UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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STUDY ON CUTTING PARAMETER ON KERF WIDTH USING WEDM OF INCONEL 718

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

by

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2014

DECLARATION

I hereby, declared this report entitled "Study On Cutting Parameter On Kerf Width Using Wedm Of Inconel 718" is the results of my own research except as cited in references.

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APPROVAL

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ABSTRAK

Artikel ini membincangkan kesan pemboleh ubah pemotongan terhadap lebar Kerf menggunakan komputer kawalan berangka mesin nyahcas elektrik (WEDM) terhadap Inconel 718. Tiga pemboleh ubah yang diguna adalah perbezaan volt, kadar suapan dan arus yang dimanipulasi di dalam eksperimen ini. Reka bentuk eksperimen disiapkan menggunakan kaedah gerak balas permukaan. Analisis varians (ANOVA) menunjukkan bahawa kadar suapan banyak memberi kesan tehadap lebar Kerf berbanding pemboleh ubah lain yang dipakai di dalam eksperimen ini. Pengoptimuman dilakukan selepas eksperimen disahkan menggunakan pemboleh ubah rawak dan pemboleh ubah optimum. Ralat yang didapati ketika menggunakan pemboleh ubah rawak adalah 5% dan 4% ketika menggunakan pemboleh ubah optimum. Kombinasi pemboleh ubah yang terbaik untuk mengoptimum lebar Kerf adalah kadar suapan 0.86 mm/min, V 41 V dan I 7A untuk mendapatkan lebar Kerf iaitu 325.119 µm.

ABSTRACT

This article considers the study of cutting parameter on Kerf width using WEDM of Inconel 718. Three numerical parameters like voltage gap, feed rate, and current are being manipulated in this experiment. Designs of experiment are done by using the response surface methodology. ANOVA shows that feedrate heavily affect the size of Kerf width compared to other parameter used in this experiment. Optimization was done after the experiment has been validated by using the random parameter and optimized parameter. The error obtained when using random parameter is 5% and 4% for the optimized parameter. The best combination of parameter to optimize the Kerf width are fz 0.86 mm/min, V 41 V and I 7A in as to obtain a Kerf width of 325.119 µm.

DEDICATION

To everyone that contributes to this research and my friend that has been helping me all along

ACKNOWLEDGEMENT

First of all, I would like to thank ALLAH for giving me the strength to get this paper done. To my supervisor, Dr. Mohd Shahir Bin Kasim in giving his advices that is good for me and my research and his belief in me to finish this research in the given time. Not to mention that all my friends those have been helping me in completing this research and my beloved parents that gives all their support in completing my project.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

CNC	Computer Numerical Control
WEDM	Wire Electrical Discharge Machining
RSM	Response Surface Methodology
DOE	Design of Experiment
ANOVA	Analysis of Variance

CHAPTER 1

INTRODUCTION

1.1 Background of study

Wire-electrical discharge machining (WEDM) is a non-traditional machining process in which a pulsed voltage difference between a wire electrode and a conductive work piece initiates sparks which erode work piece material. Removing material in such a way is often advantageous when the work piece material would be difficult to machine with traditional machine tools due to high strength, hardness, toughness, etcetera (Newton, 2008). Due to the process itself, WEDM are able to produce any complex shape but at the loss of surface integrity and some other after effect like Kerf width, Heat affected zone and etc. However, the selection of cutting parameters for obtaining higher cutting efficiency or accuracy in WEDM is still not fully solved, even with the most up-to-date WEDM machine. It is due to the hard to expect nature of the process of WEDM. As a result, the relationships between the cutting parameters and the process performance are hard to model accurately. The problems arise although the machine itself is very up to date and some people hardly make a research out of it. Nowadays, the application demands for a material that has best properties in term of strength, corrosion and other properties. The composition of material is then made according to the specific properties demanded. But, the properties also bring disadvantages on what process should be chose to manufacture the material so the composition of the material should be studied earlier before making any decision. The ease and economy with which Inconel alloy 718 can be fabricated, combined with good tensile, fatigue, creep, and rupture strength, have resulted in its use in a wide range of applications. The examples of applications that use Inconel 718 as their main material are liquid fuelled rockets, casings and other aircraft parts (Corp, 2007).

