SURFACE MODIFICATION OF MILD STEEL USING POWDER METALLURGY (PM) CU ELECTRODE

SITI NURADIBAH BINTI ZAINAL ABIDIN
B051510181

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

by

SITI NURADIBAH BINTI ZAINAL ABIDIN

B051510181

960702-01-5652

FACULTY OF MANUFACTURING ENGINEERING

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I hereby, declared this report entitled "Surface Modification of Mild Steel Using Powder Metallurgy (PM) Cu Electrode" is the result of my own research except as cited in references.

Signature : ……………………………………

Author's Name : SITI NURADIBAH BINTI ZAINAL ABIDIN

Date : 1 June 2019

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Degree of Manufacturing Engineering (Hons). The member of the supervisory committee is as follow:

……………………..

(Professor Madya Dr. Liew Pay Jun)

ABSTRAK

Salutan Discaj Elektrik (EDC) telah digunakan secara meluas dalam meningkatkan permukaan bahan di mana unsur-unsur yang berbeza dengan sifat yang lebih baik akan disalut ke permukaan bahan kerja untuk meningkatkan mikrokekerasan, memperbaiki kekasaran permukaan, serta mempertingkatkan rintangan kakisan. Mesin EDM *Die Sinker*, Sodick AQ35L telah digunakan untuk menjalankan ujikaji. Objektif utama kajian ini adalah untuk mengkaji kesan parameter EDC pada lapisan pengendapan, mikrokekerasan, dan komposisi unsur lapisan pengendapan di atas permukaan yang telah disalut menggunakan elektrod tembaga kaji logam serbuk (PM). Dalam kajian ini, dua parameter telah digunakan iaitu arus puncak (I_p) dan *pulse on-time* (T_{on}). Pelbagai teknik pencirian seperti SEM, dan EDS telah digunakan untuk mengkaji topografi, dan kewujudan bahan-bahan yang berlainan di atas permukaan bahan kerja. Sementara itu, mikrokekerasan permukaan yang telah disalut dikaji menggunakan mesin uji mikrokekerasan. Analisis yang telah dilakukan menunjukkan bahawa unsur tembaga daripada elektrod tembaga diperbuat menggunakan teknik kaji logam serbuk dan karbon daripada cecair dielektrik telah berjaya digunakan untuk pengendapan di atas permukaan keluli lembut yang telah dapat meningkatkan mikrokekerasan sebanyak 64% apabila parameter I_p = 10 A and T_{on} = 15 μs digunakan.

ABSTRACT

Electrical discharge coating (EDC) technology has been widely used in improving the surface of a material where different elements with better properties will be coated onto the surface of the workpiece to increase microhardness, enhance the surface roughness, as well as elevating its corrosion resistance. EDM die sinker machine, Sodick AQ35L is used to run the experiment. The main objective of this study is to investigate the effect of the EDC parameters on the deposition layer, micro-hardness, and weight percentage of copper on the coated surface using powder metallurgy (PM) copper electrode. In this study, two parameters, which are peak current (Ip) and pulse on-time (Ton) were selected. Various characterisation techniques such as SEM, and EDX were used to discover the topography, and existence of deposited materials on the workpiece surface. Meanwhile the micro-hardness of the coated surface is observed by using a Micro Hardness Testing Machine. The results show that copper element from PM copper electrode and carbon from dielectric fluid have successfully deposited onto the surface of mild steel which improved the micro-hardness value by 64.63% when I_P = 10 A and T_{on} = 15 µs was used

DEDICATION

Only

my beloved father, Zainal Abidin Bin Annuar

my appreciated mother, Latifah Binti Mohd Shahar

my adored sisters and brother,

for giving me moral support, money, cooperation, encouragement and also understandings

Thank You Very Much

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In the name of ALLAH, the most gracious, the most merciful, with the highest praise to Allah that I manage to complete this final year project successfully without difficulty.

