UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Manufacturing Engineering

PERFORMANCE OF EDM DIE-SINKING PARAMETERS ON MATERIAL CHARACTERISTICS OF LM6 USING GRAPHITE ELECTRODE

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PERFORMANCE OF EDM DIE - SINKING PARAMETERS ON MATERIAL CHARACTERISTICS OF LM6 USING GRAPHITE ELECTRODE

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A thesis submitted
in fulfillment of the requirements for the degree ofMaster of Manufacturing Engineering (Manufacturing System Engineering)

Faculty of Manufacturing Engineering

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2019

DECLARATION

I declare that this thesis entitled "Performance of EDM die-sinking parameters on material characteristics of LM6 using graphite electrode" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....

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Date : ....

APPROVAL

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

Signature : ……………………..

Supervisor Name : Assoc. Prof. Ir. Dr. Mohd Amran Bin Md Ali

Date : ……………………….....................................

DEDICATION

To my beloved husband Mohd Ambri Asis;

daughters, Nor Ameerah and Afeefah Zahrah;

sons, Mohd Ashraef and Muhammad Adeeb;

and to my lovely parents

ABSTRACT

Nowadays, EDM die-sinking is one of the important processes to produce a product made from a hardness material with a close tolerance. EDM die-sinking process works effectively for machining deep holes and micro holes with high accuracy.In this study, graphite electrode used to machine aluminium alloy LM6 as a work piece. Full factorial method was used as a design of experiment in order to run the matrix order. To get the significant parameters and optimize the parameters to optimum level, ANOVA analysis is needed. The objective of this project is to study the performance of die sinking parameters on material characteristics by using graphite as electrode. The input responses of this study are current, pulse on time and pulse off time. The output responses that need to measured are material removal rate (MRR), electrode wear rate (EWR) and surface roughness (Ra). From the experimental result, current is the most significant parameters that give an effect to all the three responses which are material removal rate, electrode wear rate and surface roughness. Besides, the combination of current factor with other factors such as pulse on time and pulse off time also give an effect to the responses. The higher current with high pulse on is needed to get a maximum MRR. It is find that current contribute 61.28% followed by pulse on time 1.07% and pulse off time 0.89%. for MRR. While a lower current result an optimum or lower EWR. Current factor contribute 39.16% followed by pulse on time with 15.13% and pulse off time 2.89% affect the response. The value of Ra is also depending on current and pulse on time value so current contribute 76.61%, pulse on time 19.41% and pulse off time 17.36%. The lower current and pulse on can produce a fine surface during machining. Based on the main effect plot ranking, for all the three responses show that current is the most affected factors to the responses followed by pulse on time and pulse off time.

ABSTRAK

Pada ketika ini, proses pemesinan dengan menggunakan electro discharge machine die-sinking adalah salah satu proses terpenting untuk menghasilkan produk daripada bahan yang keras dengan toleren yang sangat kecil. Proses pemesinan dengan EDM die-sinking adalah sangat efektif untuk pemesinan lubang yang dalam dan lubang mikro dengan ketepatan yang tinggi. Di dalam kajian ini, grafit digunakan sebagai elektrod untuk memesin aluminum aloi LM6 sebagai bahan kerja. Parameter masukan yang dikaji adalah arus, masa pulse on dan masa pulse off. Respon keluaran yang diukur adalah kadar penyingkiran bahan kerja, kadar penyusutan elektrod dan kekasaran permukaan. Daripada keputusan eksperimen menunjukkan bahawa arus adalah faktor yang paling banyak memainkan peranan untuk mempengaruhi nilai ketiga-tiga respon iaitu kadar penyingkiran bahan kerja, kadar penyusutan elektod dan kekasaran permukaan. Di samping itu, kombinasi di antara arus dan faktor-faktor lain iaitu masa pulse on dan masa pulse off juga menunjukkan kesan mempengaruhi respon. Nilai arus yang tinggi bersama nilai masa pulse onyang tinggi diperlukan untuk mendapatkan kadar penyingkiran bahan kerja yang maksimum. Arus memberikan kesan sebanyak 61.28% diikuti oleh masa pulse on sebanyak 1.07% dan 0.89% untuk masa pulse off yang mempengaruhi kadar penyingkiran bahan kerja. Sementara itu, arus yang rendah diperlukan untuk mendapatkan kadar penyingkiran elektrod yang minimum. Faktor arus menyumbangkan 39.16% diikuti dengan masa pulse on sebanyak 15.13% dan 2.89% bagi masa pulse off yang mempengaruhi kadar penyingkiran elektrod. Nilai kekasaran permukaan juga bergantung dengan nilai arus dan masa pulse on di mana arus mempengaruhi 76.61% diikuti oleh masa pulse on sebanyak 19.41% dan masa pulse off 17.36%. Nilai arus yang lebih rendah dan masa pulse on yang juga rendah akan menghasilkan permukaan yang halus semasa pemesinan. Berdasarkan turutan, faktor yag mempengaruhi ketiga-tiga respon menunjukkan bahawa arus adalah faktor yang paling tinggi mempengaruhi respon diikuti oleh masa pulse on dan masa pulse off.