1.2 Definition and parameters

Kerf width can be described as the width of the slot made by any cutting machine as it cuts. This term is widely used in engineering. It can be said as the working area for any machining process. The term Kerf width in WEDM can be described as the area that will be cut due to spark generated between anode and cathode. The effect of parameters used in WEDM greatly affect the Kerf width itself so by manipulating certain variables, the optimum Kerf width can be obtained. The Kerf width can be easily calculated or measured using several devices like feeler gauge. The purpose of feeler gauge is to measure the clearance between two parts. In laser cutting, it can be found on how to measure the Kerf width for example. According to Williamson (2011) , he uses a feeler gauge to measure the Kerf width and divides by the number of cuts to get the particular Kerf width for the parameter used. Somehow, it is not very practical to use the feeler gauge to measure the Kerf width on machined part since the wire of the WEDM itself is very fine and the area being cut is very small. Gupta et al. (2012) found that the effect of the Kerf width is small and it found that the average Kerf width is about 310µm. While the feeler gauge only able to measure about hundredth of millimetre, equipment are way better to be used to measure a small range of area. An optical microscope is another fine masterpiece invented by Zacharias Jansen around the year 1595 (Davidson, 2009) Nowadays, optical microscope is one of the best ways to measure a fine length for example the Kerf width on machined part which is very small and most of the length are µ sized. Parameters that affect the Kerf width in WEDM are mostly related to the pulse-on time and pulse-off time. According to Saha et al. (2013), the reason behind it is that with the increase of discharge duration, the overcut during discharge is also increased. From his analysis, the duration of discharge is increasing proportionally to overcut/Kerf width. The cutting speed also affected by the discharge duration. The parameter chose during WEDM can greatly affect the outcome of machined part for example surface roughness, heat-affected zone, recast layer and some other properties that is crucial in optimizing the outcome of the WEDM. Most of the previous researcher made a lot of contribution in determining the optimum parameter for the best result in surface roughness of WEDM cut parts. M.S. Hewidy (2005) made findings in getting the best surface roughness by manipulating the peak current. It is found that the peak current will affect the surface roughness as it increase up to a limit of 5A. Kumar and Singh (2012) found that open voltage have the greatest effect of the surface roughness where it's followed by some other parameter like wire tension, pulse on time, servo voltage pulse off time, fluid pressure , feed rate, over ride and wire feed . In his journal, Y.S.Liao (1997) found the table feed and pulse on time have significant influence on the metal removal rate, the gap voltage and the total discharge frequency. The gap width or Kerf width and the surface roughness are influenced by the pulse-on time. To summarize the above previous research, the parameters used greatly affect the outcome of the machined product while trying to keep the objective result as best as possible. But in determining the best multi objective parameter for the best configuration, the trade off need to be made where the result is not that great compared to the single objective. Meaning that the surface roughness and the Kerf width in one single experiment can be minimized a little bit compared to the experiment that has a single purpose which is only to reduce surface roughness (Kasim et al., 2013).

1.3 Problem statement

This research will focus on the study of Computer Numerical Control Wire EDM in investigating the effect of Kerf width based on the different parameter. Particularly, this study will identify, analyze and investigate the effect of feed rate, current and voltage as the manipulated variables while the other variables like pulse-on time, pulse-off time will be kept constant. The constant variables are treated like that so that the effect of manipulated variables can be studied. The parameter of WEDM greatly affects the Kerf width. While maintaining the optimum parameter, the effect for each parameter being used will affect the Kerf width and it can't be completely eliminated. This thesis will attempt to address the following:

a) What is the optimized cutting parameter as to reduce the Kerf width effect on Inconel 718 material.

