UNIVERSITI TEKNIKAL MALAYSIA MELAKA

INVESTIGATION THE EFFECTIVENESS OF EDM PERFORMANCE AND TOOL ROUGHNESS ON SURFACE FINISH OF INCONEL 718

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, declare this report entitled "Investigation the effectiveness of the EDM performance and tool roughness on the surface finish of Inconel 718" is the results of my own research except as cited in references.

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

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ABSTRACT

Inconel 718 is a high nickel content super alloy processing high strength at elevated temperature and resistance to oxidation and corrosion. Due to the abrasiveness, high hardness and low thermal conductivity, Inconel is known as difficult to be machine material. This alloy is widely used in widely uses in aerospace industry, automotive, nuclear power plant and medical purpose. Electrical Discharge Machining is one of the most popular advance machining processes. Thermal energy is used to generate heat that melts and vaporizes the workpiece by ionization within the dielectric medium. This research is focused on the ability of the EDM and the tool roughness in producing the good surface finish. Copper electrode with the diameter of 19mm has been selected as the working tool in this experiment. The roughness measures were arithmetic means roughness (Ra). Ra value is set as the input in this experiment due to the ability of EDM Sodick 3 axis Linear, Model AQ 35L to automatically display the parameter as to achieve the desired Ra. Historical data applied in this experiment. Response surface methodology (RSM) is used to formulate a mathematical model which correlates the parameter and EDM process parameters with the different machining criteria. The total experiment conducted is 13 where the smallest and highest surface roughness obtained in this experiment is 1.274µm and 5.778µm respectively. The factor involved in this experiment are current, pulse on-time, pulse off-time and tool roughness. ANOVA was used to identify the significant effect of the factors on the responses. Based on the analysis, pulse on-time was found to be the most significant factor in order to achieve minimum surface roughness. Mathematical model was generated by the ANOVA and average error resulted in 4.91%. The optimum parameter are current = 2.09A, pulse on-time = 5.178 µs and pulse off-time = 19.370 µs and the predicted surface roughness result is 1.158 µm.

ABSTRAK

Inconel 718 adalah super pemprosesan aloi yang tinggi kandungan nikel, kekuatan yang tinggi pada suhu tinggi dan rintangan kepada pengoksidaan dan kakisan. Oleh kerana abrasiveness itu, kekerasan yang tinggi dan kekonduksian haba yang rendah, Inconel dikenali sebagai bahan yang sukar untuk dimesin. Aloi ini digunakan secara meluas dalam banyak digunakan dalam industri aeroangkasa, automotif, loji kuasa nuklear dan tujuan perubatan. EDM adalah salah satu proses pemesinan terlebih dahulu yang paling popular. Tenaga haba digunakan untuk menjana haba yang cair dan mengewap bahan kerja oleh pengionan dalam medium dielektrik. Kajian ini memberi tumpuan kepada keupayaan EDM dan kekasaran alat dalam menghasilkan kemasan permukaan yang baik. Elektrod kuprum dengan diameter 19mm telah dipilih sebagai alat kerja dalam eksperimen ini. Langkah-langkah kekasaran ialah aritmetik bermakna kekasaran (Ra). Nilai Ra ditetapkan sebagai input dalam eksperimen ini kerana keupayaan EDM Sodick 3 paksi linear, Model AQ 35L untuk memaparkan parameter untuk mencapai Ra diingini secara automatik. Data sejarah digunakan dalam eksperimen ini. Metodologi permukaan Response (RSM) digunakan untuk merumuskan model matematik yang ada hubung kait parameter dan proses EDM parameter dengan kriteria pemesinan yang berbeza. Jumlah percubaan yang dilakukan ialah 13 di mana kekasaran permukaan yang paling kecil dan paling tinggi yang diperolehi dalam eksperimen ini masing-masing adalah 1.274µm dan 5.778µm. Faktor yang terlibat dalam eksperimen ini adalah current, pulse on-time, pulse off-time dan alat kekasaran. ANOVA telah digunakan untuk mengenal pasti kesan yang signifikan ke atas faktor-faktor ke atas keputusan. Berdasarkan analisis, pulse on-time didapati faktor yang paling penting untuk mencapai kekasaran permukaan minimum. Model matematik telah dijana oleh ANOVA dan kesilapan purata mengakibatkan 4.91%. Parameter optimum adalah current = 2.09A, pulse on-time = 5.178 µs dan pulse off-time = 19.370 µs dan kekasaran permukaan yang diramalkan adalah 1.158 µm.