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CHAPTER 1

INTRODUCTION

This chapter explains about the background of the study, problem statement, objectives, scope and significance of this study that are related with this project. The explanations about the purpose and its importance of doing this project are also stated.

1.1 Background of Study

Electrical discharge machining (EDM) is a controlled metal-expulsion process that is used to expel metal by methods for electric start disintegration. In this procedure, an electric is utilized as the slicing apparatus to cut the work piece to create the completed part to the coveted shape. The metal-expulsion process is performed by applying a throbbing (ON/OFF) electrical charge of high-recurrence current through the terminal to the work piece. (Ho and Newman 2003). This expels dissolves exceptionally minor bits of metal from the work piece at a controlled rate.

According to Ho and Newman (2003), EDM is one of the most widely utilized non-conventional material removal processes. Its remarkable element of utilizing warm vitality to machine electrically conductive parts in any case of hardness has been its particular preference in the make of form, car, aviation and surgical parts. The electrical discharge machining removes work piece by an electrical start disintegration process. The varieties in the machining parameters, for example, the work piece extremity, pulse on and off time, duty factor, machining voltage, release current, and dielectric fluid, extraordinarily influence the measures of the machining performance, for instance, the electrode wear rate

(EWR) and the material removal rate (MRR) (Lin et.al, 2000). Subsequently, appropriate choice of the machining parameters can bring about better machining execution in the electrical discharge machining process.

EDM is successfully used effectively in the machining of hard, high-strength, and temperature-resistant materials (Lin et.al, 2000). The EDM process can be used on any electrical conductor materials. The machining process doesn't involve mechanical energy so the hardness, strength and the toughness of the work piece material does not necessarily influence the removal rate. Kalpakjian and Schmid (2001) mentioned that electrodes for electro discharge machine are typically made of graphite in spite of the fact that metal, copper or copper tungsten alloy are likewise utilized. These electrodes are shape by forming, casting, powder metallurgy or machining techniques. Electrodes as little as 0.1 mm in diameter have been utilized and depth- to - hole diameter ratios range up to 400:1.

The purpose of this project is to obtain the optimum parameter in electro discharge machining to produce a quality parts or products with minimum defects. In this project, some responses such as the material removal rate (MRR), electrode removal rate (EWR), surface roughness (Ra) and cracking of the crater will be analysed by using Aluminium Alloy LM6 as a work piece and graphite as an electrode. The best result for the electro discharge machine can be achieved when the suitable combination of voltage and pulse on and pulse off time have been used.

For the streamlining of the parameters, design of experiment (DOE) by utilizing Full Factorial, 2 levels with 3 factors and ANOVA are performed. The design of experiment (DOE) is a viable way to deal with enhances the throughput in different process. The DOE has been executed to choose fabricating process parameters that could bring about a superior quality product.

1.2 Problem Statement

In manufacturing process, there are conventional and non-conventional material removal processes. There is a need to produce high quality products with fewer defects to reduce the operational cost and time. EDM die-sinking is a non-conventional material removal process that can be used to machine a hard or high strength material even a very complicated parts to machine such as sharp edge and deep slot. Therefore, the performance of the EDM die-sinking is studied in this project to find the best combination parameters on MRR, EWR, Ra and surface crater. The work piece material that employed in this project was Aluminium Alloy LM6 and graphite was used as an electrode. In order to achieve these output responses, the input variables that were used are current, pulse on time and pulse off time.

According to Jayaraman et al. (2013), aluminium material LM6 produced by casting process such as engine manifold, aircraft components and housing have complex shape that would be difficult to produce with conventional cutting tools. The previous study by Amran et al. (2013) is about the performance of cutting aluminium alloy LM6 using copper tungsten. The result shown that electrode wear rate less erosions due to the hardness of the electrode material. Therefore, this study investigated electrodes using graphite material to understand the erosion on graphite electrode.

