EXPERIMENTAL INVESTIGATION OF TUNGSTEN CARBIDE USING WIRE EDM

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

by

MUHAMMAD YUSUF BIN ZAKARIA
B051410064
930908-14-5877

FACULTY OF MANUFACTURING ENGINEERING
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SELANGOR.

Tarikh: 14 JUNE 2017

Cop Rasmi:
DR. LIEW PAY JUN
Senior Lecturer
Faculty of Manufacturing Engineering
Universiti Teknikal Malaysia Melaka
Hang Tuah Jaya
76100 Durian Tunggal, Melaka

Tarikh: 19/6/2017

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Signature	:	....
Author's Name	:	MUHAMMAD YUSUF BIN ZAKARIA
Date	:	22 Jun 2017

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 (Manufacturing Process) (Hons.). The member of the supervisory is as follow:

....

(Dr. Liew Pay Jun)

DR. LIEW PAY JUN
Senior Lecturer
Faculty of Manufacturing Engineering
Universiti Teknikal Malaysia Melaka
Hang Tuah Jaya
76100 Durian Tunggal, Melaka

ABSTRAK

Kajian ini membentangkan pemesinan tungsten karbida (WC - 99.95%) menggunakan WEDM dengan diameter wayar tembaga 0.2 mm digunakan sebagai elektrod. Tujuan kajian ini adalah untuk mengkaji kesan parameter WEDM kepada ciri-ciri pemesinan seperti kekasaran permukaan (Ra), kekerasan permukaan (Hv) dan mikrostruktur selepas menjalani proses WEDM. Rekabentuk ujikaji dengan pendekatan *Full Factorial* (DOE) dua tahap telah digunakan untuk merangka susun atur eksperimen dan menganalisis kesan setiap parameter seperti tempoh denyutan (ON), masa rehat (OFF) dan arus puncak (C) kepada ciri-ciri pemesinan dipilih. Ujian pengesahan juga telah dijalankan untuk mengesahkan dan membandingkan keputusan daripada ramalan teori menggunakan perisian *Design Expert* dan ujian pengesahan eksperimen. Eksperimen ini digunakan Sodick VZ 300L untuk pemesinan tungsten karbida. Secara umum, keputusan yang diperolehi adalah tempoh denyutan (ON) memberikan kesan paling besar kepada semua tindak balas disiasat. Kenaikan tempoh denyutan dan arus puncak akan menaikkan permukaan kekasaran dan permukaan kekerasan tetapi kenaikan masa rehat akan merendahkan permukaan kekasaran dan permukaan kekerasan. Secara keseluruhan, hasil daripada ujian pengesahan menunjukkan bahawa peratusan prestasi boleh diterima kerana semua keputusan yang diperolehi adalah dalam nilai-nilai yang dibenarkan iaitu kurang daripada 10% atau ralat margin.

ABSTRACT

This research presents the machining of tungsten carbide (WC – 99.95%) using wire electro-discharge machining (WEDM) with 0.2 mm diameter brass wire as the tool electrode. The purpose of this study was to investigate the effects of WEDM parameters on the machining characteristics such as surface roughness (Ra), surface hardness (Hv) and microstructure after undergone WEDM process. The Full Factorial Design of Experiment (DOE) approach with two-level was used to formulate the experimental layout and to analyze the effect of pulse on time (ON), pulse off time (OFF) and peak current (C) on the selected machining characteristics. Confirmation tests were also conducted to verify and compare the results from the theoretical prediction using Design Expert software and experimental confirmation tests. This experiment used Sodick VZ 300L for machining tungsten carbide. In general, results exposed that pulse on time (ON) have appeared to be the most significant effect to all responses investigated. Increasing of pulse on time and peak current will increase both surface roughness and surface hardness but increasing of pulse off time will decrease surface hardness and surface roughness. Overall, the results from the confirmation tests showed that the percentage of performance was acceptable due to all the results obtained were within the allowable values which was less than 10% or margin error.

DEDICATION

I am dedicating this work to my beloved parents, Zakaria bin Mohd Noor and Norma Binti Shukor, who always inspire and support me with their boundless love to endeavor in achieving a success in everything I do.

To my supervisor, Dr. Liew Pay Jun, family and all my friends, without whom none of my success would be possible.

