UNIVERSITI PUTRA MALAYSIA

ELECTRICAL DISCHARGE MACHINING OF BERYLLIUM COPPER ALLOYS USING GRAPHITE ELECTRODE

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Thesis Submitted to the Graduate Studies, Universiti Putra Malaysia in Fulfilment of the Requirement for the Degree of Master of Science

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DEDICATION

To my lovely wife Rasina Nilofer for her loving, dedication and support, my beloved son Ameer Farhan and Ahmad Faaiz and not to forget my loving parents.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

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Chairman: Associate Professor Datin Napsiah Bt. Ismail, PhD

Faculty: Engineering

Electrical Discharge Machining (EDM) is commonly used to produce molds and dies, to drill small, burr-free holes and to make prototype quantities of contacts for the aerospace and electronics markets. Most of EDM machines are manufactured and equipped with built-in 'machining technology' for steels. Apart from steel, beryllium copper alloys are amongst essential material for mould and die making. Therefore, the present study elucidates the die-sinking EDM characteristics of beryllium copper alloys with graphite as an electrode. Experiments were conducted on EDM Die Sinking Charmilles Robofom 35P. The output responses investigated were Material Removal Rate (MRR) and Surface Roughness (Ra). Full factorial and Linear Regression analysis of Design of Experiment (DOE) module in Minitab was employed as a principal methodology to examine the effects of current, polarity, pulse duration and voltage over output responses. The significant and optimum machining parameters for each output responses was also identified and established. Experiment results indicate that the

Material Removal Rate (MRR) was mainly affected by current, pulse duration, voltage and interaction between current*pulse duration. For the Surface Roughness (Ra), the significant factors were current, voltage and pulse duration. Confirmation tests were carried out and used to compare results obtained by theoretical predication with those experimentally. It was found that the error margin of factors influenced between the predicted and actual results is 5% for Material Removal Rate (MRR) and 4.2% for Surface Roughness (Ra).

Abstrak tesis yang dikemukan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Sarjana Sains

PEMESINAN NYAHCAS ELEKTRIK BERYLLIUM KUPRUM ALOI MENGGUNAKAN ELEKTROD GRAFIT

Oleh

SHAIK MOHAMED B. MOHAMED YUSOFF

Jun 2009

Pengerusi: Profesor Madya Datin Napsiah Bt. Ismail, PhD

Fakulti : Kejuruteraan

Pemesinan Nyahcas Elektrik (EDM) ialah kaedah pemesinan yang lazim digunakan di dalam industri acuan dan die, untuk pengerudian kecil, membuat lubang tanpa gerigis dan penghasilan prototaip yang ada kaitan dengan industri elektronik dan aeroangkasa. Kebanyakkan mesin dilengkapi dengan “teknologi pemesinan” bagi bahan keluli. Selain daripada keluli, aloi beryllium kuprum juga adalah bahan yang penting pembuatan acuan dan die. Oleh itu kajian ini telah dijalankan, dimana aloi beryllium kuprum telah digunakan sebagai bahan kerja dan grafit sebagai alat elektrod. Ujikaji ini dijalankan mengunakan mesin *EDM Charmilles Robofom 35P Die Sinkings*. Parameter proses yang dikaji ialah ialah kadar pembuangan dan penyudahan permukaan benda kerja. *Full Factorial* dan *Linear Regression* digunakan sebagai bahan metodologi untuk rekabentuk ujikaji ialah *Design of Experiment (DOE)*. Parameter-parameter pemesinan yang penting telah dikenaplasti dan dioptimun telah ditentukan melalui analisis mengunakan perisian Minitab. Parameter -parameter yang penting mempengaruhi kadar

pembuangan logam bahan ialah arus, jangkamasa denyutan dan voltan dan interaksi antara arus*jangkamasa denyutan. Bagi penyudahan permukaan benda kerja parameter-parameter yang mempengaruhi ialah arus, voltan dan jangkamasa denyutan. Pengesahan ujikaji telah dijalankan bertujuan untuk membandingkan keputusan diperolehi melalui ramalan teori dan ujikaji. Perbezaan bagi kadar pembuangan bahan logam (MRR) ialah 5% manakala penyudahan permukaan benda kerja (Ra) ialah 4.2%.