1.3 Objective

The main objective of this study is to investigate the performance of EDM die-sinking parameters on material characteristics when using an Aluminium Alloy LM6 as a work piece and graphite as an electrode using full factorial method. The sub objectives of this study are:

1. To investigate the most significant of the EDM die-sinking parameters such as current, pulse on time and pulse off time that can affect on EDM machining characteristics in material removal rate (MRR), electrode removal rate (EWR), surface roughness (Ra) and surface appearance using full factorial method and ANOVA.
2. To determine the interactions of parameters such as current, pulse on time and pulse off time by using full factorial methods.
3. To optimize the MRR, EWR and Ra of responses using single and multi-response optimization.

1.4 Scope of Study

This research studies the performance of EDM die-sinking parameters on material characteristics. The selected work piece material is Aluminium Alloy LM6 and the electrode is graphite. This study focuses on the machining characteristics of Aluminium Alloy LM6 in material removal rate, electrode removal rate, surface roughness and surface morphology. There are parameters that will affect the performance of EDM die sinking such as current, pulse on time and pulse off time. For optimization process, design of experiment (DOE) using full factorial method and analysis of variance (ANOVA) are used to find the best parameters combination of output variables.

1.5 Significance of Study

In this study Aluminium Alloy LM6 is using as a raw material or work piece. Aluminium Alloy LM6 widely used in automotive industry for example in production of engine block. The study of performance of EDM die-sinking parameters can give benefits to manufacturing industry because this study will come out with the best combination of parameters such as pulse on and pulse off time and also the current. These will help to produce quality product with less defect and also reduce production cost and minimize production time.

1.6 Organization of Report

This master project report consists of 5 chapters. Generally, in chapter 1, there are backgrounds of the study, problem statement, objectives of the study and the scope of study is discussed. Next for chapter 2 is a literature review of the study such as introduction to electro discharge machine die-sinking, process of removal rate using EDM die-sinking, machine, parameters of machining, machining characteristics, Aluminium Alloy LM6 for work piece, graphite for electrode and optimization method by using full factorial method and analysis of variance (ANOVA). Chapter 3 discusses the methodology of study which will explain the experimental set-up, preparation of work piece and electrode, equipment that used in experiment and experimental procedure.

Chapter 4 consists of all results and data collection from the experiments and also discussion regarding this project. Lastly, in chapter 5, the conclusion part that explains the conclusion of the findings and also the suggestion for improvement and future works.

CHAPTER 2

LITERATURE REVIEW

This chapter reviews the previous research about the EDM die sinking process. In this chapter, the issues that to be discussed are electrical discharge machine, material removal process using EDM die sinking machine, parameters of EDM die sinking machining, machining characteristics, Aluminium Alloy LM6 as a workpiece, graphite as an electrode, design of experiment using full factorial method and analysis of variance (ANOVA).

2.1 Introduction of EDM

Erosion of craters left by electric releases on the cathode surface was first found by Joseph Priestly, an English scholar and scientific expert in 1776. From that point forward, arcs have been utilized for an assortment of purposes and not really for the expulsion of metal. The principal utilization of circular segment for expelling metal was endeavoured by the Russian researcher (Singh et al. 2004). They were examining the wear caused by starting between tungsten electrical contacts which was basic for upkeep of car motors amid the Second World War under a task from the Soviet government.

Singh et al. (2004) stated that EDM innovation is progressively being utilized as a part of tool, die and mould making, for machining of heat treated apparatus steels and propelled materials (super alloys, metal matrix composite and ceramics. Its requiring high accuracy, complex shapes and high surface wrap up. Conventional machining method is frequently in view of the material expulsion utilizing device material harder than the work material and can't machine them monetarily. Heat treated device steels have turned out to be to a great degree hard to-machine utilizing conventional forms, because of fast instrument wear, low machining rates, failure to produce complex shapes and bestowing better surface finish.

The present the vast majority of the pass on sinking EDM applications require different goes to get the coveted precision and surface complete on the machined parts. This is finished by applying distinctive mix of machining parameters like current, voltage, release on/off time and so forth which are consequently decisively controlled by PC with the assistance of pre-set conditions database. Figure 2.1 shows the mechanism of EDM die sinking process.

