UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Manufacturing Engineering

EFFECT OF WIRE-EDM PARAMETERS ON MACHINING CHARACTERISTICS OF TITANIUM ALLOY (Ti6Al4V) USING TAGUCHI METHOD

Noor Azam B Hj Jaafar

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NOOR AZAM B HJ JAAFAR

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ABSTRACT

Wire electrical discharge machining (WEDM) is a modification of electro discharge machining (EDM) which has been widely used for a long time in producing mould, die and other machine parts of conductive materials. Capability of cutting variety of conductive materials with intricate shapes makes it important in the market. Now, WEDM is extensively used in the field of mould making, medical, aerospace, and automobile industries. But, selection of optimum machining parameter is challenging task in WEDM due to the presence of a large number of process variables and stochastic process mechanism. In this study, WEDM of Titanium alloy (Ti6Al4V) is experimentally studied. The influence of pulse duration, pulse interval, servo voltage and ignition pulse current on material removal rate, surface roughness and kerf width is studied using Taguchi method. Analysis of varience method (ANOVA) will be used for recognizing the level of significance of WEDM cutting parameter for optimizing the above mentioned machining performance. Finally the results are particularly useful for machine manufacturers and researchers to determine the best combination of parameters which lead to optimize the machining performance.

ABSTRAK

Mesin nyahcas elektrik berwayar (WEDM) adalah modifikasi daripada mesin pelepasan elektro (EDM) yang digunakan secara meluas untuk masa yang lama dalam menghasilkan acuan, alat tekan dan bahagian-bahagian mesin lain yang bersifat bahan konduktif. Keupayaan memotong pelbagai bahan konduktif dengan bentuk yang rumit menjadikan ianya penting dalam pasaran. Kini, WEDM digunakan secara meluas dalam bidang pembuatan acuan, perubatan, aeroangkasa, dan juga industri automobil. Tetapi, pemilihan parameter untuk pemesinan yang optimum merupakan cabaran dalam WEDM kerana ianya disebabkan oleh kehadiran sebilangan besar pembolehubah proses dan mekanisme proses yang stokastik. Dalam kajian ini, Titanium Aloi (Ti6Al4V) dikaji. Pengaruh pulse duration, pulse interval, servo voltage dan ignition pulse current pada kadar pembuangan bahan, kekasaran permukaan dan lebar garitan dikaji menggunakan kaedah Taguchi. Analisis kaedah variasi (ANOVA) akan digunakan untuk mengenalpasti tahap kepentingan parameter WEDM untuk mengoptimumkan prestasi pemesinan yang disebutkan di atas. Akhir sekali keputusan yang diperolehi amat berguna kepada pengeluar mesin dan penyelidik untuk menentukan kombinasi paramater yang terbaik seterusnya membawa kepada mengoptimumkan prestasi pemesinan.

DEDICATION

This work is dedicated to my beloved wife, son, daughters and parents, without their caring support and the respect for education it would not have been possible.

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I am grateful to my family. Wife who understands and encourages me through this learning period, daughters and son who always understand my time constraint and parents who always pray for my success.

DECLARATION

I declare that this thesis entitle "Effect of Wire-EDM Parameters on Machining Characteristics of Titanium Alloy (Ti6Al4V) Using Taguchi Method" 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 : ....

Name : NOOR AZAM B JAAPAR

Date : 29-7-2013

APPROVAL

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

....

Dr. Mohd Amran Bin Md Ali
Pensyarah Kanan
Fakulti Kejuruteraan Pembuatan,
Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya,
76100 Durian Tunggal, Melaka, Malaysia.

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LIST OF ABBREVIATIONS

ANOVA	-	Analysis of variance
CNC	-	Computer numerical control
EDM	-	Electro discharge machine
IP Current	-	Ignition pulse current
MRR	-	Material removal rate
NC	-	Numerical control
S/N Ratio	-	Signal to Noise ratio
SR	-	Surface roughness
Ra	-	Arithmetic average roughness height
WEDM	-	Wire electrical discharge machine

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CHAPTER 1

INTRODUCTION

1.1 Background

Electrical Discharge Machining (EDM) was first discovered by the English scientist Joseph Priestly in 1770, but its advantages were utilized completely only in the year 1943 by the Russian scientists and it was commercially developed in the year 1970 (Basil Kuriachen et.al 2012). EDM is a non-traditional thermoelectric process which erodes material from the work piece by a series of discrete sparks between a work and tool electrode immersed in a liquid dielectric (non-conductive) medium. These electrical discharges melt and vaporize minute amounts of the work material, which are then ejected and flush away by the dielectric fluid. Most commonly used dielectric fluids are kerosene and de-ionized water.