1.4 Scope of research

In this report, the usage of WEDM and the parameter involved are feedrate, voltage and current used to construct the experiment. The machine used is Mitsubishi WEDM RA90 Series and the parameters used are mainly based on the configuration of the machine itself. The range of parameters used are being chosen based on the previous research regarding the WEDM on Inconel 718 and the allowable ranges of parameter on the machine. A design of experiment using Response Surface Methodology (RSM) will generate an array of combination of parameter that will be used in the experiment and the Kerf width then analyzed using the optical microscope. The characteristic of the Kerf width will be analyzed in order to determine the relationship between the parameter used with the Kerf width result on the Inconel 718 material.

1.5 Objective

The objective of this experiment is to analyse the Kerf width based on the WEDM parameter like feed rate, current and voltage. The results of the experiment are then analysed using Design Expert software to visualize the effect of each parameter on the Kerf width.

To investigate the effect of feed rate, voltage gap and current on Kerf width on Inconel 718 using WEDM.

To develop a mathematical model for Kerf width using Response Surface Methodology (RSM).

To identify the optimized cutting parameter for WEDM in reducing the Kerf width.

1.6 Thesis organization

The thesis organization for this thesis will cover six Chapter, starting with Chapter 1 that will briefly described the main title of this research which is Kerf width in WEDM. Chapter 2 will first discuss the development of electrical discharge machining, followed by a summary of reported knowledge about the effects of various process parameters. A detail research of parameter used in WEDM on Inconel 718 will be covered, along with a detailed description of Inconel 718. Chapter 3 will cover the experiment, method, result and analysis of this experiment. Chapter 4 will cover the result and data analysis. Last but not least, Chapter 5 covers the discussion of the study.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

2.1.1 Wire EDM

Wire Electrical Discharge Machine (WEDM) is mainly used to cut a very intricate shape which other machines can't do. Somehow, it's only usable on the metal based product since electric is the main source for the cutting of product. The process of cutting the metal product is very complicated since lots of factor need to be considered in order to achieve a perfect finish product. The area that needs to be removed are greatly affected by the parameter used on the machine like the voltage, current, pulse on-time, off time, federate and other factors.

2.1.2 Pulse-on time and pulse-off time

Based on the previous research about WEDM on Inconel 718, Lee and Tai (2003) explains that the pulse-on time means that the time during the machining is performed thus the machining process becomes faster after increasing the pulse on time that also cause the material removal rate increase and poor surface finish on the material surface. Study by R. Manikandan (2012) discovered that discharge current which gives the highest electric current that can occur during the discharge (if no capacitor is used). Pulse-on time is the duration of the impulse generated by the impulse generator; pulse-off time is the time between two impulses.

2.1.3 Surface roughness

Most of the previous researcher made lots of contributions in WEDM on the surface roughness, recast layer and etcetera but rarely did they do the research on the Kerf width. Previous researcher made a huge finding in improving the surface roughness by altering the parameter used on the WEDM machine. M.S. Hewidy (2005) found that surface roughness increasing as peak current rise and decreases as duty factor and wire tension increase. It is clear that surface roughness slightly increased with the increased of peak current value up to a certain limit and then dramatically improves with any increase of peak current. While, Sudhakara et al. (2012) founds that surface roughness change in magnitude when the current increased. When the current is rising, the metal removal rate is also increased. Normally when the metal removal rate rises, the surface roughness also will be increased. In term of parameters, when the discharge current is set to high, it will caused the spark intensity and discharge power to increase, forming a large crater depth on the surface of the work piece that produced a rough surface. Kumar and Singh (2012) found that surface roughness reduce with the rise of pulse on time, open voltage and wire feed and escalate with step-up in feed rate override and servo voltage. He also found that surface roughness first decline then surge with pulse off time and surface roughness first increase then decrease with wire tension. He concluded that The most significant parameter that affect the surface roughness in descending order are wire tension, pulse on time, servo voltage, pulse off time, fluid pressure, feed rate over ride and wire feed and the other parameters are not very significant. In conclusion, surface roughness mainly affected by the voltage and the current set. He also found that pulse off time also can reduce the surface roughness although not very significant.