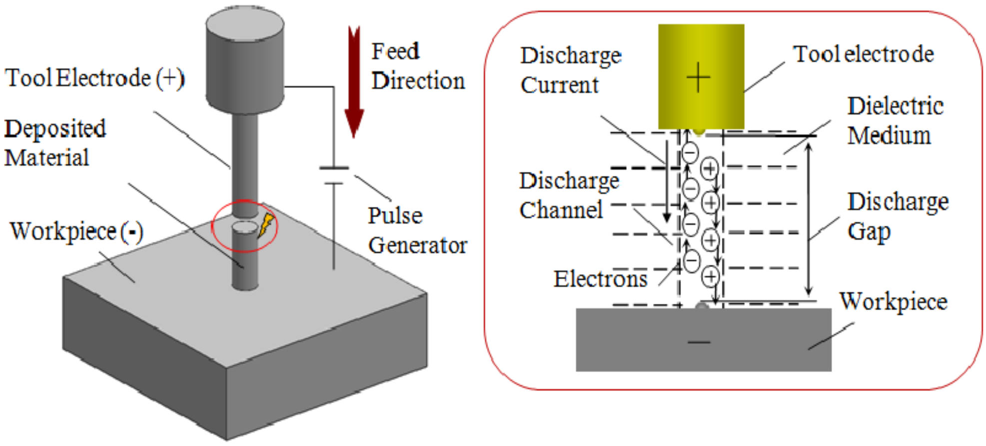

Figure 2.1: EDM Die-Sinking (Zilong et al. 2014)

2.1.1 EDM Principles

EDM is a thermal procedure where material is expelled by a progression of electrical releases occurring between an electrode and a work piece plunged in a dielectric liquid. Each release ionizes a confined plasma canal where temperature can move toward becoming very high (up to 10 000 ^{0}C), prompting combination and elation of metal of both confronting materials. A bubble is created, the pressure of which can be high (up to hundreds bars). Due to an extremely rapid heat change with the encompassing dielectric liquid, a piece of the liquefied metal is shot out of the work piece. A portion of the liquefied material remains on put and re-solidifies, demonstrating trademark blemishes on the edge of the crater (Kremer et.al. 1989). Figure 2.2 shows the working principle of EDM.

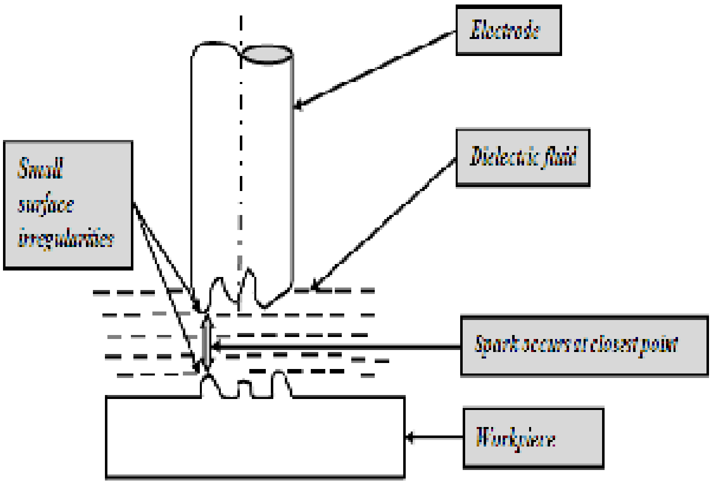

Figure 2.2: Working Principle of EDM (Abulais, 2014)

According Singh et al. (2004) dissolving and vaporization of the work material rules the material expulsion process in EDM, leaving small holes (craters) on the surface of the work material. EDM has no contact also any cutting force process, and accordingly does not makes direct contact between electrode and the work material. This dispenses with the odds of mechanical pressure, chatter and vibration issues, as is unmistakable in conventional machining. It has been perceived for a long time that a powerful spark will cause pitting or disintegration of the metal at both the anode (+) and cathod (-). This procedure is used in EDM die sinking.

Adithan (2009) stated that this procedure is additionally called as spark machining or sparks erosion machining. The EDM procedure includes a controlled erosion of electrically conductive materials by the start of fast and dull spark releases between the device and work piece isolated by a little hole of around 0.01 to 0.50 mm. This spark gap is either overwhelmed or immersed in a dielectric liquid. The controlled beating of the direct current between the tool and the work creates the spark discharge.

In the electrical discharge machining, before introducing the procedure the work piece is associated with the positive terminal and the device is associated with the negative terminal as shown in Figure 2.3. In the middle of the apparatus material and the work piece material a potential contrast is made. Electrically conductive materials are associated with the tool and the work piece material. Both instrument and work piece material must be submerged in the di-electric fluid and subject to electric voltage. In the middle of the device and the work piece material a gap is kept up to build up the electric field.