When a continuously travelling wire used as the tool electrode in EDM, the process is called wire electro-discharge machining (WEDM). The movement of wire is controlled numerically to achieve the desired three-dimensional shape and accuracy of the work piece. Typically wires electrode are made from thin copper, brass, tungsten or sometimes has been coated for expanding the wires capability. The wire sizes are in diameter, ranging from 0.05 to 0.3 mm.

WEDM was first introduced to the manufacturing industry in the late 1960s due to seeking a technique to replace the machine electrode used in EDM. In the present scenario the technology of WEDM is improved significantly to satisfy the requirements in many area of manufacturing fields. According to K.H.Ho et al.(2004) WEDM supposes gain higher machining rate with the desired accuracy, reduced wire breakage and minimum surface damage. However, due to a large number of machining parameter, i.e. the frequency and energy of the electrical pulses, the wire electrode diameter and its tension, the length of cut, the wire speed, dielectric flow rate etc., it is difficult to establish the machining parameters, even for an experience operator.

Titanium and titanium alloys(e.g Ti- 6Al-4V) has a resistivity on the order of five times larger than steel. Titanium alloys have relatively high melting temperature, low thermal conductivities and high electrical resistivity when compared to other common materials, but electrical resistivity is highly dependent on the temperature. It also has been classified as difficult to machine materials by conventional machining method (Shajan Kuriakose et al 2004). The main reasons are rapid tool wear and high cutting temperatures. Therefore for machining these materials unconventional machining such as WEDM is recommended. But according to K.K.Ho et al (2004) parameters setting that provided by manufacturers are only for the common steel grades. Other than that material, most of the machining parameters are came from the machinists through their experience during handling with WEDM machine. Therefore the setting for machining advance materials such as Titanium alloys have to be further optimized experimentally. This material has been widely used in medical, aerospace, military, sport and commercial applications.

The most machining performance of WEDM that been studied by many researchers are material removal rate (MRR), surface roughness and kerf width. All these responds are depend on various machining parameters such as pulse on, pulse interval, servo voltage, dielectric fluid pressure, wire tension etc. Selection of parameters combination to optimized machining performance is a challenging task. It is not only for experience machinist but for researchers as well. This is due to the presence of large numbers of variables.

1.2 Problem statement

The parameter setting that provided by manufacturers for machining is only for common steel grades (K.H.Ho et al. 2004). The correct parameter setting for newly developed materials or advanced materials is not readily available. Currently, most of machinist who deals with this kind of materials, usually they utilize their experiences in term of selecting parameters when do machining processes.

In WEDM, the selection of parameters plays a main role in producing good surface quality and high material removal rate (MRR). This study aims to examine the influence of four important parameters viz. 'pulse on', 'pulse interval', 'servo voltage' and 'ignition pulse current' on material removal rate and surface roughness of titanium alloys Ti6Al-4V. Spark gap or kerf width of machining area also will be measured. Deeper studies of these selected different parameters which are able to deliver better results in terms of surface quality and material removal rate of this particular material. The problem might be interfered the result in this experiment when the selection of the parameters are not suitable and improper to investigate on these machining characteristics.

1.3 Project objective

The objectives of this project are;

i. To design the matrix of machining parameters using Taguchi Method.
ii. To analyze the significant parameters and percentage of contribution to the machining characteristics such as material removal rate (MRR), surface roughness (SR) and kerf width using analysis of variance (ANOVA).

iii. To find the optimum machining parameters such as material removal rate (MRR), surface rouhness (SR) and kerf width by using Taguchi Method.

1.4 Scope of study

i. Wire EDM Sodick VZ500L machine will be used in this project.

ii. Machining with brass 0.2 mm as electrode. Wire material composition was consisting of 60% Cu and 40%Zn.

iii. Specimen is Titanium Alloy – Ti6Al4V with density 4.42 g/cm^3

iv. Control parameters to be studied are pulse on, pulse interval, servo voltage and ignition pulse current.

v. Responds to be studied are material removal rate, surface roughness and kerf width.

vi. Design of experiment is based on Taguchi method and further analysis on significant of parameter's contribution to machining performance will be conducted by ANOVA.

