UNIVERSITI TEKNIKAL MALAYSIA MELAKA

CARBON NANOTUBES RELATED TO CARBON STEEL

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Engineering Materials) with Honours.

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Engineering Materials) with Honours. The member of the supervisory committee is as follow:

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ABSTRAK

Keluli karbon adalah salah satu bahan yang paling banyak digunakan dalam industri. Bahan ini digunakan tidak hanya dalam banyak tekanan wap air dan mengandungi sistem penjanaan kuasa tetapi juga dalam menyokong sesuatu sistem. Tiub nano karbon memiliki sejumlah besar aplikasi dalam bidang kejuruteraan bahan, elektronik, pembebasan lapangan, biologi, perubatan, dan elektrokimia. Projek ini untuk mempelajari tentang 'carbon nanotubes steel' dengan menggunakan serbuk 'multi-wall carbon nanotubes' (MWCNTs), fokus pada perubahan sifat mekanik dan struktur mikro. Persiapan Sampel yang melibatkan kaedah metalurgi serbuk di mana pencampuran serbuk ferit murni dengan serbuk MWCNTs dan pengikat. Tiga (3) sampel yang berbeza peratusan berat 'multi wall carbon nanotubes' (MWCNTs) (0wt.%, 0.025wt. % and 0.075wt.%) dan dua (2) suhu 'sintering', (900 º C dan 1000 º C) sebagai pembolehubah. Kemudian, sampel akan dipadatkan untuk membentuk 'green body'. Sampel akan disinter dalam tungku untuk membentuk 'dense body'. Teknik ujian yang telah dilakukan adalah 'Macro-Rockwell hardness', 'X-Ray Diffraction' (XRD), 'Scanning Electron Microscopy' (SEM). 'Macro-Rockwell hardness' digunakan untuk menentukan kekerasan 'carbon nanotubes steel', 'X-Ray Diffraction' (XRD) pula digunakan untuk menganalisis tahap dalam sampel dan 'Scanning Electron Microscopy'(SEM) untuk menganalisis struktur mikro.

ABSTRACT

Carbon steel is one of the most widely used materials in the industry. This material is used not only in many of the water and steam-pressure containing systems in power plants but also in the supports for these systems. Carbon nanotubes have a vast amount of applications in the fields of materials, electronics, field emission, biology, medicine, and electrochemistry. This project to study carbon nanotube steel using multi-wall carbon nanotubes (MWCNTs) powder, focusing on mechanical properties alter and microstructure. Sample preparation will involved powder metallurgy method where mixing of pure ferrite powder with MWCNTs powder and binder. Three(3) different sample weight percentages of multi-wall carbon nanotubes (MWCNTs) (0wt.%, 0.025wt. % and 0.075wt.%) and two (2) sintering temperature, (900 ºC and 1000 ºC) as the variable. Then, the sample will compacted to form green bodies. Sample will be sintered in the furnace to form dense body. Mechanical testing that been carried out are Macro-Rockwell hardness, X-Ray Diffraction (XRD) and Scanning Electron Microscopy (SEM). Macro-Rockwell hardness test use to determine hardness of carbon nanotubes steel, X-Ray Diffraction use to analysis the phases in the sample and scanning electron microscope (SEM) for microstructure analysis.

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DEDICATION

For my beloved mom, dad, family and dearest friends

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LIST ABBREVIATION

SWNTs	-	Single-Walled Nanotubes
MWCNTs	-	Multi-Wall Carbon Nanotubes
CNTs	-	Carbon Nanotubes
PM	-	Powder Metallurgy
Min	-	Minute
T	-	Temperature
MPa	-	Mega pascal
SEM	-	Scanning Electron Microscope
XRD	-	X-Ray Diffraction
UNS	-	Unified Numbering System
DINs	-	Deutsches Institut für Normung
CENs	-	European Committee for Standardization
ASME	-	American Society of Mechanical Engineers
AISI	-	American Iron and Steel Institute
ASTM	-	America Standard for Testing Material Standard
BISRA	-	The Corporate Laboratories of the British Steel Corporation
EDS	-	Energy Dispersive X-ray Spectroscopy

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Carbon nanotubes are allotropes of carbon with a cylindrical nanostructure. Nanotubes have been constructed with length to diameter ratio of up to 132,000,000:1 which is significantly larger than any other material. These cylindrical carbon molecules have novel properties which make them potentially useful in many applications in nanotechnology, electronics, optics and other fields of materials science, as well as potential uses in architectural fields. They exhibit extraordinary strength and unique electrical properties, and are efficient thermal conductors (O'Connell, et al., 2006).

