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THERMAL CONDUCTIVITY AND WEAR BEHAVIOUR OF COPPER MATRIX COMPOSITES REINFORCED WITH CARBON NANOTUBES USING POWDER METALLURGY ROUTE

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AUTHOR'S DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Teknologi MARA. It is original and is the results of my own work, unless otherwise indicated or acknowledged as referenced work. This thesis has not been submitted to any other academic institution or non-academic institution for any degree or qualification.

I, hereby, acknowledge that I have been supplied with the Academic Rules and Regulations for Post Graduate, Universiti Teknologi MARA, regulating the conduct of my study and research.

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ABSTRACT

Recently, carbon nanotubes (CNTs) reinforced with metal matrix composites (MMCs) have attracted an increasing interest due to their promising properties. One of the challenges in metal matrix-CNTs composites research is producing a uniform dispersion of CNTs. A poor dispersion of CNTs within the matrix, attributed to strong CNTs entanglement caused by Van der Waals forces. In this study, acid treatment process was used to obtain homogenously dispersed CNTs in Cu powder for preparing Cu/CNTs composites. In this treatment process, a mixture of sulphuric acid (H_2SO_4) and nitric acid (HNO_3) was used with the ratio of 3:1. The comparison between pristine CNTs (PCNTs) and acid treated CNTs (ACNTs) was done using FT-IR, TEM and FESEM. The dispersion stability of the CNTs in distilled water was also investigated. The result showed that after treatment, the ACNTs exhibited better dispersion and less agglomeration compared to PCNTs. Powder metallurgy method was used in fabricating Cu/CNTs composites. The process comprised of mixing Cu powder with CNTs, compacting of the powder mixture to form green parts and sintering in an argon atmosphere. The green body was initially heated isothermally at 100°C for 1 hour with heating rate of 1.0 °C/min and sintered at a temperature of 900°C for 2 hours with heating rate of 0.5 °C/min. The composites contained 0 to 4 vol% of PCNTs and ACNTs, respectively. It was observed that as the CNTs content increased, the density of the composites was also decreased owing to low density of the CNTs. Besides, the shrinkage volume of the composites also inversely proportional with the CNTs content ranging from 12.41% to 17.02% (Cu/PCNTs) and 13.36% to 19.30% (Cu/ACNTs). The microstructure of the Cu/CNTs composites was evaluated via SEM. Big pore size distributions of Cu/PCNTs were visible at few locations due to the agglomeration and cluster of CNTs at certain area. While for Cu/ACNTs, the grain growth occurred between the particles and porosity was observed leads to the scattering pores due to the scattered dispersions of the treated CNTs.The correlation between the density, thermal conductivity, hardness and wear properties of the sintered Cu/CNTs were studied. For thermal conductivity of Cu/CNTs composites, the results showed that the thermal conductivity decreased after the incorporation of CNTs. The analysis revealed that the interfacial thermal resistance between the Cu matrix and CNTs plays a significant role in determining the thermal conductivity performances. Besides, the influences of porosity and distribution of CNTs also affected the thermal conductivity results. While for hardness and wear behaviour, the results showed that composite with 3%ACNTs exhibited a higher hardness value of 115.99 HV, 55.0% greater than the pure Cu resulting lower coefficient of friction (COF) which 41.0% lower in comparison with pure Cu and 23% lower compared to Cu/PCNTs . This study demonstrated that the properties of carbon nanotubes can be tailored by acid treatment process which can improved the properties of the composites.

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CHAPTER ONE
INTRODUCTION

1.1 RESEARCH BACKGROUND

Applications of composite materials have been found in many areas of daily life and have become an important material in modern technologies. Composite is made up of at least two or more materials where the mixture provides better properties than its constituent. The composites consist of a matrix with one or more physical distinct and distributed phases known as reinforcements. These reinforcements give the desired properties to the composites such as toughness, strength, thermal conductivity, electrical conductivity, wear resistance and others (Agarwal et al., 2011). In recent years, metal matrix composites (MMCs) have been widely investigated such as aluminium-matrix composites, nickel-matrix composites and copper-matrix composites (A. Absawy, 2014; Pham et al., 2011; Bakshi et al.,2010).

A major consideration for the production of MMCs based on copper (Cu) is widely used in the electrical applications and bearing materials due to their excellent thermal and electrical conductivity properties (Kainer, 2006). They are often mixed with graphite and compacted to form the electrical brushes that carry current in electric motors (Pease and West, 2002). Figure 1.1 shows a schematic diagram of a cross-sectional view of electrical brushes used in electrical component and Figure 1.2 shows the example of worn brush. During sliding the electrical brush contacted on the copper commutator in order to transform electrical energy into mechanical energy, wear of both components occurred which should be considerably low to allow long services life of the motor. In most applications, the brush life need to be maximized to avoid excessive replacements of brush which leads to higher operating and maintenance cost. An appropriate brush material with the desired properties must be selected to enhance the life of the brushes. Some of the common failure in electrical motor concerning of (Coupar, 2012; Hall et al., 2010; Heidenfelder, 2001) :

i) Brush damage due to thermal stability and electrical performances
ii) Copper dragging due to commutator wear
iii) Arcing across the commutator