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LIST OF ABBREVIATIONS

BPR	-	Ball to Powder Ratio
CNF	-	Carbon Nano Fibre
CNT	-	Carbon Nano Tube
CVD	-	Chemical Vapour Deposition
EDC	-	Electrical Discharge Coating
EDM	-	Electrical Discharge Machining
EDS	-	Energy Dispersive Spectroscopy
EDX	-	Energy Dispersive X-ray
HAZ	-	Heat Affected Zone
HRB	-	Rockwell B Hardness Number
HV	-	Vickers Hardness
MDR	-	Material Deposition Rate
MH	-	Micro-hardness
MTR	-	Material Transfer Rate
PCA	-	Process Control Agent
PM	-	Powder Metallurgy
PVD	-	Physical Vapour Deposition
SBF	-	Stimulated Body Fluid
SEM	-	Scanning Electron Microscopy
SR	-	Surface Roughness

LIST OF SYMBOLS

wt. %	-	Weight Percentage
I_p	-	Peak Current
Ton	-	Pulse On Time
Toff	-	Pulse Off Time
A	-	Ampere
µs	-	Microsecond
τ	-	Duty Factor
^oC	-	Degree Celsius
kN	-	Kilo Newton
MPa	-	Mega Pascal
%	-	Percent
V	-	Voltage
min	-	Minute
µm	-	Micrometers
V/m	-	Volt Per Meter
mm	-	Millimetres
kg/m^3	-	Kilogram Per Meter Cube
g/min	-	Gram Per Minute
mg/min	-	Milligram Per Minute
kgf/cm^2	-	Kilogram Force Per Centimeter Square

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Recently, the studies on the Electrical Discharge Machining (EDM) has been developing rapidly in the scope of metal processing technologies like cutting, shaping, and surface coating. EDM is one of the earliest non-conventional machining processes to make moulds, dies, and also being used for finishing parts for aerospace and automotive industry and surgical components. By using EDM, any desired shape even the most complicated one can be machined with the experienced operator to operate the machine. The main components in every EDM process are servo control, electrode, and dielectric fluid (Payal et al., 2003).

A new method of using EDM has been developed to improve surface of a material by coating mechanism which is called as Electrical Discharge Coating (EDC), where it adapted the EDM mechanisms to encourage the material deposition from the tool electrode onto the surface of the workpiece. The tool electrode that is usually used in EDC is made of Powder Metallurgy (PM) technique, where the electrode can be green compact, semi-sintered, or fully sintered electrode. During the process, current flow through the electrode causing ionisation with a temperature of more than 7726.85^{o}C where local melting and vaporisation of electrode and workpiece takes place in the sparking gap (Bröcking et al., 2015).

1.2 Problem Statement

Nowadays, metals manufacturing industries are increasing and growing rapidly to produce more metal-based materials. A lot of the industries have been using mild steel as a die, mould, base plate, fixtures, rings, automotive, gears, and machinery parts because of its properties such as consistent hardness, high tensile strength, and less expensive when compared to other materials (CES EduPack, 2010).

Mild steel is a ferrous metal that contain maximum of 0.25% of carbon (CES EduPack, 2010) and is prone to oxidation which will lead to rust, thus it often wear faster that it should. Dey et al. (2018) stated that corrosion of metal especially iron and steel is a serious problem. Due to mild steel composition is mostly iron, it can rust easily when oxidation occur where it become very brittle and flakes off the surface and constantly exposing a new surface. This lead to the need of corrosion protection on the surface of the steels to ensure its safety besides reducing the cost associated with corrosion (Vernhes et al., 2013).

Often when the mild steel starting to rust and wear, it will be disposed and replaced with a newly produce ones without figuring out ways to actually improve it so that it can be used for a longer period of time. This will also indirectly causing the industries to spend more money on buying new products with the same material.

Hence, this research will focus on improving the surface of mild steel by using EDC. The effects of EDC parameters on the composition of deposited element on the coated surface, deposition layer, and micro-hardness were investigated.

1.3 Objectives

The objectives for this research are:

i. To fabricate the copper electrode using Powder Metallurgy (PM) technique.
ii. To investigate the effect of EDC parameters on the composition of deposited element on the coated surface, deposition layer, and micro-hardness using PM copper electrode.