Nanotubes are members of the fullerene structural family, which also includes the spherical buckyballs. The ends of a nanotube may be capped with a hemisphere of the buckyball structure. Their name is derived from their size, since the diameter of a nanotube is on the order of a few nanometers (approximately 1/50,000th of the width of a human hair), while they can be up to 18 centimeters in length. Nanotubes are categorized as single-walled nanotubes (SWNTs) and multi-walled nanotubes (MWNTs) (O'Connell, et al., 2006).

Carbon nanotubes, also known as CNTs, are cylindrical tubes of carbon, typically around one nanometer (10^{-9}meters) in diameter. They can be at most a few millimetres long, however advancements are constantly being made to increase their length. In order to understand the structure of carbon nanotubes, one must first consider carbon's other more common allotropes. The two main molecular structures of carbon are diamond and graphite. In diamond, carbon forms a regular crystal lattice which is the source of diamond's legendary strength. Conversely, when in the graphite form carbon creates repeating layers of hexagonal structure. Carbon nanotubes can be visualized as rolled-up layers of graphite, however this is not a good representation when considering the nanotubes properties and synthesis. In recent years, advances in nanotechnology have allowed for the creation of a new form of carbon, the buckminsterfullerene, or fullerene for short. Fullerenes are molecular spheres, containing upwards of 60 carbon atoms, with the smaller amounts being more common. Carbon nanotubes are, in essence, fullerenes extended into a tube. In fact, most nanotubes have a 'cap' at one or both ends, which is a hemisphere fullerene. The carbon nanotube's unique shape grants it many interesting and useful properties that are not seen in other materials. One such property is its variable conductance. Based on the direction that a carbon nanotube is 'rolled', it will have electrical properties varying from a metallic conductor 1000 times more efficient than copper to a semiconductor (Collins). This occurs because electrons travelling through the tightly rolled graphite sheet interact with one another in ways that can either assist or inhibit flow, depending on the arrangement of molecular bonds (Kasra Daneshvar, 2007)

An additional property of the carbon nanotube that has a myriad of useful applications is its thermal conductance. Nanotubes exhibit a characteristic known as ballistic conduction along their length, which makes them extremely high efficiency conductors along their axis but insulators against their axis. Ballistic conduction is a property of crystalline structures, and it occurs because of the ease of electron flow through the nanotube. In the diagram to the left, red arrows represent the direction that heat can travel easily, and blue arrows represent the direction in which CNTs act as thermal insulators. The superior linear heat conductance of carbon nanotubes is likely to be used in microelectronic circuits, where heat needs to be dissipated in small spaces, and in heat sinks for electric motors. The insulator property of carbon nanotubes along any direction other than their lengths is very useful in that it allows heat to be directed with minimal loss (Min-Feng et al.,2000).

As with any new material, mass production is of primary concern if carbon nanotubes are to become commonplace in modern technology. Pure single-walled carbon nanotubes are highly expensive, usually 50-100 dollars per gram, but advances are constantly being made. There are currently three main methods of CNT synthesis in use, arc discharge, laser ablation, and chemical vapor deposition. Arc discharge was the first widely used method of CNT creation, and its accidental discovery by Sumio Iijima (1991) brought carbon nanotubes into the scientific realm as an upcoming nano material (Sumio Iijima, 1991).

1.2 Problem Statement

Carbon steel is one of the most widely used materials in the industry. This material is used not only in many of the water and steam-pressure containing systems in power plants but also in the supports for these systems. This research concentrates primarily on the containing applications of carbon steels, with its use in fabrication of structural components based on carbon. From previous researches, it is identified that carbon steel have the distinctive qualities by preparing carbon nanotubes steel using multi-wall carbon nanotubes powder (MWCNTs) as example mild steel, the mild steel used because less research to study the mild steel compare other material like stainless steel, tool steel, alloy aluminum and so on. Thereby, many of the handbook or other journal is not states specify the standard value as the guide for this research. Moreover, this material many used in an industrial application mainly in construction and automotive sector as a main source to produce the product.

This problem statement of carbon steel has poor corrosion resistance for engineering problems and therefore, oxidation need to decrease readily at elevated temperatures. In this task, the carbon steel need to improve by mixed with different percentage of CNTs. This because the readily carbon steel cannot be strengthening without significant loss and low toughness (impact resistance) and ductility .