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I certify that a Thesis Examination Committee has met on 9 June 2009 to conduct the final examination of Shaik Mohamed B. Mohamed Yusoff on his thesis entitled "Electrical Discharge Machining of Beryllium Copper Alloys Using Graphite Electrode" in accordance with Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U. (A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

Members of the Examination Committee are as follows:

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This thesis as submitted to Senate of Universiti Putra Malaysia and has been accepted has fulfilment of Degree of Master of Science. The members of Supervisory Committee were as follows:

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Date: 11 September 2009

DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

SHAIK MOHAMED BIN MOHAMED YUSOFF

DATE: 6 June 2009

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CHAPTER I

INTRODUCTION

1.1 Electrical Discharge Machining

Electrical Discharge Machining (EDM) is a non-traditional manufacturing process based on removing material from a part by means of series of repeated electrical discharge (created by electric pulse generators at short intervals) between tool, called electrode and the part being machined in the presence of a dielectric fluid. It is also used for finishing parts for aerospace, automotive industry, injection molding tools and surgical parts (Abbas, et al., 2007).

At present, EDM is a widespread technique used in industry for high-precision machining of all types of conductive material such metals, metallic, alloy, graphite or even some ceramic material. The melting point, hardness, toughness or brittleness of material imposes no limitation. It thus provides a relatively simple method for making holes of any desired cross section in material that are too hard or brittle to be machined by most other methods (Chen and Mahdivian, 2000).

There are virtually zero forces between the tool and the workpiece, so that very delicate work can be done. The process leaves no burn on the edges. The frequency of discharge or the energy per discharge is usually varied to control the removal rate as are the voltage and current.

Electrical discharge machining has become an indispensable machining method in the mould and dies industry. The EDM is best suitable for machining deep and thin cavities in hard materials and lends itself to integration in a CIM environment (Abbas, et al., 2007). Most of the EDM machines are manufactured and equipped with built in "machining technology" for steels and others material like Beryllium Copper Alloy.

1.2 Problem Statement

Modern EDM machinery is capable of machining geometrically complex or hard material component, that are precise and difficult to machine such as heat treated tool steels, composites, super alloy, and ceramic. Electrical Discharge Machining performance is influenced by various parameters. All the parameters have their own effect to the machining performance. Some of the parameters will produce the contradictory result between one and another; for example, increasing the discharge current will increase Material Removal Rate but at the same time will reduce the Surface Quality.

As expected, the criteria for high Material Removal Rate (MRR) and Surface Roughness (Ra) can reached simultaneously. However, no specific combination of EDM parameters can be achieved, either in terms of optimum productivity, optimum dimensional precision or optimum surface finish. The requirement for higher Material Removal Rate (MRR), although possible, also produces a very poor surface integrity, thus higher MRR is required only in rough finishing. A lower Surface Roughness (Ra) removes the recast the layer, thus the lower surface roughness is required for fine finishing.

In previous practice, most of the researcher used the method called 'one variable at a time' (Chen and Mahdivian, 2000; Singh et al., 1985; Madan et al. 1995, Lin et al., 1998) and some others used DOE with Taguchi method like (Wang et al., 2000; Lin et al., 2000) in finding the optimal parameter. In the 'one variable at the time' technique, only one parameter will be varied and other selected parameters will be fixed during the experiment. The influences of various parameters on the machined material cannot be monitored easily and the experiment result just produced the effect of one parameter only. The actual affects by varying more than one parameter and the significant level of the parameter against one another has still not clearly been discussed. The optimum parameters for the Surface Roughness and Material Removal Rate for Beryllium Copper Alloy using Electrical Discharge Machining process has not many been conducted. This material need to machining in the optimum parameters for manufacturing of parts for several industries involving die cast component, mould in for aerospace and automotive industry.

Due the limitation of the previous method, this project has been conducted to monitor the effects of changing various parameters of Electrical Discharge Machining on Beryllium Copper Alloys. The optimum parameters of Surface Roughness and Material Removal Rate for Beryllium Copper Alloys can be achieved. In the same time the measures that can be taken to obtain reduced variants in determining the optimum parameters for the EDM. The important to achieve optimum Surface Roughness and Material Removal Rate for Beryllium Copper Alloys and for this problem statement will be answer by Design of experiment (DOE). This approach has been employed since is more powerful in providing information about the machining process EDM. Applying DOE to monitor the process characteristic in EDM is the correct decision because the discussion about the best setting of the EDM will be achieved according the multi objectives.