2.1.4 Kerf width

Kerf width or commonly called as working gap are the response that will be discussed later on in this research. Working gap, peak current has a significant effect on the micro milling WEDM process where working gap is related to high thermal stress that exceeds the ultimate tensile strength of the material, as well as with plastic deformation and fluctuation in pulse energy will increase the Kerf width (Mao-Yong Lin et al., 2013). High pulse off-time and spark gap, and a reduced peak current and pulse on-time can obtain a low working gap in the micro milling WEDM process, which is due to less input discharge energy (Mao-Yong Lin et al., 2013). Khanra et al. (2007) found that when the peak current and pulse on-time increase, sparking from the side-wall of electrode on affected area increases leads to bigger working gap. From the findings of these two researchers, it seems like feed rate is insignificant in changing the Kerf width. It is notified that the voltage and current are the only parameters that have significant effect of the size of Kerf width.

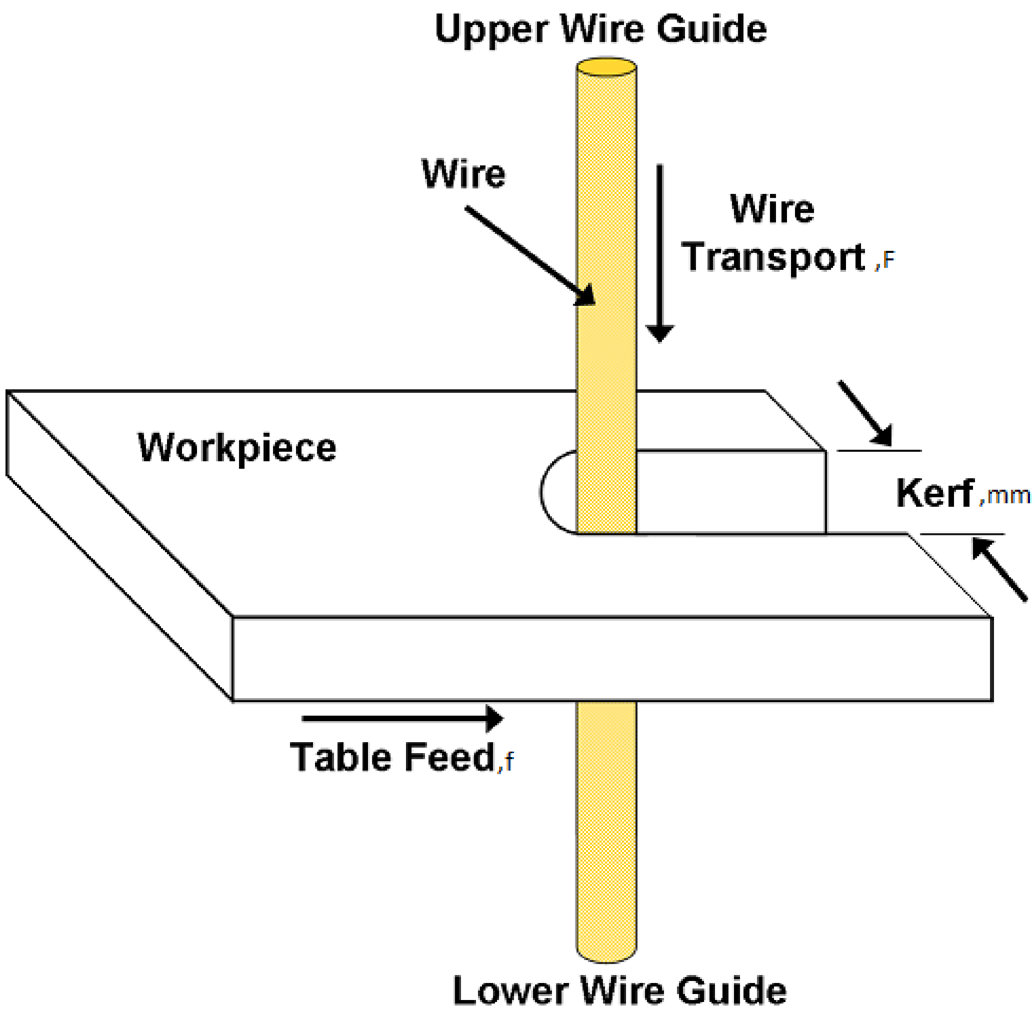

Figure 2.1: Kerf width in Wire EDM machining (Newton, 2008)

2.2 Previous research in Wire EDM

Table 2.1 until 2.6 conclude all the previous research regarding the WEDM and the component for these experiments are all based on the previous so that the research is not being done for the second time by duplicating the previous research.