This study is generally employed for following purpose such as to improve mechanical ability, to change or refine grain size, to improve mechanical properties like hardness and ductility. That way, this research concentrate on the Microvicker hardness test, X-ray diffraction test and microstructure test to obtain various collection data before it can be evaluate to determine the result compare with the standard data of mild steel as comparison. The expected result (general mild steel) that included in this research is based from The Corporate Laboratories of the British Steel Corporation (BISRA) and other sources are American Iron and Steel Institute (AISI) and America Standard for Testing Metarial standard data provided by (ASTM).

1.3 Objectives

The main objectives of this study is :

i. To analyzed mechanical properties carbon nanotubes steel using carbon nanotubes multi-wall (MWCNTs).
ii. To study the effect of sintering temperature and addition MWCNTs produced compaction by manually hydraulic press.
iii. To study the microstructure and phases present in the carbon steel samples produced.

1.4 Scope of study

i. To compare mechanical properties of virgin pure ferrite powder with carbon nanotubes steel using carbon nanotubes multi-wall (MWCNTs).
ii. Study the preparation of carbon nanotubes steel using carbon nanotubes multi-wall (MWCNTs).

1.5 Research Methodology

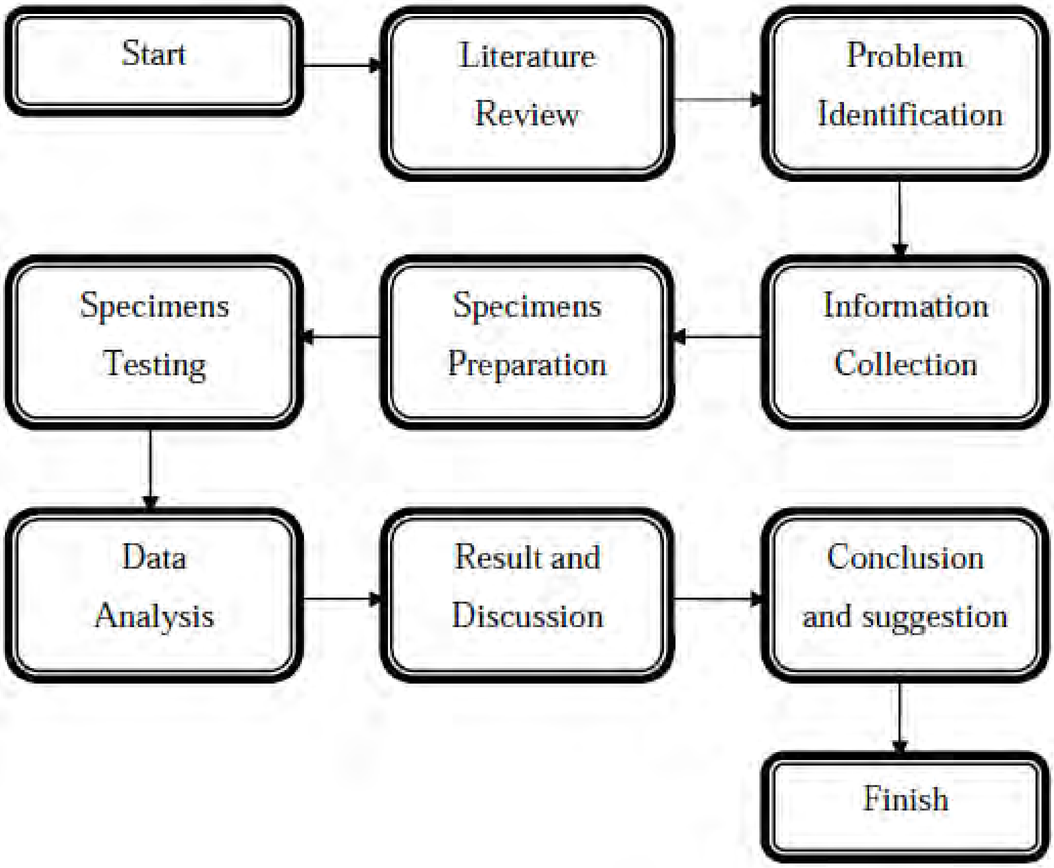

Figure 1.1: The Methodology Structure

In material selection process, it is establishing the link between material and function. It is important to start with the full menu materials in mind and failure to do so many mean a missed opportunity according by Michael (2005, p. 80). Figure 1.1 shows the project methodology which used in this study. The objectives and scopes of the project were defined at the beginning of the project. Literature review was done to understand the nature of the project and also involve the experiment and the scope study. The objective of the project was defined by the experiment.