CHAPTER 2

LITERATURE REVIEW

2.1 Wire Electrical Discharge Machine (WEDM)

Wire Electrical Discharge Machine (WEDM) is thermal mass-reducing process that used a continuously moving wire to remove material by means of rapid, controlled and repetitive spark discharge. A dielectric fluid is used to flush the removed particles, regulate the discharge and keep the wire and work piece cool. The wire and work piece must be electrically conductive. Fig. 2.1 shows the basic features of the WEDM machine.

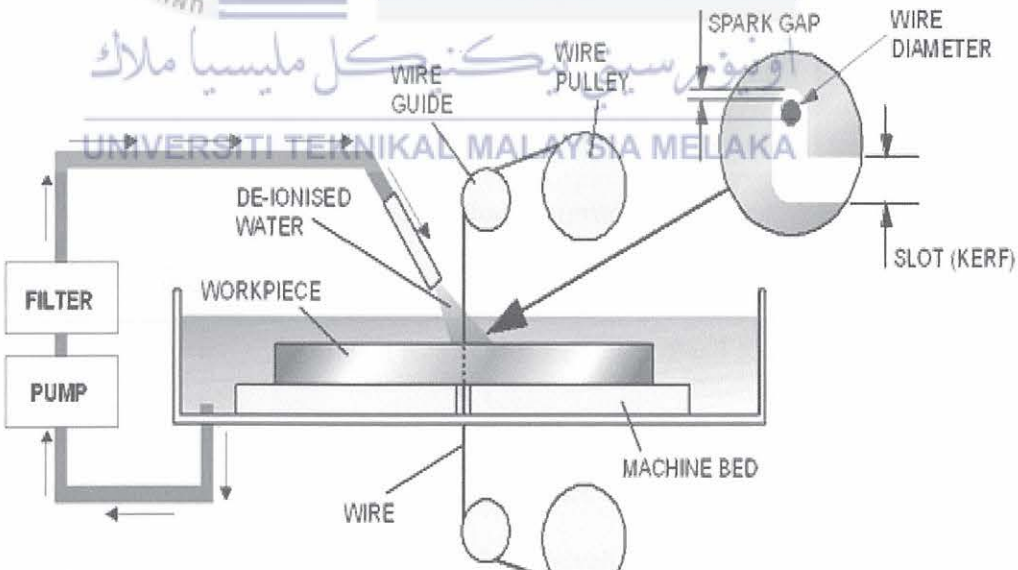

Figure 2.1: Schematic illustration of WEDM process

There are many parameters need to be considered when used this non-traditional machine. Follows are the part of WEDM parameters, for instance pulse on, pulse off, servo voltage, ignition pulse current, wire tension, wire speed and dielectric flow rate. A little bit change for this parameters will result a different value in responds.

There are many of journals that reveal the influence of WEDM parameters on responds or machining performance such as surface roughness, material removal rate and kerf width using different materials and different approaches. Tarng et al. (1995) used a neural network system with a simulated annealing (SA) algorithm to clarify the relationships between the cutting parameters and cutting performance. Huang et al. (1999) investigated the effect of machining parameters on the Kerf width, the surface roughness, and the recast layer thickness on the machined work piece surface experimentally. Shajan Kuriokose et al., (2003) found the parameters such as time pulses, pulse duration, injection pressure, wire speed, wire tension have more influence on the surface characteristics and among them the time between two pulses was the sensitive parameters. They did the experiment to most difficult to cut material Titanium alloy Ti6Al4V. Y.S. Liao et al,.(2004) also found that surface roughness is most affected by the pulse on time. S.S Mahapatra et al,.(2006) also conducted an experiment on D2 tool steel and tried to find the best combination of parameters including discharge current, pulse current, pulse frequency, wire speed, wire tension and DI flow rate. They found that current, pulse duration and dielectric pressure play most significant role in surface finish. Basil Kuriachen et al,.(2012) observed that pulse on time , dielectric pressure, the interaction of voltage and pulse on time are significant parameters which affect the surface roughness experimentally and did the modeling to investigate the study. Daniel Godsiyeh et al,.(2012) by using Taguchi method design of experiment revealed that peak current and pulse on time give significant affect to MRR when WEDMed on Titanium alloy.

