UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Manufacturing Engineering

THE INFLUENCE OF PROCESS PARAMETERS OF ELECTROPHORETIC DEPOSITION (EPD) OF CARBON NANOTUBES (CNTs) ON BRASS WIRE FOR ELECTRICAL DISCHARGE MACHINING (EDM)

Mohd Hishamuddin Mikail Lim

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MOHD HISHAMUDDIN MIKAIL LIM

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Alamat Tetap:
220, JALAN DELIMA 2,
TAMAN DELIMA,
09000 KULIM, KEDAH.

Cop Rasmi:
PROF. MADYA DR. NORAIHAM BINTI MOHAMAD
Profesor Madya
Fakulti Kejuruteraan Pembuatan
Universiti Teknikal Malaysia Melaka

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I hereby declare that I have read this dissertation/report and in my opinion this dissertation/report is sufficient in terms of scope and quality as a partial fulfillment of Master of Manufacturing Engineering (System Engineering).

Signature : ....

Supervisor Name : PROF. MADYA DR. NORAIHAM BINTI MOHAMAD
Profesor Madya
Fakulti Kejuruteraan Pembuatan
Universiti Teknikal Malaysia Melaka

Date : 10/8/2017

DEDICATION

To my undenied love father and mother, Mikail Lim and Sapariah Ahmad, and for the Manufacturing Engineering purpose.

ABSTRACT

Recently, the product came from carbon nanotubes (CNTs) are very impressive due to their mechanical, electrical and thermal properties. This can lead to expend the usage of this carbon nanotube composite in many various ways, including the usage inside the advance manufacturing fields, especially on wire electrical discharge machining (WEDM). In WEDM, wire breaks are the main issue to be tackled. This research aims to study the feasibility of processing parameter that would affect the properties of the coated EDM wire with carbon nanotubes (CNTs) through electrophoretic disposition (EPD) process. This wire cutting tools, specifically brass, are being chosen to be the electrode in this process in order to insulate it with CNTs composite. By using Aqueous Solution (CNT/Ethanol) in room temperature, the experiment is conducted and relaying on the process parameters such as polarity and supply voltage used. With the supply DC voltage of 20V, it is sufficient to create the deposition effect on the brass wire. Duration on 30mins are seems relevant enough to allow the deposition process to occur with 0.5mg/L of CNTs. The usage of 0.3% PVA as a binder is optional. With the same distance along the two electrodes it provides the desire deposition compared to the non-linear distance between it. This EPD suspension with the brass wire as the electrode given the Anodic type of EPD. The formation of cylindrical shape of MWCNT with the SEM image deposition on brass wire with Galvanize Iron as the counter electrode creating continuous twisting and bundles of MWCNT. A highly interconnected thin petal-like crystallites, forming relatively large grains in the shape of globular features with size larger than 1μm when Graphite is acting as the counter electrode. Deposition of Galvanize Iron otherwise shows the most excellent deposition when SEM image provides a rearrangement of the MWCNT in a crystallinity of the nano-particles structure.