CHAPTER 2

LITERATURE RIVIEW

2.1 Introduction of Carbon Nanotubes

Carbon nanotubes are hollow cylinders of graphite carbon atoms. (O'Connell M, 2006.) These tubes are on the nanoscale (10^{-9} m), which is so small that 10,000 of them could fit in the width of 1 human hair (NanoNY, 2007). Since their discovery in 1991 by Iijima, the synthesis, properties and applications of carbon nanotubes have become a major research area due to their unique properties. They provide the highest Young's modulus (or stiffness), highest thermal conductivity, highest electrical conductivity and highest current density of any known material, while having a low density (Baddour, C.E and Briens, C. 2005).

With such special properties, carbon nanotubes have a vast amount of applications in the fields of materials, electronics, field emission, biology, medicine, and electrochemistry. This paper will focus on carbon nanotubes in composite materials.

2.2 Types of Carbon Nanotubes (CNTs)

Carbon nanotubes come in two forms, as single-walled carbon nanotubes and multiwalled carbon nanotubes. Single-walled carbon nanotubes have cylinder walls one molecule thick, and multi-walled carbon nanotubes have several single-walled carbon nanotubes embedded inside one another (O'Connell, M, 2006). Figure 1 is a photo of a multi-walled carbon nanotube underneath a microscope.

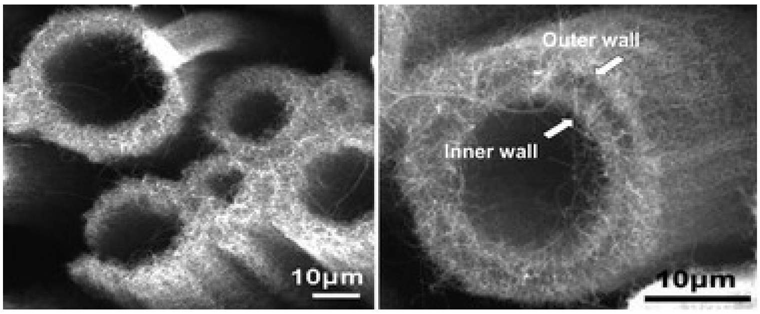

Figure. 2.1 : Multi-walled carbon nanotubes underneath a microscope.
(Royal Society of Chemistry Publishing, 2007).

Sumio Iijima discovered single-walled carbon nanotubes in 1991. (O'Connell, M. et al., 2006) Single walled carbon nanotubes tend to be stronger and more flexible than their multi-walled counterparts. One reason that multi-walled carbon nanotubes are weaker, is because the individual cylinders slide inside one another. Single-walled carbon nanotubes are also better electrical conductors and are more transparent. However, their production is difficult and they are challenging to purify. Single-walled carbon nanotubes are also more expensive to make (single-walled carbon nanotubes cost about $500/g and multi-walled carbon nanotubes cost about $10/g) by O'Connell, M. (2006) and this may not change until there is a large-scale market for single-walled carbon nanotubes. Currently, multi-walled carbon nanotubes are more widely used in composite materials than single-walled carbon nanotubes for these reasons (O'Connell, M, 2006).

2.3 Examples of Uses For Carbon Nanotube Composites

When carbon nanotubes are added to a matrix material, the newly formed composite will take on some of the properties of the carbon nanotubes. Some selected current applications are below.

i. *Sporting Equipment.* Carbon nanotubes have already been added to sports equipment such as bats, bicycles, golf clubs, and hockey sticks in order to impart more strength and absorb vibrations.
ii. *Displays.* Single-walled carbon nanotubes can be used as transparent conductors, and can be used to make any sort of display from televisions to phones. This is also because they are flexible, can handle large current densities, and have sharp tips that help emit electrons (O'Connell, M, 2006).
iii. *Auto parts.* 60 percent of cars produced today now have fuel lines made with carbon nanotubes. The carbon nanotubes inside the fuel lines are intended to reduce the risk of explosions by inhibiting static electricity. Carbon nanotubes are also being put in exterior auto-body parts.
iv. *Conductive polymers.* Normally, polymers are insulators, but when conducting carbon nanotubes are added, the polymer composite becomes conductive. This also makes the polymer more robust (Eindhoven University of Technology, 2003, February 27).
v. *Thermal grease.* Thermal grease is used on computer processors to help conduct the heat away. Nanotubes are being put in the thermal grease to increase the thermal conductivity of the grease, allowing more heat to be removed from the processor (Louisea, A., Petit, P. et. al., 2006).
vi. *Fibers and yarns.* Weaving would allow the carbon nanotubes to be aligned and woven into textile structures that can be used as cables (O'Connell, M, 2006).