2.2 Difficult to machine material Titanium alloy (Ti6Al4V)

For this project, Titanium alloy Ti6Al4V has been considered as a specimen. This material now day has attractive characteristics such as low density ($4.42g/cm^3$), excellent resistance to ignition, oxidation resistance and high temperature strength retention. Because of the excellent properties that it has this material gains a great interest in many industries such as aerospace, medical, mould making and automobile. Most of these components have performed well in laboratory tests as well as in the field. Product such as engine valves, turbine blades, screws and airframes are some examples which made by titanium alloy (W.Voice, 1999). But the problem with this material is due to its properties such as not ductile and has low fracture toughness at room temperature which makes them difficult to fabricate (B.Pan et al., 2001). Machining by conventional machine is difficult because of rapid tool wear due to excellent strength properties. Therefore, non-traditional machining such as WEDM widely used for machining a variety of difficult to machine material including above mentioned material. Due of a lot of WEDMs parameter and the material mechanical properties, the process of machining become complex and tougher.

Though number of researches presented the study of optimizing WEDM process, these studies limit to a few number of parameters. In the present work, wire electrical discharge machining of titanium alloy (Ti6Al4V) is studied with four control parameters. By using Taguchi Method as a design of experiment, 9 sets of controls parameter has been determined for experiment and the machining performance or responds such as surface roughness (SR), material removal rate (MRR) and kerf width will be studied.

CHAPTER 3

METHODOLOGY

3.1 Experimental method

The experiments were performed at VZ500L linear motor 4-axis CNC WEDM, which manufactured by Sodick Inc.Ltd. VZ500L allows the operator to choose the parameter for machining base on thickness, type of material and electrode size. But for this experiments default setting can't be used due to provided parameter are not covered for advanced material such as Titanium alloys. Exermined parameters had been input in NC programme manually.

Electrode brass wire is widely used in WEDM processes due to its good machining properties and can be die-casted or extruded for specialized application (Aniza Alias et.al 2012). Many machinists used brass wire as the electrode of WEDM because it has high tensile strength, high electrical conductivity, and good wire draw ability to close tolerances. The ideal wire electrode material for this process has three important criteria i.e. high electrical conductivity, sufficient mechanical strength and optimum sparks and flushes characteristics. For this experiment wire size of 0.2mm has been use as electrode.

Workpiece material is Titanium alloy (Ti6Al4V, density 4.42g/cm3, Composition : C=0-0.08%, Fe=0-0.25%, Al=5.5-6.76%, O=0-0.2%, N=0-0.05%, V=3.5-4.5%, H=0-0.375%, balance Ti) and the size is 260 mm x 60 mm x 4 mm.

Nine sets of parameters of experiments were conducted to determine all responds i.e. material removal rate (MRR), surface roughness (SR) and kerf width. For each set of parameters the workpiece was cut for a length of 20 mm as Figure 3.1. Each set will consist of three trials of cutting.