ABSTRAK

Pada zaman kini, produk yang diperbuat dari tiub karbon nano (CNTs) adalah sangat menarik kerana sifat-sifat mekanik, elektrik dan haba nya. Ini boleh membawa kepada kepelbagaian penggunaan tiub karbon nano komposit ini dalam banyak cara termasuk penggunaan dalam bidang pembuatan termaju, terutamanya pada pemesinan pelepasan elektrik berwayar (WEDM). Di dalam WEDM, wayar pemotong yang putus adalah isu utama yang perlu ditangani. Kajian ini bertujuan untuk mengkaji pengaruh parameter pemprosesan yang akan mempengaruhi daya ketahanan teganggan wayar EDM yang disalut dengan tiub karbon nano (CNTs) melalui proses pemendapan electroporik (EPD). Mata alat wayar pemotongan, khususnya tembaga, telah dipilih untuk menjadi elektrod dalam proses ini untuk menyadur ia dengan CNTs komposit. Dengan menggunakan kaedah akueus (CNT/Ethanol) di dalam suhu bilik, eksperimen ini dijalankan dan bersandaran kepada kutub dan voltan bekalan yang digunakan. Dengan bekalan voltan DC 20V, ia mencukupi untuk mewujudkan kesan pemendapan pada dawai tembaga. Jangka masa 30 minit kelihatan cukup relevan untuk membolehkan proses pemendapan berlaku dengan 0.5mg / L CNTs. Penggunaan 0.3% PVA sebagai pengikat adalah pilihan. Dengan jarak yang sama di sepanjang dua elektrod memberikan pemendapan sekata yang di inginkan berbanding dengan jarak bukan linear di antaranya. Proces EPD ini dengan dawai tembaga sebagai elektrod memberikan jenis EPD Anodik. Pembentukan bentuk silinder MWCNT dengan pemendapan imej SEM pada dawai tembaga dengan Galvanize Iron sebagai elektrod tentangan mejadikan ikatan pintalan berterusan MWCNT. Kelenjar kristal nipis yang saling bersambung dan membentuk butiran yang agak besar dalam bentuk ciri-ciri globular dengan saiz yang lebih besar daripada 1μm apabila Graphite bertindak sebagai elektrod tentangan. Pemendapan Galvanize Iron sebaliknya menunjukkan pemendapan yang paling baik apabila imej SEM menyaksikan penyusunan semula MWCNT dalam struktur crystallinity struktur zarah nano yang teratur.

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Amp	-	Ampere
CNTs	-	Carbon Nanotubes
CVD	-	Chemical Vapor Deposition
DC	-	Direct Current
EDM	-	Electro Discharge Machining
EDP	-	Electropoheric Deposition
GHz	-	Giga Hertz
IACS	-	International Annealed Copper Standard
K	-	Kilo
Mm	-	Millimeters
MWCNT	-	Multi-Walled Carbon Nanotube
N/mm2	-	Newton per millimeters square
PVA	-	Polyvinyl Alcohol
SEM	-	Scanning Electron Microscopic
SWCNT	-	Single-Walled Carbon Nanotube
TPa	-	Terra Pascal
UTeM	-	Universiti Teknikal Malaysia Melaka
V	-	Volt
WEDM	-	Wire-cut Electrical Discharge Machining

CHAPTER 1

INTRODUCTION

1.1 Background of The Study

This research is based on the exploitation of Carbon Nanotubes (CNTs) potential in engineering application. The CNTs are molecular-scale tubes of graphitic carbon, which can be categorized into two types, 1) single walled carbon nanotubes (SWCNT) and 2) multi-walled carbon nanotubes (MWCNT). The CNTs are in the form of cylindrical carbon molecules with different shape and sizes. It exhibits novel properties which make them potentially useful in a wide variety of applications in nanotechnology, electronics, optics and other fields of materials science (Eatemadi et al., 2014). This CNTs are among the stiffest and strongest fibres known, having an outstanding properties such as extraordinary strength and unique electrical properties, and are efficient conductors of heat (Meunier, 2010).

This research is focusing to study the feasibility of coating brass based cutting tool with CNTs via electrophoretic deposition (EPD) method for an advanced machining process; wire cut electrical discharge machining (WEDM). The process parameters and CNTs content for coating brass wire with CNTs will be studied.

1.2 Problem Statement

According to Roger (2007) in his article on improving wire EDM productivity, a systematic approach need to be develop in order to optimize the cutting performance. One of the approach is manipulating the wire used for the application. There are issues which widely reported on the aspect of wire dependency on the cutting performance. The biggest problem to be tackled is wire breaks during operations.

The most significant factor in wire breakage is not the tensile load exerted on the wire, but the flaws created by the sparks which attack the wire's cross section. As the results, it is no guarantee of non-occurrence of wire breakage by having a high tensile strength wire during operation. Coating is known technology or approach that can be utilized to improve properties of engineering materials. It is postulated that possibility of wire breakage can be reduced by external coating layer onto the wire.. This coating will improve the performance of cutting operation and protect the wire from premature failure. The material chosen for the coating are carbon nanotubes which coated on a brass wire through Electrophoretic Deposition (EPD) process. In many cases, high performance coated wires will provide significant performance measured via standard machine settings for established similar type of wires (Roger, 2007).