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LIST OF ABBREVIATIONS

A	-	Pulse On Time Parameter
Al	-	Aluminium
Amp	-	Ampere
ANOVA	-	Analysis Of Variance
B	-	Pulse Off Time Parameter
C	-	Peak Current Parameter
CI	-	Confidence Interval
Cu	-	Copper
Co	-	Cobalt
DOE	-	Design Of Experiment
EDM	-	Electrical Discharge Machining
FKP	-	Fakulti Kejuruteraan Pembuatan
Hv	-	Surface Hardness
IP	-	Peak Current
Mm	-	Millimeter
Mpa	-	Mega Pascal
MRR	-	Material Rate Removal

ON	-	Pulse On-Time
OFF	-	Pulse Off – Time
Ra	-	Surface Roughness
SEM	-	Scanning Electron Microscopy
SV	-	Servo Voltage
WC	-	Tungsten Carbide
WEDM	-	Wire Electrical Discharge Machining
ZN	-	Zinc

LIST OF SYMBOLS

$^{\circ}C$	-	Degree Celsius
G/Cm^3	-	Density
μm	-	Micrometer
μs	-	Micro Second
%	-	Percentage

CHAPTER 1

INTRODUCTION

1.1 Background

Non-traditional manufacturing process has many types and one of the Electrical Discharge Machining (EDM). It is broadly used in industry to eliminate excess material by numerous methods including mechanical, thermal, electrical or chemical energy without the help of sharp cutting tools. It is also used when the traditional machining process are not reliable to cut very soft and brittle material to be machined. (Patil *et al.*, 2016)

Complicated components in the fabrication of dies and moulds can be cut by wire EDM process. The selection of tungsten carbide (WC) for this research is appropriate for the workpiece due to its large range of application in tooling industries. Tungsten carbide (WC) includes of tungsten and carbon atoms and it has wear-resistance characteristics over wide range of temperature with the melting point of 2800°C. (Ayu, 2006)

Achieving high accuracy, surface finish and tighter tolerances during machining of materials is essential for many industries. Wire Electrical Discharge Machining (WEDM) allows us to produce parts that could not be made traditionally. WEDM can cut any conductive material regardless of their hardness and strength. In aerospace, automobile, tool and dies industry where accuracy and surface finish is having great importance, WEDM process is usually used. It can produce parts with complicated geometrical shapes, a quality edge and close tolerances and has the ability to cut production time and cost. To exploit the full potential of the WEDM machine tool, the machine should run at optimum conditions.

Rough cuts and trim cuts are performed on the work material using WEDM (Nain *et al.*, 2016).

1.2 Problem Statement

The efficiency of EDM process is depending on the higher rate of removal process in shorter period of time. Due to wider applications of tungsten carbide in dies and mould industry, recent developments focus to achieve this goal but at the same time maintain the surface integrity. In previous study by Soo *et al.* (2003), the common problem in shaping or machining tungsten carbide is the difficulty to achieve high accuracy and high productivity with less damage on its surface. To machine tungsten carbide by using EDM process, the relation of machining parameters and responses involved is limited and lacking due to its large number of variables and uncertain nature of process (Lee *et al.*, 2001).

Research about the surface integrity by Mas Ayu (2006), the region in which that is most thermally affected during machining process has induced some cracks and residual stresses. Therefore, there is essential to learn and understand the significant parameters that critically effects surface topography when machining tungsten carbide using WEDM.

1.3 Objectives

The objectives of this research are:

i. To study the effects of parameters of wire EDM for machining tungsten carbide using design of experiment.
ii. To investigate the surface topography of tungsten carbide after wire EDM process.

1.4 Scope of Study

The scope of this study will be narrowed to investigate the effects of parameter of wire EDM on tungsten carbide, in terms of surface hardness, microstructure and surface roughness. The parameters studied include pulse on time, pulse off time and peak current. The specific machining process under study is Wire Electro Discharge Machining, using brass as the electrode wire. The parameters will be decided by Design of Experiment (DOE) using full factorial.

1.5 Significant of Study

The importance of the study is to determine which parameter will produce desirable surface topography which is surface roughness, surface hardness and microstructure. A better surface topography can improve the quality in the manufacturing industry. A good surface finish can be obtained when the optimum parameters of cutting EDM is achieved.

1.6 Organization of Report

This thesis consists of 5 chapters. Chapter 1 discusses the background of the study and the machine that will be used in this project. Problems are identified and followed by objectives to be achieved throughout the study and scope of study which narrow down the area of the study. The impact of the study to the material is also exposed.