DEDICATION

To everyone that contributes to this research, especially my family and my friends who always pray for the best and always help when in need.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

ANOVA	-	Analysis of variance
DOE	-	Design of Experiment
EDM	-	Electrical Discharge Machining
WEDM	-	Wire Electric Discharge Machine
RSM	-	Response Surface Methodology
Ra	-	Surface roughness
CCD	-	Central composite design
Cu	-	Copper
DOC	-	Design of Experiment
FCC	-	Faced-centered cubic
ISO	-	International Standard Organization
Mn	-	Manganese
Mo	-	Molybdenum
MRR	-	Material rate removal
Nb	-	Niobium
Ni	-	Nickel
Si	-	Silicone
Ti	-	Titanium

CHAPTER 1

INTRODUCTION

This chapter explains the background of the project in which the electrical discharge machining (EDM) is used in carrying out this experiment. The properties and applications of Inconel 718 are briefly described in this chapter, including the problem statement, objectives and scope covered in this project.

1.1 Project Background

Electrical discharged machining (EDM) is one of the prominent advance material removal processes. The different with this non-traditional and conventional process are the features that against normal rule for conventional machining that require contact between cutting tool and workpiece, large chip formation, the die must harder than workpiece and use mechanical energy (motion) (Kasim et al., 2013). Due to the demand in high precison engineering component from hard metal and alloy, some process using conventional machining is not be feasible, Therefore the application of EDM is widely accepted in the manufacturing of forming tools to produce molds and dies. EDM also has become a basic machining method for the manufacturing of microscopic, high precision, intricate part in critical industries such as aerospace, automotive, nuclear and medical (M. Kiyak, 2007).

The basic principle of EDM in removing material is by erosion process of workpiece by electrical spark (Dhirendra nath mishra et al., 2014). Tool and workpiece separated by a gap 10 to 200 µm (Manohar et al., 2014). This series of thermo electrical spark between workpiece and die which immersed in dielectric fluid melt and vaporize the work material. The residual of the process known as debris was ejected and flushed away by the electric (Rajaneesh N. Marigoudara, 2013).

This research involves the EDM process of Inconel 718. This nickel based super alloy is one of the hardest materials widely used in many industries such as aerospace, chemical and nuclear industries. The features of maintain strength, hardness , creep resistance, good ductility and anti-fatigue make this material to be selected in the rotating parts of gas turbine engine, blades, shaft and disks (F.Jafarian, 2014).

Surface roughness of the components or products is one of the important parameter in the engineering which is can represent the quality of the products. According to Rodriguez (2011), surface roughness has important role in the daily activities because the friction and wear in two solids sliding against each other are occurred frequently. Therefore, minimizing the surface roughness is very important in various industries such as automotive and aerospace. In EDM, many factors affecting the surface roughness such as, current, pulse on-time, pulse of-time and voltage. Surface roughness also affected by the type of working tool and workpiece used (S.Ahmad, 2013).

Working tool or electrode is one of the important components in EDM process. The selection of the best electrode in producing the good surface finish is very important. Good electrical conductivities, easy to be machined, high melting point, wear resistance and can produce fine surface finish are the main characteristic must be considered in selection of the working tool. Copper and graphite are commonly used as the working tool in EDM process. According to Ben Salem (2011), copper tool can produce better surface finish than graphite tool.

1.2 Problem statement

Inconel 718 is well known to be one of the most difficult materials to be machined. It is because of its high hardness, maintain the high strength at very high temperature and a low thermal conductivity (Ulutan et al., 2011). Due to its high strength and thermal resistance Nickel-based super alloy, Inconel 718 widely used and very important in the gas turbine industry, aircraft, nuclear and vehicles (Zhou et al., 2012).

These alloys also exhibit tensile resistance at temperatures below freezing point, causing widely used in the construction of aircraft components, power generators, medical equipment and components in nuclear reactors. High demand for the use of

Nickel-based alloys is increased to 40% relative to the overall total weight of the engine, which is 10% more than the use of Titanium (Ezugwu et al., 2005).