2.4 Properties of Nanotubes

Carbon nanotubes have properties unlike any other substance on earth of which we currently know. Even though carbon nanotubes are made out of graphite carbon, they have different properties than bulk graphite because of their size, shape, and crystallography. While carbon nanotubes may have the potential for being the next supermaterial for our society, actually utilizing all of their mechanical, and electrical properties is still an unsolved challenge (O'Connell, M. 2006).

2.4.1 Mechanical

Single-walled carbon nanotubes possess incredible mechanical resistance because their carbon atoms are united by the strongest bonds in nature (σ bonds) (Meyyappan, M ed et al., 2005) and they have a regular crystal lattice. In addition, they are highly flexible, and can be bent repeatedly up to 90° without being damaged (O'Connell, M, 2006). They have a very low density, about 1/6 of the density of steel, (Meyyappan. M, 2005) but are much stronger than steel. If single-walled carbon nanotubes are positioned vertically, with their diameter being normal to a surface, they would have the highest Young's modulus (or stiffness) of any material 1 TPa, (Robertson, J. et al., 2004) which is five times the stiffness of steel. However, this is a theoretical value, and aligning the single-walled carbon nanotubes in such a manner is still a challenge. Putting all of these properties together, one can visualize carbon nanotubes as being the strongest, most ductile material for its weight (O'Connell, M, 2006).

2.4.2 Electrical

Carbon nanotubes have the unique ability to be insulators, semiconductors, or conductors, depending on the way the carbon atoms are arranged. Chirality is the term used to define the "twist" of the single-walled carbon nanotubes and is directly related to the electrical properties (Meyyappan, M. et al.,2005). Carbon nanotubes can have an electrical conductivity up to 1000 times that of copper. If the carbon atoms in the carbon nanotubes are arranged a certain way, they can be almost perfect conductors along their axial direction (almost no electrical resistance) at temperatures close to absolute freezing (-273 °C) (Baddour, C.E and Briens, C, 2005) which is very rare. Given their high thermal conductivity, tolerance for high current density, and sharp tips, carbon nanotubes are the best field emitters of any material, meaning they are ideal for flat panel displays, such as the ones on television, phones, or computers. Single-walled carbon nanotubes can also carry the highest current density of any known material, measured as high as 109 amps/cm_2 (Baddour, C.E and Briens, C, 2005).

2.5 Carbon Nanotubes Composites

When carbon nanotubes are added to a matrix material, the composite will take on some of the carbon nanotubes properties, due to the rule of mixtures (Meyyappan. M, 2005). For instance, plastics are normally insulators, but when conducting carbon nanotubes are added, the plastic can become a semiconductor. Carbon nanotubes can also be added to adhesives or polymers to give the substances enhanced thermal conductivity and improved robustness. Unfortunately, the enhancement from adding carbon nanotubes is modest. In some of the best cases, the measured tensile strength improves ten to twenty percent and the stiffness of the material may double. Companies are not obtaining the theoretical property values of carbon nanotubes in their composites because engineering and manufacturing methods are not yet designed to make fully integrated composites. Currently, carbon nanotubes are used as particulate reinforcement, so the properties of the composite are limited to the rule of mixture. If ways of using more carbon nanotubes in composites were developed, such as in carbon nanotubes fiber reinforced mats, the composites' properties should begin to reach the theoretical values of carbon nanotubes properties. This is a goal of many carbon nanotubes composite companies (Meyyappan. M, 2005).

2.6 Introduction of Carbon Steel

It is important to clarify the meaning of carbon steel in the generic sense and in the more narrow context used in this report. The term steel is usually taken to mean an iron-based alloy containing carbon in amounts less than about 2%. Carbon steels (sometimes also termed plain carbon steels, ordinary steels, or straight carbon steels) can be defined as steels that contain only residual amounts of elements other than carbon, except those (such as silicon and aluminum) added for deoxidation and those (such as manganese and cerium) added to counteract certain deleterious effects of residual sulfur. However, silicon and manganese can be added in amounts greater than those required strictly to meet these criteria so that arbitrary upper limits for these elements have to be set, usually 0.60% for silicon and 1.65% for manganese are accepted as the limits for carbon steel (J. E. Bringas et al., 2002).