UNIVERSITI TEKNIKAL MALAYSIA MELAKA

INFLUENCE OF PARAMETERS ON THE OVERCUT AND SURFACE ROUGHNESS OF DEEP CAVITY FEATURE USING EDM DIE SINKING

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

by

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DECLARATION

I, hereby, declared this report entitled "Influence of Parameters on the Overcut and Surface Roughness of Deep Cavity Feature Using EDM Die Sinking" is the results of my own research except as cited in references.

Signature : ....

Author's Name : ....

Date : ....

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfilment of the requirements for the degree of Bachelor of Manufacturing Engineering (Process) (Hons). The member of the supervisory committee is as follow:

……………………………………………………………………………

(Professor Madya Dr. Md Nizam Bin Abd Rahman)

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ABSTRAK

EDM telah digunakan dengan meluas dalam industri alat dan acuan kerana ia mampu menghasilkan bentuk yang kompleks tanpa mengira kekerasan bahan. Objektif utama kajian ini adalah untuk menentukan kesan *current* (I_p), *pulse on-time* (T_{on}), *pulse off-time* (T_{off}), dan *depth of cut* (D) dalam *overcut* dan kekasaran permukaan menggunakan EDM. Ia juga untuk menghasilkan model matematik yang mentakrifkan hubungan antara *input parameter* dengan *output responses*. Elektrod yang digunakan dalam eksperimen ini adalah Grafit ISO 63, dan bahan kerja yang digunakan ialah AISI D2 keluli. SODICK NC EDM mesin telah digunakan untuk menjalankan eksperimen, Zeiss CMM Contura G2 mesin digunakan untuk mengukur diameter lubang, dan Mitutoyo SJ 301 Penguji Kekasaran Permukaan digunakan untuk mengukur kekasaran permukaan. *Full Factorial Design of Experiment* dengan dua replikasi telah digunakan untuk pendekatan eksperimen. Hasil dapatan telah dianalisi dengan menggunakan *Analysis of Variance* (ANOVA), *Main Effect*, dan *Interaction.* Hasil dapatan yang diperolehi daripada ANOVA menunjukkan bahawa pulse on-time (T_{on}) dan *depth of cut* (D) adalah faktor yang paling penting dalam mempengaruhi *overcut* dan kekasaran pemukaan. Model matematik pun telah didapatkan daripada ANOVA.

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ABSTRACT

EDM is extensively used in the tool, mould, and dies industries as it is able to produce complex shapes regardless of the hardness of material. The objective of this study is to determine the effect of current (I_p), pulse on-time (T_{on}), pulse off-time (T_{off}), and depth of machining (D) on the overcut and surface roughness of deep cavity machining using EDM. It is also to develop mathematical modelling that defines the relationship between input parameters and output responses. The electrode used in this experiment was graphite ISO 63, and the workpiece used was AISI D2 steel. Experiments were conducted by SODICK NC Electrical Discharge Machine AQ35L, and the output response of diameter of cut was measured by using Zeiss coordinate measuring machine Contura G2 and calculated, whereas surface roughness was measured by using Mitutoyo SJ 301 portable surface roughness Tester. Full factorial Design of Experiment with two replications was used for experimental approach. The analyses carried out were the ANOVA, main effect, and interaction analysis. ANOVA results showed that pulse on-time (T_{on}) and depth of machining (D) were the most significant factors in affecting the overcut and surface roughness respectively. The mathematical modelling was also obtained from ANOVA.

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DEDICATION

To my beloved parents and sister.

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LIST OF ABBREVIATIONS, SYMBOLS, SPECIALIZED NOMENCLATURE

A	Ampere
AISI	American Iron and Steel Institute
ANOVA	Analysis of Variance
C	Carbon
CMM	Coordinate Measuring Machine
Cr	Chromium
D	Depth of Machining
DC	Direct Current
DOE	Design of Experiment
EDM	Electrical Discharge Machining
Fe	Iron
HAZ	Heat Affected Zone
I_P	Peak Current
mm	millimeter
Mn	Manganese
Mo `	Molybdenum
MRR	Material Removal Rate
S	Second
Si	Silicon
SR	Surface Roughness

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TWR	Tool Wear Rate
T_{on}	Pulse On-Time
T_{off}	Pulse Off-Time
v	Voltage
V	Vanadium
Wt%	Weight Percentage
°C	Degree Celcius

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CHAPTER 1

INTRODUCTION

This chapter present the introduction of this project. The background of this project is on EDM die-sinking. Other than that, the problem statement, objectives, and scope which act as a framework for this project are also included in this chapter.