Inconel was introduced in 1988 with the durability at a temperature of 600℃ in the aerospace industry. Heat treatment process causes the micro-structure matrix (SG) becomes finer, with increasing hardness to 455HV and yield strength of 740 MPa (Olovsjö et al., 2012). Due to that, more than 50% Inconel 718 material was used in jet aircraft components and aerospace transport (Kalluri et al., 1995).

Surface roughness is important to describe the quality and performance of the finished products. Therefore, minimizing the surface roughness in manufacturing sectors such as, automotive and aerospace is very important(Md. Anayet U. Patwari, 2012). The used of Inconel 718 on the component parts of the engine at temperatures above 1000℃ must meet several criteria, including (Klocke et al., 2012):

a) Surface roughness value (Ra) must not exceed 0.8 μm
b) No white layer
c) No foreign material, the depth must not exceed 0.01mm

This Bachelor Degree Project will attempt to identify the effectiveness of the EDM performance and tool surface roughness in producing surface finish.

1.3 Objectives

To meet ends, the following objective has been set:

a) To identify the effect of EDM performances and tool roughness on surface finishing.
b) To develop a mathematical model for surface roughness using response surface methodology (RSM)
c) To identify the optimize parameter of EDM in reducing the surface roughness

1.4 Scope

The scope of this Bachelor Degree Project is investigated on surface roughness during machining of electrical discharge machine (EDM). This study is to analyse the machining performance and the effect of tool roughness on the surface finish of Inconel 718. The comparison will be made between desired Ra, with the Ra value of Inconel 718 obtained from the experiment. The cutting parameter of servo Voltage, Current, and Time on that suggested by EDM machine at specific set Ra will be recorded. This data will be considered as input data include the surface roughness of electrode. As to study the variance effect of this parameter on Ra, ANOVA will be used based on observed data. The historical data of Response Surface Methodology will be used as a tool of design of experiment. The diameter of 19 mm copper electrode will be used as the working tool in this experiment.

1.5 Report Outline

Generally, Chapter 1 is describes about the research background and problem statement, objectives and scope that leads to this research. Chapter 2 consist a review from previous study on machining Inconel 718 and other research about EDM. Methods and technique in conducting the experiment is briefly described in Chapter 3. This chapter also mentioned about the material, equipment, and solution tool. Additionally, the method of measurement and analysis process covered in this chapter. Result and discussion of the effectiveness of EDM performance and tool roughness toward the surface finish of Inconel 718 discussed in chapter 4. Lastly, Chapter 5 is the conclusion about the key findings of this project.

CHAPTER 2

LITERATURE REVIEW

The literature review works as a guide to run this analysis. From this chapter, the information about the EDM machining described and the idea for experimentation offered. Several of research studies have been carried out such as journals, books, and article. These review included the information about the EDM, machining method, parameter, data analysis, result and discussion.

2.1 Introduction

In year 1770, Joseph Priestly, an English Scientist has discovered the Electrical Discharged Machine techniques by noticing that electrical discharges had removal material of the electrodes during the experiments. Despite the fact that it was initially discovered by Priestly, EDM is inaccurate and filled with failure. The soviet scientist chose to damage the destructive effect of an electrical discharged and create a controlled strategy for metal machining. By the year of 1943, the construction of the first park erosion machining was announced. Lazarenko circuit, the spark generator used in 1943, has been utilized for a few years in power supplies for EDM machines and a progress structure is utilized as a part of numerous application. EDM technique was created commercially and transferred to a machine tool. This transforms made EDM more generally accessible and more preferred choice over conventional machining techniques (Sandeep, 2013).

For better performances of electrical discharge machining, lot of work has been carried out to improve the process and technique identified with discovering the attainability of harder material. The most important step to be considered is the correct selection of manufacturing conditions, especially the process that related to Electrical Discharged Machine (EDM). EDM is one the non-conventional machine that's able to machine the geometrically complex material, precise tool, composites, super alloys, tool steels, ceramics and carbides. The parameter that has been figured out in EDM such as discharges current, materials, possess greater strength and toughness (Ashok Kumar, 2010).