The result from Table 2.2.2 shows the achievement by the researcher for their experiment that is aligned with their objectives. From the Table 2.2.2, there are lots of factors that have been affecting the results which are the parameters itself and the combined parameters have significant and less significant effect on the response for example Kerf width, surface roughness and etc. So, to obtain a good result based on the objective, the most significant parameter need to be optimized.

Material, tool and workpiece used in Table 2.1 state the related material, tool and workpiece used in their experiment. Most of them use the wire with the diameter of 0.25mm and some of them also used the Inconel 718 as the material being cut. While, the material and wire used are different than Inconel 718, the properties of the material in their experiment are somehow does not differ a lot than Inconel 718..

Due to the WEDM require a decent voltage and other parameters that will be later used in the experiment, the range of parameter that will be used as shown in Table 2.3 should be within the range of the machine and the stock size of the material for the experiment like the stock size in Table 2.2 also need to be considered. The feed rate is chosen are based on the ability of the machine to cut one of the hard material for example tungsten carbide. The parameter chosen are also based on the manual book for the machine where it list all the configuration of the parameter that need to be set up before starting the cutting process.

The Table 2.4 shows that the findings for the previous research where it can be used to validate this experiment or vice versa. These findings are related between each other and some researchers have been doing research in obtaining a multiple response based on the parameter selected. Any findings from the previous one can be used to validate the statements of each article.

The lists of machine used by the researcher are stated in Table 2.5 and the equipment that will be used in this particular experiment is based on the availability of the equipment itself where it can be found in Utem laboratory. The optical microscope used are placed in the Meterology lab where it is used to measure physical properties for example length, angle and etcetera for a fine material. The resolution of the machine is still within the range of Kerf width so any length of Kerf width is still can be measured when using this equipment.

The Table 2.6 shows the design of experiment (DOE) method used to analyze the interaction and generate optimized parameter for the experiment. The statistics software used to design for this experiment are generated by using the Design Expert software and it is based on the Response Surface methodology. The software generates the possible combination of parameter and the number of required experiment. The result of the experiment can be later used on for generating the related graph to find for any relationship between the parameter and the result.

2.2.1 Material, tool and work piece used

Table 2.1: Material, tool and work piece used

Author	Tool	Workpiece
(Huang et al., 1999)	0.25 diameter mm brass wire	SKD11 alloy steel
(Tosun et al., 2004)	CuZn37 Master brass wire with 0.25mm diameter	AISI 4140 steel (DIN 42CrMo4)
(M.S. Hewidy, 2005)	brass CuZn377 with 0.25mm in diameter	Inconel 601
(Okada et al., 2008)	TKC, TKC-Normal, TKC-Low Ts Wire-A Tungsten	Metal mold steel SKD11
(Ramakrishnan and Karunamoorthy, 2008)	brass wire of 0.25mmdiameter	Inconel 718
(Rakwal and Bamberg, 2009)	50 and 200 micron molybdenum wire And brass wire	Germanium wafer
(Ghewade and Nipanikar, 2011)		Inconel 718
(Gostimirovic et al., 2011)	manganese-vanadium tool steel (ASTM A681)	graphite tool electrodes 20×10mm
(Gupta et al., 2012)	CuZn37 Master Brass Wire (250 micron)	High strength low alloy steel
(Kumar and Singh, 2012)	0.25 mm diameter brass wire	SKD 61 alloy steel plate
(Sudhakara et al., 2012)	electrolytic rectangular copper block of 12 x 8 mm	Inconel-718
(Rodge et al., 2013)	brass wire of 0.25 mm diameter	Inconel 625
(Saha et al., 2013)	Brass wire, diameter 250micron	5 vol% TiC/austenitic manganese steel in-situ