1.3 Objectives of the Study

The objectives of the study are:-

1. To investigate the significant electrical discharge machining parameters that affects on the process performance noted as Material Removal Rate (MRR) and Surface Roughness (Ra).
2. To establish the optimum Electrical Discharge Machining parameters for EDM machine for Beryllium Copper Alloys
3. To develop the mathematical model for Electrical Discharge Machining process of Beryllium Copper Alloys by using Design of Experiment (DOE).

1.4 Scope of the Study

The focus of this research work is to present the characteristics of Electrical Discharge Machining of Beryllium Copper Alloys as workpiece using EDM Die Sinking Charmilles Robofom 35P machine with 25mm diameter graphite as an electrode. Full Factorial and Linear Regression analysis of classical Design of Experiment (DOE) have been adopted to explore the effects of the process variables on the Material Removal Rate (MRR) and Surface Roughness (Ra).The design factors specified were current (A) , work piece polarity, pulse duration (μs) and voltage (V).

CHAPTER II

LITERATURE REVIEW

2.1 Electrical Discharge Machining

Electrical Discharge Machining (EDM) die sinking known as spark machining, is a nontraditional method of removing metal by series of rapidly recurring electrical discharges between an electrode and the work piece in the presence of a dielectric fluid. Minute particles of metal or chips generally in the form of hollow spheres are removed by melting and vaporization and are washed from the gap by the dielectric fluid which is continuously flushed between tool and work piece. A typical Electrical Discharge Machining is shown in Figure 2.1.

The tool is mounted on the chuck attached to the machine spindle whose vertical feed is controlled by the servo motor through a reduction gear box. The work piece is placed in the tank filled with a dielectric fluid a depth of at least 50 mm over the work surface is maintained to eliminate the risk of fire. The tool and work piece are connected to a Direct current (DC) relaxation circuit fed either from a DC generator or commonly a mercury or selenium type rectifier. Dielectric fluid is circulated under pressure by a pump usually through a hole or holes in the tool electrode (Chen and Mahdivian, 2000).

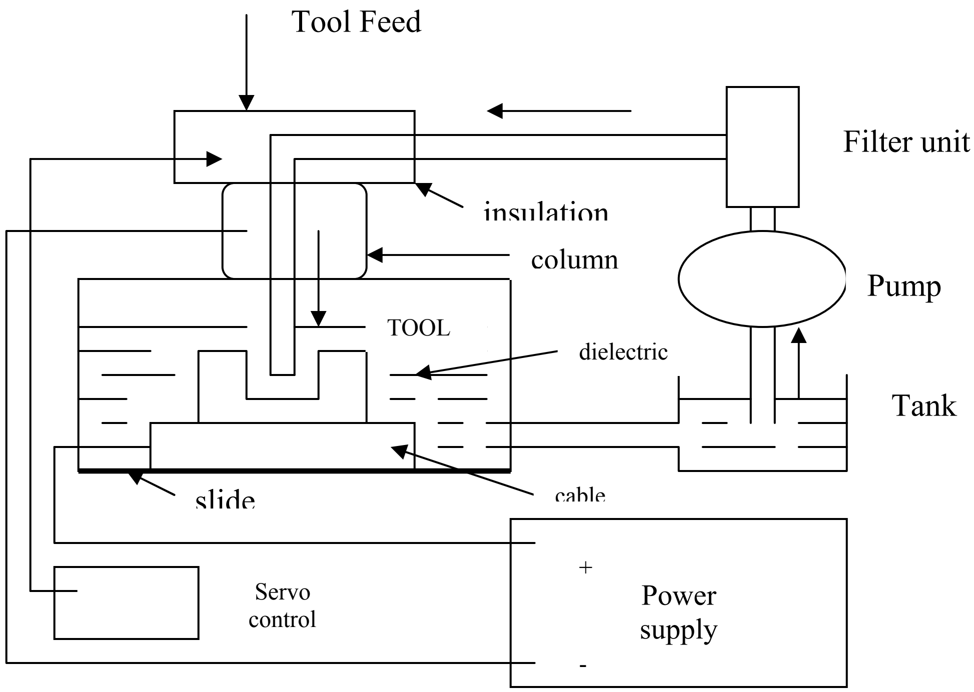

Figure 2.1: Schematic diagram of typical Electrical Discharge Machining (Chen and Mahdivian, 2000)

A spark gap typical of about 0.01 to 0.5 mm is maintained by the servo motor. The physicist has to define differences between sparks and arcs in the workshop instead found quickly a good distinction (Mcgeough, 1998). “Spark” machining is needed for manageable, precise and good quality work, while “arcing” characterizes deteriorated machining, which result in discharge concentration, melting and overheating at surface spots (Schumacher, 2003).