2.2 Principle of Electrical Discharged Machine (EDM)

Erosion begins by rapidly spark reduced occurred between the tool and workpiece in the EDM process, the metal is removed from the workpieces. A thin gap about 0.025mm is always ensured between the tool and workpiece by a servo system. For the further process, both tool and workpiece are submerged in a dielectric fluid. General types of dielectric medium used in EDM process are kerosene, hydrocarbon oil and deionized water (Sandeep, 2013).

The thermoelectric energy, energy that occurred between a workpiece and an working tool submerged in dielectric fluids with the present of electric current. Pulse arc in the small gap between the electrode and the workpiece filled with a dielectric medium like kerosene, hydrocarbon oil and deionized water. The spark gap is reduced when the electrode moved toward the workpiece and the dielectric fluid is ionized due to the high voltage applied. The working principle of EDM process is based on the thermoelectric energy. Spark gap is reduced when the electrode moves toward the workpiece and the applied voltage is sufficiently high to ionize the dielectric fluid. Short duration discharges are generated in a liquid dielectric gap between the electrode and workpiece. The erosive effect of the electrical discharges erodes the material from the tool and workpiece. The dielectric fluid cools the electrodes and flushes away the products of machine from the gap (Kuldeep, 2010).

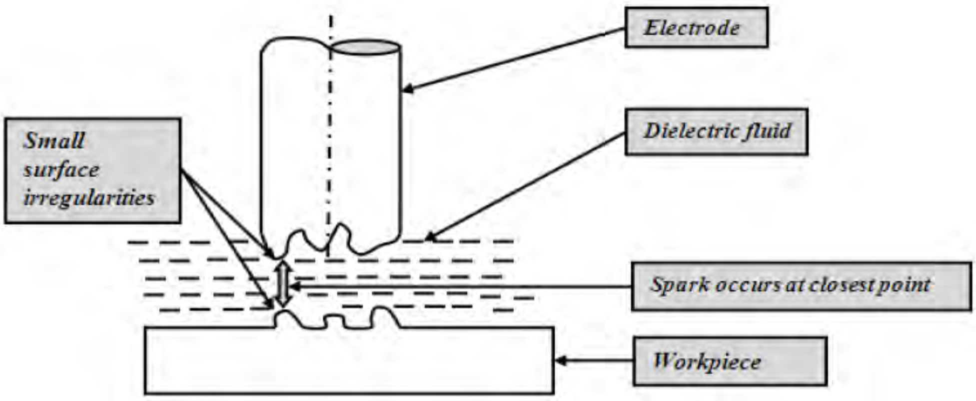

Figure 2.1: Working Principle of EDM (Kuldeep, 2010)

2.3 Dielectric Fluid

The dielectric fluid is a very important component in EDM process because it creates the spark gap and removes metal particles from the spark erosion area. The function of dielectric fluids mainly to cool the workpiece, electrode and the molten particle, solidify and flush the metal particles away from the gap (Mohammed B Ndaliman et al., 2013).

Dielectric is used to keep up the sparking gap between the electrode and the workpiece. EDM die sinking usually use the hydrocarbon oil as a dielectric, while wire-cut EDM use deionized water. The fundamental characteristics of dielectric fluid are electrical insulator. At the ionization point, the fluids changes into an electrical conductor and the spark occurs. At the point when the spark turned off, the fluids return to being an electrical insulator. This is happens for each spark. The function of dielectric fluids are: (Elman C, 2001).

1. Control the sparking-gap spacing between the tool and workpiece
2. Cools the hot material and form chip
3. Remove EDM chips from machining area

2.3.1 Flushing

In order to get the efficient cutting, flushing is the most important function in EDM because eroded particle must be removed from the gap. Flushing process, introducing fresh dielectric fluid into the gap and cools the electrode and workpiece. Improper applied flushing can cause erratic cutting and distract the EDMs performances. The metal removal becomes slower due to the high pressure of fluid. However, the chip's not completely removed with low pressure of the fluid. This will lead to the short circuit (Lei Li, 2011).