1.4 Scope

This research is carried out to focus on the effect of EDC parameters on deposition layer , micro-hardness of coated surface and composition of the deposited element on the coated surface of mild steel using PM copper electrode. EDM machine, Sodick AQ35L with kerosene as the dielectric fluid was used for the experiment. The copper electrodes in this study were fabricated using PM method which involved mixing, compaction, and sintering. The parameters used in this research included peak current (I_p) and pulse on-time (T_{on}) while the discharge voltage (V), pulse off time (T_{off}), and machining time (min) are constant. Other responses like material deposition rate, microcracks, and surface hardness will not be covered in this research.

1.5 Importance of Study

The findings of this study will rebind to benefit of the industries that widely uses mild steel as the machinery parts, in order to improve the corrosion resistance and prolong the life of the parts where it can also result in decreasing the amount of waste. This study will also help in observing the influence of machining parameters such as peak current and pulse on time on the material deposition layer thickness, corrosion resistance, and composition of the machined workpiece. Thus, the industries can later apply the recommended approach derived from the outcomes of this study in their manufacturing or machining processes.

1.6 Organization of the Report

This research consists of few chapters that will start with chapter 1 which is the introduction, chapter 2 is the literature review, chapter 3 will discuss on the methodology, chapter 4 will discuss on the result and discussion of the experiment, and chapter 5 will discuss on the conclusion of this research.

Chapter 1: Introduction
This chapter discusses the background of the study that includes the elaborated explanation on the title of the research. Problem is identified and observed through a thorough literature review. This followed by objectives need to be achieved throughout the conducted research period and scope that narrows down to the specific area of the research. The effect of this research to the industry is also stated.

Chapter 2: Literature Review

This chapter includes the detail explanation regarding the research topic and previous studies conducted from the journal, article, book, and internet. The usual parameter used as well as different responses being observed is explained. Lastly, the detailed information about the material being used as electrode and workpiece is also included.

Chapter 3: Methodology

This chapter will explain the techniques and design of experimental research methodology employed in this study. By taking into consideration the availability of various research techniques the pros and cons, several research methods that have been selected will be discussed.

Chapter 4: Results and Discussion

This chapter provides a discussion of the main findings from the research and links the literature review that has been conducted to the results.

Chapter 5: Conclusion

This chapter summarised the research that has been done and drawn a conclusion on whether the objectives of this research is achieved.

CHAPTER 2

LITERATURE REVIEW

2.1 Electrical Discharge Machining (EDM)

Electrical discharge machining (EDM) is often recognized as spark erosion machining where it uses a series of fine, electrical discharges or sparks to erode the workpiece material (Bralla, 2007). A full functioning EDM system consists of a power supply, a servo system which is servo and servo control, a dielectric tank, and filtration system. The workpiece, which is a conductive material is placed in the dielectric tank and fixed to a metal plate in the tank. The dielectric fluid which is commonly used in the industry is made of hydrocarbon dielectric fluid such as kerosene (Fleming, 2005).

Figure 2.1 shows a schematic illustration of how the EDM process works. On the workpiece surface, when the potential difference between the tool electrode and the workpiece is sufficiently high, the dielectric breaks down and a transient spark discharges through the fluid which remove a tiny piece of metal. The most important physical properties that determine the volume of metal removed per discharge are melting point and latent heat of melting (Kalpakjian, 2009). EDM has been utilized in producing mould, die, automotive, region and surgical parts (El-Taweel, 2009).