1.7 Summary

Several research papers have been written relating to machining of tungsten carbide using die sinker EDM. This research is essential to identify the effects of parameters of wire EDM for machining tungsten carbide using design of experiment. The surface topography is also observed. The introduction in chapter 1 will be followed by an extensive literature review in chapter 2. Next, in chapter 3, the methodology applied for this study is explained. Chapter 4 will detail the results of the experiments and analyze the results. Finally in chapter 5, conclusion is made and recommendation for future studies will be suggested.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction of EDM Machine

Electrical discharge machining (EDM) is a non-conventional process to cut and shape materials which broadly used in dies and mould industries. Singh et al. (2009) defined that the rule of EDM is using thermoelectric process to eliminate unwanted materials by generating electrical sparks that happen between the parts and the electrode. The conventional machining processes depend on stronger tool or abrasive material to eliminate the softer material whereby non-conventional machining processes such as EDM uses electrical spark or thermal energy to remove undesired material in order to produce wanted form. Therefore, the factor for EDM processes that is hardness of the material is no longer affecting the processes (Lajis, 2009).

2.1.1 EDM (Sinker EDM)

Sinker EDM as shown in Figure 2.1 can also be called as cavity type EDM or volume EDM. The basic principle of Sinker EDM is an electrode and the work piece will be dipped in a non-conductive liquid such as deionized water, oil or other dielectric fluid. Both work piece and electrode are connected with sufficient power supply. The power supply creates an electrical field between the both parts. As the electrode travels nearer to the work piece, dielectric breakdown happens in the fluid, creating a plasma channel and small spark jumps. These sparks often strike subsequently. These sparks occur in large numbers at obviously shuffle places between both work piece and electrode. As the base metal is eroded and the spark gap consequently increased, the electrode power is lowered automatically by the machine so that the process can repeat undisturbed. A few hundred thousand sparks happen each second, with the actual duty cycle cautiously fixed by the parameters (Dhirendra *et al.*, 2014).

Figure 2.1: EDM Die Sinker

2.1.2 Wire EDM

Wire electrical discharge machining or in short, WEDM is a specific heat machining process able to produce accurately machining parts with different range of hardness or complicated shapes, which have sharp corner that are very uneasy to be machined by conventional machining process. This advanced technology of WEDM process is referring on the traditional EDM sparking phenomenon that basically is a non-contact technique or material elimination. Since the beginning of the process, this advanced technology of machining has been upgraded to the most suitable alternative of creating micro-scale parts with the exact accuracy of dimension and good quality of surface finish (Ho *et al.*, 2004).

WEDM machine is a process of advancing wire that travel along an authorized path and eliminate part of material from the work piece. The material is eliminated by a sequence of discrete discharge between both work piece and wire electrode while submerged in dielectric fluid, which produces a path for discharge as the fluid becomes ionized in the gap (Singh *et al.*, 2009). The positive and negative terminal is represented by work piece and wire electrode in a DC electrical circuit and usually distinguished by a constant gap, continuously maintain by the machine. The cycle of WEDM process starts with the selected area that has been discharged gradually heated to extremely high temperature. The discharged area will be melted and carried away by the continuously moving dielectric fluids. Schematic diagram of WEDM process is shown in Figure 2.2.

The benefits of the machining are the cutting tool used which is wire is affordable the electrodes used in die sinking EDM, reasonable cost for machining are needed due to almost no wear happened and tiny wastes of work piece is produced. Nonetheless, the limitations of this processes are it can only for scroll surfaces and the wire may bend or break while machining, which can make the shape of desired part is broken and extremely decreasing the efficiency and accuracy of WEDM operation. Hence, nowadays WEDM process is basically run on parts that are fully immersed in a tank contained dielectric fluid. A immersed method of WEDM is used as it is reducing increasing of temperature and flushing debris efficiently (Ho *et al.*, 2004).

Even though WEDM can be done in any ways such as immersed in tank contained dielectric or dry machining, the most important is to obtain the best quality of surface topography and accuracy of dimension of work piece after been machined. Concerning this factor, a sufficient total of study has exposed the various methods of accomplish the ideal WEDM goals of optimizing the various process parameters analytically with the total withdrawal of the wire breakages thereby also developing the machining dependability.