2.4 Inconel 718

Nickel-based super alloy, Inconel 718 widely use and very important in the gas turbine industry, aircraft, nuclear and vehicles. Due to the high temperature strength and high corrosion resistance, Inconel 718 merely used in the hot section gas turbine engine (N.G.Patil et al., 2014). The properties of Inconel 718 is shown in Table 2.1

Table 2.1: Material properties of Inconel 718 (Alloy Wire International Ltd., 2012)

Property	**Value**
Melting point	1425℃
Heat expansion	13 μm/m.C (20-100℃)
Conductivity (20℃)	0.15 W/cm. ℃
Density	8.19 g/cm^3
Modulus of rigidity	77.2 kN/mm^2
Modulus of elasticity	204.9 kN/mm^2

2.5 Copper Electrode

Copper with the present of power supply setting enables low wear burning. Copper turned into the metal anode due to the improvement of transistorized and pulse-type power supplies. Due to the structural integrity copper can create fine surface finish, even without special polishing circuits (S.Ahmad, 2013). In a poor flushing circumstance, the structural integrity makes copper electrode resistant to DC arcing. Copper is also commonly used for tubing for certain brands of High Speed Small Hole Machines. Copper electrodes are additionally the favoured material for all High Speed Small Hole applications including aerospace alloys as well as Carbide. (Kern, 2008).

Table 2.2: Material properties of copper electrode (Mohammadreza Shabgard, 2011)

Property	**Value**
Melting point	1083℃
Boiling Temperature	2595℃
Thermal Conductivity	0.15 W/m.K
Specific heat	0.092 cal/g. ℃
Specific gravity at 20℃	8.9 g/m^3
Coefficent of thermal expansion	17 x10^{-6}(1/℃)

Before the experimentation, the surface of the working tool was polished by using the grinding machine in order to get the best value surface finish.(S.Ahmad, 2013)

The experiment is carried out to investigate the best value of the surface roughness by using copper and brass as the tool. Copper with the density of 8.94x1000 kg/m^3 and brass desity is 8.75x1000 kg/m^3. The melting point is 1085℃ and 930℃ respectively. From the result obtained, Copper give lower Ra value compare to the brass (M. Hafiz Helmi, 2009).

The voltage was 60 V, the range of pulse interval from 12.8 to 200 μs and the peak current was from 3 to 25A. The tool materials are copper and graphite which are determined by the hardness of 100 HB and 10HB respectively. With the same discharged energy, copper tool produces a better surface finish than graphite tool (Ben Salem, 2011).

a) Copper electrode, Ra= 2.94μm b) Graphite electrode, Ra= 3.55 μm

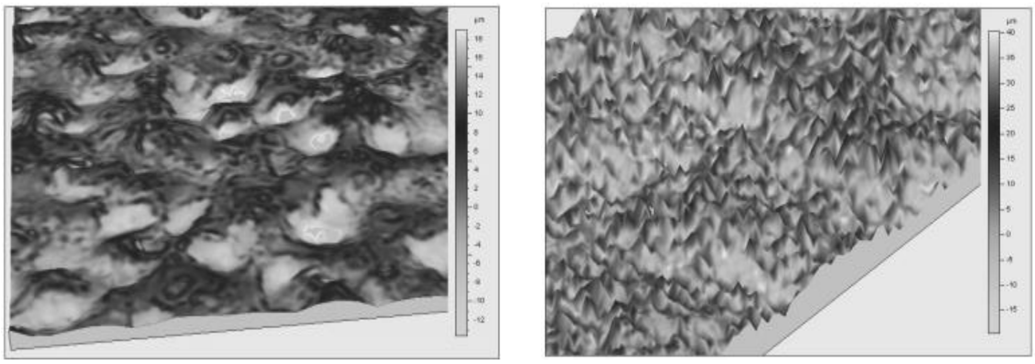

Figure 2.2: Surface roughness influenced by the types of tool (Ben Salem, 2011)

2.6 Surface Roughness Parameter

Several findings from previous work have been compiled. Based on the literature discharge current and pulse duration is the most influenced factor that affect the surface roughness. Surface roughness increases when discharged current and pulse duration increases. The circular tool electrode gives a better surface finish than the square one. Duty cycle and voltage does not significant to surface roughness. (Pushpendra S Bharti, 2010)