1.3 Objective of Study

The main objective of this project is to study the feasibility of EPD process parameters using MWCNT/Ethanol solutions to deposit on WEDM brass wire by using different type of polarity and aim for :

i. To determine the electrophoretic deposition (EPD) process parameters and carbon nanotube (CNT) content.
ii. To study the feasibility of the EDP process parameter on the different type of deposition (Anodic and Cathodic) with different type of combination of polarity.
iii. To compare the morphological structure of the CNT on coated brass wire and uncoated brass wire through the different voltage supply.

1.4 Scope Of Study

The study is focusing on optimizing the processing parameters of EPD (type of electrodes, polarity, suspensions and voltage supply) and CNTs content to improve the physical and properties of the CNTs coated brass wire that can be potential to improve the WEDM process. In this study, the brass wire was firstly coated with CNTs via electrophoretic deposition technique at different parameters as well as different CNTs content. Then, the properties of the wires were determined, analysed and evaluated for the performance. The findings were than compared with the properties of the uncoated brass wire. The results were supported with scanning electron microscopy (SEM).

1.5 Significance of Study

To date, there are scare study conducted on CNTs coated brass wire. The closest example was coating the EDM aluminium wire with CNTs (Castro et al., 2011). From their study, it was proven that coating of EDM metal wire can significantly reduce the chance of wire breakage during cutting. This present effort it to explore the possibility of enhancing brass wire performance by CNTs coating. The findings would be valuable contributions to the next generation of non-traditional machining method. It would be useful to improve and elevate the quality of processing and bring a significant impact to non-traditional machining process; especially WEDM industries in the future.

1.6 Research Planning

This research starts with the enhancement of knowledge in the related area by a literature review which conducted on recent technology and application shared via online journals, articles, books, website, lecture notes and standard. Then, the methodology of the whole research works was carefully planned by referring to relevant standard and other research works. It was followed by samples preparation and testing conducted in laboratories. The data from experimental works was gathered from time to time and analysed using SEM. Then, the results were evaluated and the findings were reported to answer the specific objectives of the study.

CHAPTER II

LITERATURE RIVIEW

2.1 Introduction

So far the related topics are found for coating aluminium wire with CNTs (Castro et al., 2010), the use of CNTs in EDM (Prabhu, 2014) and recently a Graphene electrode had been pattern by Roberto Perez and Denis Lyet in 2016 (US20160228964 A1) . EPD is one of the platforms can be used to study the CNTs and its influence parameter. Since pristine nanotubes are insoluble in many liquids such as water, polymer resins, and most solvents, selection of liquid dispersing agent in EPD for CNT are challenging to be determine. Many of previous research had been conducted by using different solution type come out with different result as been state by Boccaccini et al. in 2006. The dispersing agent must be able to mix and blend together with CNTs, making it stable suspension in the EPD process. Because the purpose of this process are to insulate the electrode completely, the EPD is a good process that capable to coating things that having complex shapes. By the theoretical, the voltage charged brass wire acting as electrode will attract the CNTs towards it in the effect of electric fields and helps the CNTs insulate the electrode. The influence parameter of the EPD such as voltage and duration had to be list up base on recent research in order to get different result by manipulating others parameters.

2.2 Carbon Nanotubes (CNTs)

Most of the physical properties of carbon nanotubes derive from graphene. It was first known discover by Radushkevich and Lukyanovich that publish a paper in the Soviet Journal of Physical Chemistry, showing hollow graphitic carbon fibers that are 50 nanometers in diameter (Monthioux, M., 2006). Ever since that, the study of carbons are evolve until research done by Iijima in 1991, which provide a nanotubes synthesize of hollow carbon molecules and determined their crystal structure for the first time in the soot of arc discharge.

Because of many interesting properties that carbon nanotubes exhibit, CNTs have emerged to be one of the most intensively investigated nanostructure materials. Their properties, the strength and flexibility of carbon nanotubes make them potential to be used in controlling other nanoscale structures, which is makes them have a significant role in nanotechnology engineering. The hybridization of carbon builds a layered construction with weak out-of-plane bonding of the Van der Waals form and strong in-plane bounds. Multi-layer of the cylindrical carbon plane with the regular periodic interlayer spacing locate around ordinary central hollow (SWCNTs) made the form of MWCNTs (Eatemadi et al., 2014) as been described in figure 2.1.