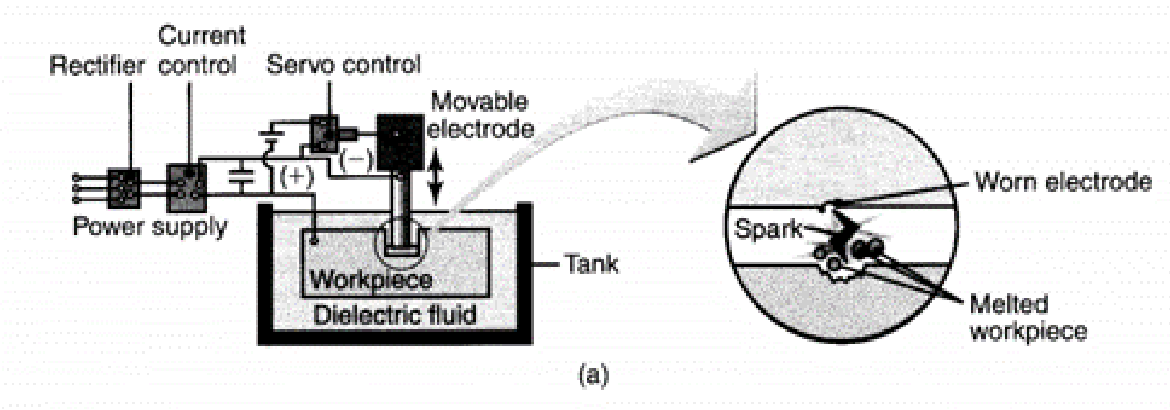

Figure 2.1: EDM process (Kalpakjian, 2009).

2.2 Surface Modification

A lot of technologies have been developed in order to improve the surface of materials, such as Physical Vapour Deposition (PVD), Chemical Vapour Deposition (CVD), and Electrical Discharge Coating (EDC). These technologies not only can improve the surface, but also help in improving the mechanical properties of the materials such as hardness, increase wear rate, and corrosion resistance.

2.2.1 Physical vapour deposition (PVD)

The fundamental of PVD processes can be divided into three categories, which are vacuum deposition or arc evaporation, sputtering, and ion plating. All the three processes are carried out in a high vacuum and at a temperature ranging from 200^{o}C to 500^{o}C. As shown in Figure 2.2, during vacuum deposition, the metal is evaporated at high temperature in a vacuum condition and deposited on the substrate that is usually at room temperature or a little bit higher to improve bonding between material (Kalpakjian, 2009).

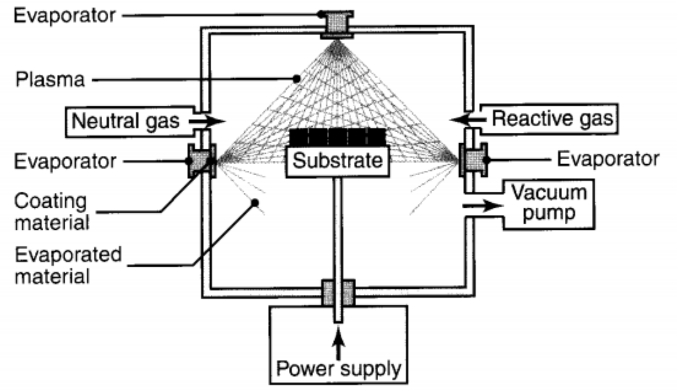

Figure 2.2: Physical vapour deposition process (Kalpakjian, 2009).

In a sputtering process shown in Figure 2.3, electric field ionizes an inert gas which is usually argon where the positive ions bombard the coating material (cathode) that cause sputtering of its atoms. The atoms then deposited on the workpiece, which is then heated to improve the bonding.

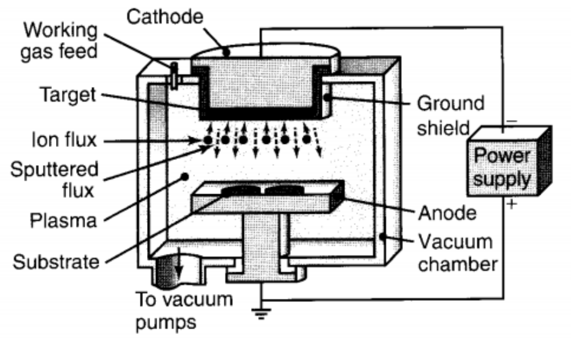

Figure 2.3: Sputtering process (Kalpakjian, 2009).

Ion plating as shown in Figure 2.4, is a combination process of sputtering and vacuum evaporation where an electric field causes a glow that generates a plasma. In this process, the vaporized atoms are only partially ionized. To produce thin films as a coating for semiconductor, tribological, and optical applications, ion-beam-enhanced deposition can be used (Kalpakjian, 2009).