1.1 Background

Machining is a material removal process where a cutting tool is used to remove unwanted material from a workpiece to produce the desired shape. It can be divided into two categories, which are conventional and non-conventional machining. Conventional machining, also known as traditional machining, are those processes that mechanically remove small chips of material using sharp tool. It requires mainly mechanical energy to remove the material from a workpiece. Examples of conventional machining are milling, turning, drilling, boring and grinding.

In some industries, there are several hard and brittle materials such as high speed steels and tungsten carbide. These materials are difficult to be machined with conventional machining as the cutting tool will undergo extreme wear or it will damage the workpiece. Hence, non-conventional machining (or advance machining), is used to overcome these drawbacks. Non-conventional machining are those processes that remove material by the means of etching, evaporation, melting, chemical dissolution, and hydrodynamic action with the aid of fine abrasive particles, instead of producing chips as in conventional machining (Kalpakjian and Schmid,

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2010). An advantage of these processes is that the hardness of the material is not relevant. Examples of non-conventional machining include electrical discharge machining, abrasive jet machining, electrochemical machining, and chemical machining.

Among all the non-conventional machining methods, electrical discharge machining (EDM) is used extensively for high hardness materials (Iqbal and Khan, 2010). EDM is an important non-conventional machining method in the tool, mould, and dies industries as it is able to produce complex shapes. In EDM process, the tool does not contact with the workpiece, so the cutting forces are not generated. In addition, the workpiece can be of any materials with good electrical conductivity (Singh and Kumar, 2012). Therefore, it is applied widely for machining superior materials since it performs superior machining characteristics.

Since long, researchers have looked into a number of ways to enhance and optimize the EDM process. Most of the research work in this area shares the same objectives of achieving high material removal rate coupled with low tool wear rate and improved surface quality. It can be noticed that various machining parameters influenced the surface roughness significantly. However, there is a gap in the research work where not much interest is paid on the issue of overcut.

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1.2 Problem Statement

In manufacturing industries, it is important to get optimum machining process with high dimensional accuracy and good surface quality. Researchers had been looked into several ways to improve and optimize the EDM process by achieving high material removal rate, coupled with low tool wear rate and improved surface quality. However, there is a gap in the research area as the problem of overcut of EDM process has not been explored thoroughly. Thus, this project aimed to fill in the research gap by studying the effect of EDM parameters on the overcut and the surface roughness of deep cavity machining using EDM die sinking.

1.3 Objectives

The objectives of this project are:

i. To study the effect of process parameters on overcut and surface roughness of deep cavity machining using EDM.

ii. To develop mathematical modeling that defines the relationship between input parameters and output responses.

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1.4 Scope

In this project, Sodick (NC Electrical Discharge Machine) model AQ35L was used for the deep cavity EDM. The material of AISI D2 tool steel was used as the workpiece, and graphite was used as the electrode. For such a part, the overcut was selected to monitor the dimensional accuracy of the parts produced by EDM, and surface roughness was selected to monitor the performance of EDM. The four input parameters were current (I_P), pulse on-time (T_{on}), pulse off-time (T_{off}), and depth of machining (D). The Full Factorial Design of Experiment was used to run and execute the experiment. A Coordinate Measuring Machine (CMM) and a Portable Surface Roughness Tester were used to measure the output responses, which were diameter of the cavity and surface roughness (SR). The results were then analyzed by using ANOVA, Main Effect Analysis, and Interaction. The expected outcome of this project is to determine the effects of four input parameters on the overcut and surface roughness of a typical component part produced by EDM.

