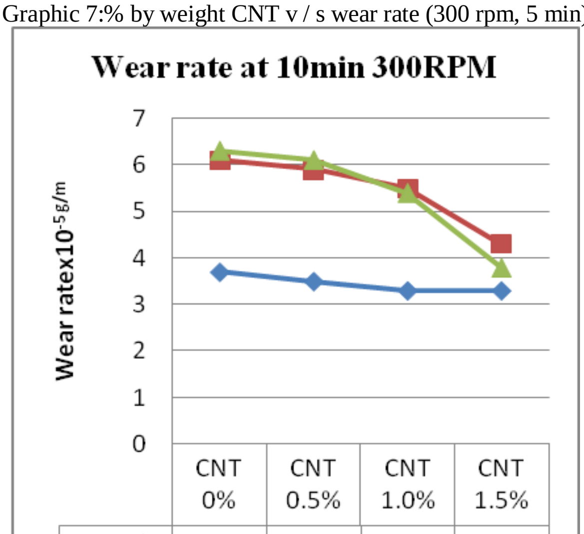
	CNT 0%	CNT 0.5%	CNT 1.0%	CNT 1.5%
5kg	7.2	6.8	6	6.2
7kg	11.9	11.6	10.8	8.5
9kg	12.3	12.1	10.5	7.4

Graphic 7:% by weight CNT v / s wear rate (300 rpm, 5 min)



	CNT 0%	CNT 0.5%	CNT 1.0%	CNT 1.5%
5kg	3.3	2.6	2.6	2.4
7kg	4.3	4	3.9	3.4
9kg	4.7	4.5	3.8	3.3

Graphic 6:% by weight CNT v / s wear rate (200 rpm, 15 min)



	CNT 0%	CNT 0.5%	CNT 1.0%	CNT 1.5%
5kg	3.7	3.5	3.3	3.3
7kg	6.1	5.9	5.5	4.3
9kg	6.3	6.1	5.4	3.8

Graphic 8:% by weight CNT v / s wear rate (300 rpm, 10 min)

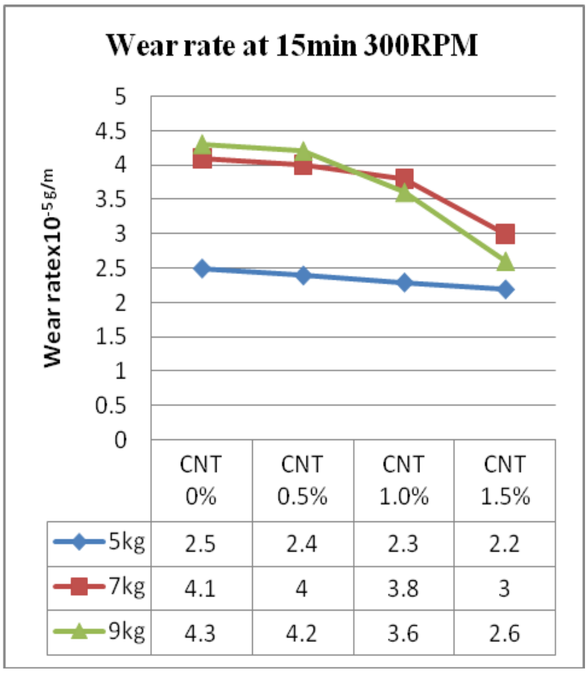


Diagram 9: wt .-% CNT v / s wear rate (300 rpm, 15 min)

The changes in the average wear rate versus the weight fraction of the CNTs for sliding in the steady state at various loads are shown in the graph. The wear rate value for the composite decreased as the load applied increased and the percentage of CNT increased. The wear rate of the test materials is defined as the total mass loss divided by the total creepage distance. Composites with a weight fraction of CNT between 1.0 and 1.5 wt .-% show a lower porosity. Increasing the weight percentage of CNTs decreases the rate of wear of the composites. It can be seen from Figure 9 that the wear rates of these composites decrease as the weight fraction of CNT, the speed (300 rpm) and the contact time (15 minutes) increase.

V. CONCLUSION

- The copper matrix and the CNT-reinforced composite were successfully developed through powder metallurgy.
- The composite showed a lower coefficient of friction with the reinforced copper alloy, and the coefficient of friction decreased slightly as the weight fraction of the CNTs increased.
- Due to the effect of reinforcing and reducing friction, the rate of wear of the composite decreased as the weight fraction of CNTs increased at lower and intermediate loads.
- The dispersion of the metal powder depends on the compaction and the sintering process can be influenced by the SEM analysis.

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