When the power supply is switched ON, the condenser voltage (Vc) begins to increase exponentially toward the supply voltage (Vs). It will transform the Alternative Current (AC) supply from the main and provides a rectangular voltage waveform as shown in

Figure 2.2. During this initial period the spark gap behaves as an open circuit and no current flows. As the voltage, Vc builds, it reaches the gap breakdown voltage gap (Vg) (determined by the gap width and the dielectric fluid) a spark is produced across the gap, the dielectric fluid ionizes and the condenser is discharged. The surrounding dielectric fluid deionises so that it again become an effective insulator and the cycle is repeated. The amount of material removed from the workpiece depends on the characteristics of the voltage, current and time.

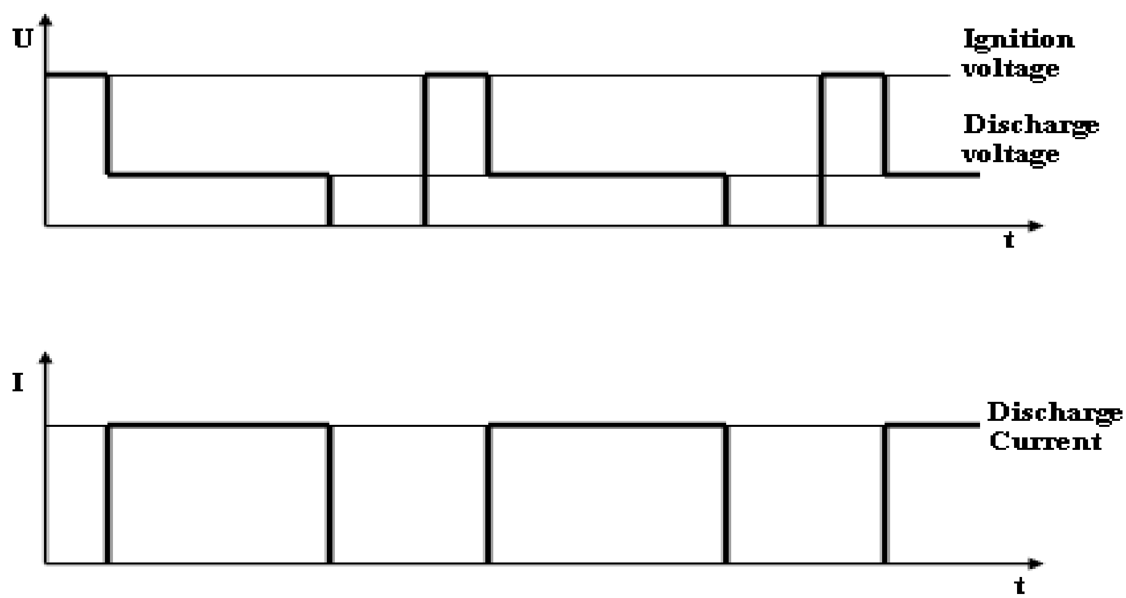

Figure 2.2: Voltage and current diagram in Electrical Discharge Machining (Chen and Mahdivian, 2000)

As a consequence of this electrical field, positive ions and electrons are accelerated, producing a discharge channel that conductive. It is just at this point when spark jumps causing collisions between ions and electrons and creating a channel of plasma. A sudden drop of the electric resistance of the previous channel allows that current density reaches very high values producing an increase of ionization and creation of a powerful magnetic field. These effects make a little part of metal volume melt or even vaporize. In these conditions, that is ions and electrons crashing among them and therefore creating high temperatures in both poles, a gas ball or bubble is formed around the plasma channel and then begins to grow providing just at the end of the discharge a large ball of gas. The dielectric fluid breaks it making the ball implode. In Figure 2.3 shows the picture of EDM physical process stage by stage.