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CHAPTER 2

LITERATURE REVIEW

This section works as a reference, which give information and guidance for this project. This chapter gives a brief explanation on die-sinking electrical discharge machining (EDM). Research journals, books, and online conference article were the main source in the project guides. An overview of current research trends, the important parameters of EDM, and the performance measures of EDM are also included in this chapter.

2.1 Electrical Discharge Machining (EDM)

Electrical Discharge Machining (EDM) is a non-conventional machining technique that has been used extensively for more than fifty years. In EDM process, material is removed by a series of discontinuous electrical sparks between the workpiece and the electrode which are immersed in a dielectric fluid (Iqbal & Khan, 2010). This material removal process which is regardless of the hardness of the material has been its advantage to machine difficult-to-machines and high strength temperature resistant alloy. It is mainly used to produce complex shapes in the manufacture of moulds and dies component, automotive industry, watches, machines, surgical instrument, and electronic component (Schaller et al., 2006). Figure 2.1 shows some examples of EDM die-sinking finished parts.

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(a) (b)

Figure 2.1: Examples of EDM die-sinking finished parts: (a) High Speed Turbine; (b) Screw thread mold of the PET bottles. (Schaller et al., 2006)

EDM has multiple advantages as compared to conventional machining processes such as turning or milling. The main advantages of EDM is that it is able to machine any electrically conductive materials despite of its hardness such as tungsten carbide, hardened steel, and special alloys for aerospace application. Moreover, it can be used to produce parts with complex geometry, sharp corners and superior finishes. It does not produce mechanical stress on the workpiece as the tool does not contact with the workpiece, there is no cutting force has been generated, therefore allowing the machining of small and fragile pieces. However, it has relatively low metal removal rates than conventional machining processes, and undesirable erosion of material can occurs. Furthermore, as the geometry of mould cavities are exactly duplicated from the tool electrodes, lead time is needed to produce the specific corresponding electrode shapes (Schaller et al., 2006).

2.1.1 History of EDM

In 1770, Joseph Priestley – an English physicist, discovered that electrical discharges have erosive effect on various metals. However, it was not fully taken advantage of until the Soviet researchers B.R. and N.I Lazarenko learned how to control the destructive effects of an electrical discharge based on Priestley’s earlier research, and they developed a controlled process for metals machining.

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In 1943, a new machining method had been found, which is known as the spark machining process, where an outbreak of spark (electrical discharges) developed between two electrical conductive materials that are immersed in a dielectric fluid. They developed the “Lazarenko Circuit” which helped to maintain the gap width between the workpiece and the tool. It was used to erode hard materials, for example tungsten carbide, and the circuit maintained as the standard EDM generator for years.

In 1952, the first EDM machine was produced by the manufacturer Charmilles, but the machine performances were limited at that time due to the electronic components which have poor quality. In the 1970’s, they added feedback loops with ultra fast servos and numerical control, thus further improving the performance of EDM. Improvements were made continuously in the following decades and the world market of EDM started to expand greatly. Finally, in 1990’s, new EDM process control arose.