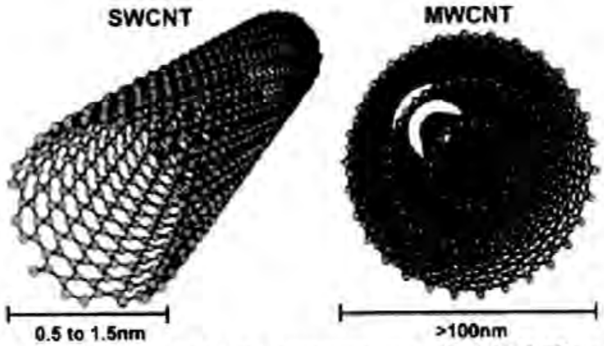

Figure 2.1 : Dimension and physical appearance of SWCNT and MWCNT (source: www.quora.com)

2.2.1 SWCNT and MWCNT Structure

SWCNTs structure is based on a pair of indices (n, m) that will determine the chiral vector and directly have an effect towards electric properties. The number of unit vectors in the honeycomb crystal lattice of graphene along two directions is determined by the integers n and m. Plenty of parameters and vectors will reflect to the nanotubes structure. There are three different forms of SWCNTs such as armchair, chiral and zigzag (Eatemadi et al., 2014) as shown in figure 2.2 .

There is two model of MWCNTs structure, Russian Doll and Parchment. Russian Doll model takes a form when a carbon nanotube contains another nanotube inside it and the outer nanotube has a greater diameter than thinner nanotube. But in case of Parchment model, a single graphene sheet is wrapped around itself manifold times, the same as a rolled up scroll of paper. Because of the multilayer nature of MWCNTs, the outer walls can not only shield the inner carbon nanotubes from chemical interactions with outside substances but also present high tensile strength properties, which do not exist in SWCNTs (WanderWal, 2003).

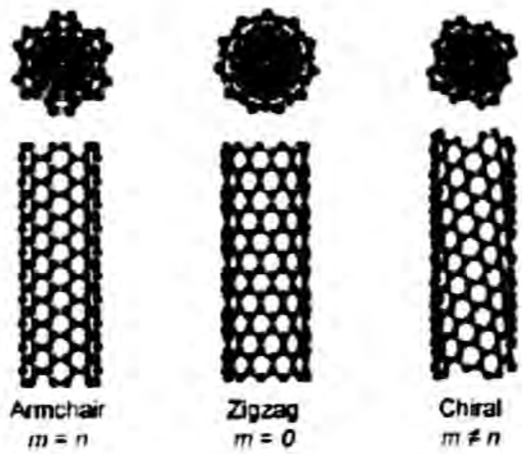

Figure 2.2 : SWCNT structure. Armchair, Zigzag and Chiral.(Source: MRSEC Education Group - University of Wisconsin–Madison)

2.2.2 Synthesis Method of CNT

Their superlative mechanical properties make them the filler material of choice for composite reinforcement from virtually the moment nanotubes that they would display by analogy with graphite (Coleman et al., 2006). The properties of the CNTs will different depend on the processing methods to synthesis it as been shown by Eatemadi et al. (2014).

The remarkable of its properties resulting by the synthesis method creates a wide application usage in nano technology, including in bio medical. This is because the manipulation of individuals CNT through the synthesis methods that change the structure, surface area, surface charge, size distribution, surface chemistry and agglomeration state as well as purity of it having significant impact towards the reactivity of carbon nanotubes. Thus, this manipulation can be play in order to change the properties of carbon nanotubes that we desire accordingly that suit for specific usage.

Common technique or synthesis method that been used to produce CNT by using chemical vapour disposition (CVD), laser ablation and arc discharge as can be refer at table 2.1. The technique used in high temperature at the beginning on the discovery of CNT synthesis but currently techniques have been substituted by low temperature chemical vapour deposition (CVD) methods (<800°C), since the nanotube length, diameter, alignment, purity, density, and orientation of CNTs can be accurately controlled in the low temperature chemical vapour deposition (CVD) methods (Ganesh, 2013).