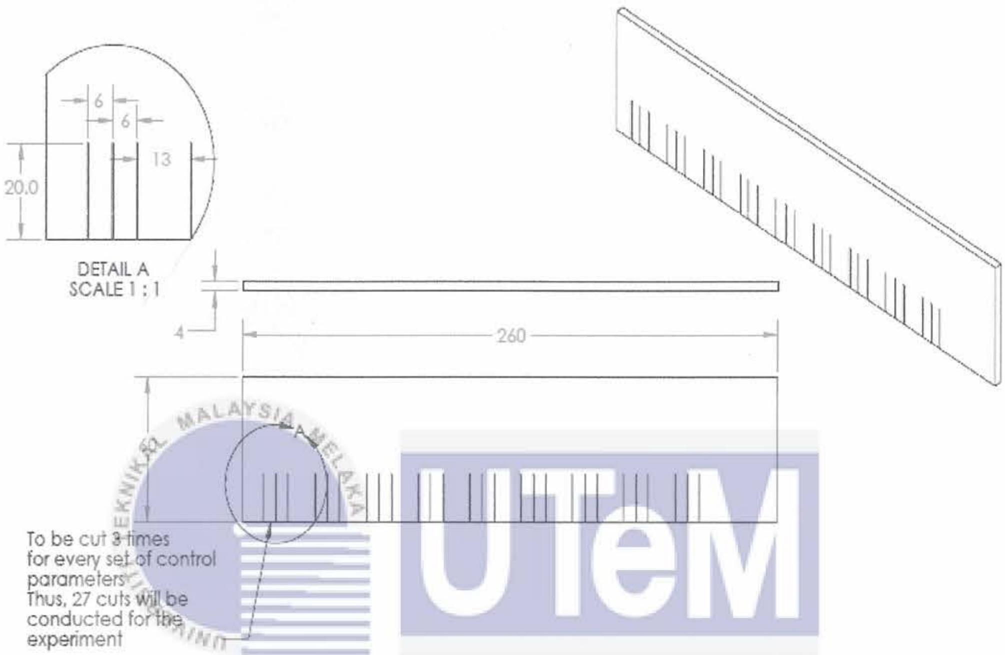

Figure 3.1: Cutting method of workpiece

Weight before and after cutting proses was measured as well as time taken to cut the work piece. The following equition will be used to calculate the MRR value :

$$\text{MRR} = \frac{Wa - Wb}{Tm} \text{(g/min)} \qquad (\textit{Equation 1})$$

Where, *Wb* and *Wa* are weights of work piece material before and after machining. *Tm* is machining time and calculated in minutes.

Each piece was cleaned and the surface roughness was measured as *Ra* value by using Surftest 400V Mitutoyo. *Ra* value will be measured for length 8 mm at cutting surface and three readings was taken before average it. Measuring method can be simplified as Figure 3.2.

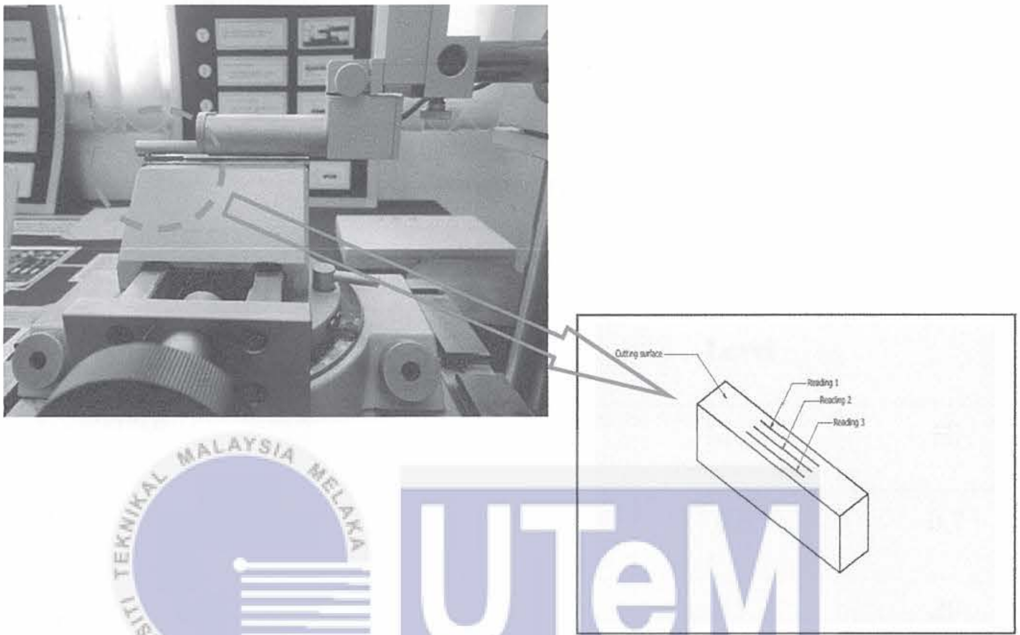

Figure 3.2: Surface roughness measuring method

Kerf width is measured by using Mitutoyo microscope as the sum of the wire diameter and twice wire work piece gap as Figure 3.3.

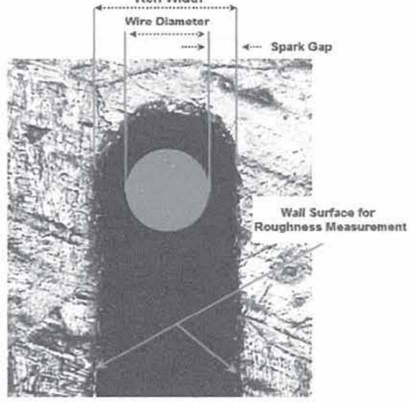

Figure 3.3: Measurement of kerf width (Aniza Alias et al.2012)