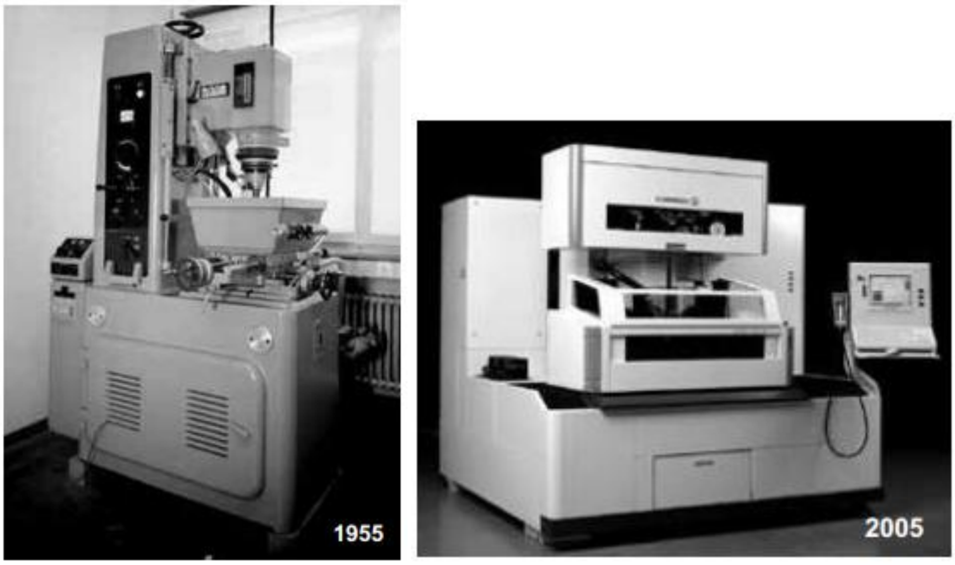

Figure 2.2: Evolution of EDM machines in 50 years: Eleroda D1 (1995) and Charmilles Robofil 2050 TW (2005).

(Source: http://www.charmilles.ch)

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2.1.2 Principles of Electric Discharge Machining (EDM)

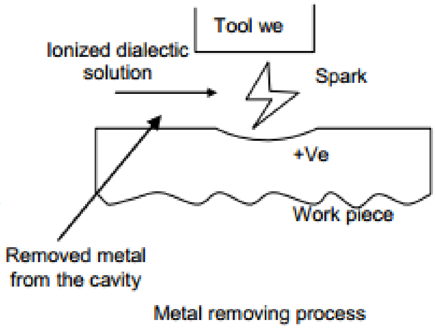

Figure 2.3: Schematic representation of the basic EDM working principle

Figure 2.3 shows that the principle of EDM is different from the conventional machining processes as physical contact between the electrode and the workpiece does not occur, hence chatter, mechanical stresses and vibration problems do not exist while machining (Ho and Newman, 2003). The electrode must always be placed away by the distance required for sparking from the workpiece, called as the spark gap. EDM is carried out in the presence of dielectric fluid which is generally kerosene or deionised water that creates path for discharge.

When a potential difference is applied to the electrode, rapidly recurring spark discharge took place, the material is then removed by the erosion effect of sparks (Singh and Kumar, 2012). Electrically conductive electrode and the workpiece are used so an electric field would be established. The volume of material removed by a single spark is in the range of 10^{-6} to 10^{-4} mm^3, which is very small. However, this single spark occurs for typically 10,000 times per second (Schaller et al., 2006).

Generally, negative terminal of the generator is connected to the electrode to make it negative and the workpiece is made positive as shown in Figure 2.4.

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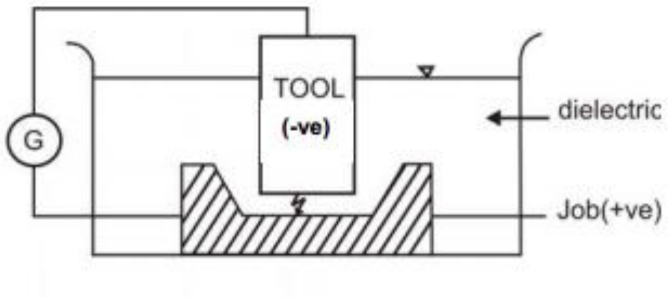

Figure 2.4: Schematic representation of the charges of electrode and workpiece of EDM process (Shailesh, 2010).

When an electric field is built up in the spark gap, electrostatic forces are subjected onto the free electrons on the electrode. The electrons are released from the electrode if the electron bonding energy is low. This type of electrons emission is known as “cold emission”.

The released electrons are then accelerated toward the workpiece through the dielectric fluid. When the electrons have gained enough energy and velocity, collisions would occur between the electrons and dielectric molecules, and dielectric molecule would ionize depending on the energy of an electron and the ionization energy of a dielectric molecule. The collision results in the generation of more positive ions and electrons. Thus, the concentration of electrons and ions between the electrode and workpiece would increase and creating a channel which is called as “plasma”.

When plasma is created, high amount of electrons will release from the electrode to the workpiece and ions will release from the workpiece to the electrode. This movement of electrons and ions is known as spark. Therefore, the electrical energy is converted into thermal energy of the spark.

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