CHAPTER 3

METHODOLOGY

3.1 Introduction

This project has the objective to evaluate the performance of WEDM on DF2 tool steel. As such, proper experimentation planning and execution is needed in order to achieve the desired results. This project covers four areas:

a. Research design and data analysis
b. Machining parameters
c. Research procedure
d. Instrumentations

The above areas represent the main framework of this research. Design of experiment using the Taguchi method will be employed, and data will be analysed using the Minitab version 15.1.1.0 software. Confirmation test was also implemented in order to check the reliability of the WEDM results for the DF2 tool steel.

3.2 Research Design and Data Analysis

This design of experiment (DOE) will be using the Taguchi four factors with two-levels method. Taguchi matrices are derived from classical Full Factorial arrays. Taguchi designs have been developed to study factors at two-levels, three-levels, four-levels, and even with mixed levels. Multi-factor experiments are designed to evaluate multiple factors set at multiple levels. One approach is called a Full Factorial experiment, in which each factor is tested at each level in every possible combination with the other factors and their levels. Full factorial experiments that study all paired interactions can be economic and practical if there are few factors and only 2 or 3 levels per factor. The advantage is that all paired interactions can be studied. However, the number of runs goes up exponentially as additional factors are added.

As this project will be studying the effect of four machining input parameters, the experiment will cover all the possible combination factors at two levels (low and high value) for each parameter. As such, the L16 Orthogonal Array will be selected over the L8 Orthogonal Array. The table below shows the notation used to denoted these levels; (2) for high value and (1) for low value. The arrangement of the factors for this project was based on the Minitab version 15.1.1.0 software. This program will randomly choose the combination of factors to run the experiment and automatically analyse all the experimental results to investigate the influence of WEDM machining parameter on the surface integrity of DF2.

Table 3.1: Taguchi four factors with two-levels design

No.	Factors			
	1	**2**	**3**	**4**
	Open Current Voltage	**Pulse Duration**	**Wire Speed (WF)**	**Flushing Pressure**
	(OV)	**(ON)**	**(WF)**	**(WA)**
1	1	1	1	1
2	1	1	1	2
3	1	1	2	1
4	1	1	2	2
5	1	2	1	1
6	1	2	1	2
7	1	2	2	1
8	1	2	2	2
9	2	1	1	1
10	2	1	1	2
11	2	1	2	1
12	2	1	2	2
13	2	2	1	1
14	2	2	1	2
15	2	2	2	1
16	2	2	2	2

3.3 Research Design Variable

For this project, the design variables are divided into two groups: machining parameters and response parameters.

Machining parameters also known as independent variables, are the variables that we can set in the WEDM machine:

a. Open Circuit Voltage (OV, V)

b. Pulse Duration (ON, µs)

c. Wire Speed (WF, mm/s)

d. Flushing Pressure (WA, Kg/cm^2)

Response parameters, also known dependent variables, are the responses that we can measure as the result of the machining process:

a. Material removal rate

b. Surface roughness

c. Sparking gap

d. Cutting speed

3.3.1 Machining Parameters

There are many machining parameters in a WEDM machine. From journals, it was found that most researchers identified four main WEDM cutting parameters that greatly affect the machining output. They are open circuit voltage(OV), pulse duration(ON), wire speed(WF), flushing pressure(WA) while wire tension, table feed rate and pulse interval time are to be constant. Liao & Su (1997) found that pulse-on time have a significant influence on material removal rate. Kanlayasiri & Boonmung (2007) found that pulse-on time is a signififant factor affecting surface roughness. Rao et al (2011) has studied on the effects of pulse-on time and pressure of dielectric fluid amongst others, on her study of machining using WEDM. Nihat Tosun et al (2004) concluded that based on ANOVA method the highly effective parameters on both the kerf and MRR were found as open circuit and pulse duration. Ramakrishnan & Karunamoorthy (2008) concluded that wire feed rate plays a very significant role for allotting equal importance surface roughness and material removal rate.

The table below shows the High and Low setting of the parameters of the WEDM being studied:

Table 3.2: High and Low setting of the parameters being studied

MACHINING PARAMETERS	**LEVEL**	
	1 (LOW)	**2 (HIGH)**
Open circuit voltage (OV)	4 V	24 V
Pulse duration (ON)	4 s	18 s
Wire speed (WF)	2 mm/s	15 mm/s
Flushing pressure (WA)	4 kg/cm	8 kg/cm

The table below shows the experiment runs with the setting of machining parameters:

Table 3.3: Actual value of experimental design

Experiment Run no.	Factors			
	OV	ON	WF	WA
	Open Circuit Voltage (v)	Pulse Duration (µs)	Wire Speed (mm/s)	Flushing Pressure (kg/cm^2)
1	4	4	2	4
2	4	4	2	8
3	4	4	15	4
4	4	4	15	8
5	4	18	2	4
6	4	18	2	8
7	4	18	15	4
8	4	18	15	8
9	24	4	2	4
10	24	4	2	8
11	24	4	15	4
12	24	4	15	8
13	24	18	2	4
14	24	18	2	8
15	24	18	15	4
16	24	18	15	8

3.3.2 Machining Characteristics

Machining characteristic such as material removal rate (MMR) and surface roughness (R_a) are being studied in this project paper. Many manufacturers used these machining characteristic factors to determine the quality of the cutting surface through surface roughness and also how efficient is the WEDM.

3.3.3 Surface Roughness (R_a)

The general quality of a machined surface is known as surface roughness. Surface roughness can be specified in two common methods: such as peak to valley height (h) and arithmetic average, R_a (µm). The R_a value also known as centre line average and arithmetic average. This value is obtained by averaging the height of the surface above and below the centre line. Mitutoyo surface roughness tester was used to measure the surface roughness of the cutting sample. The R_a values of the surface were obtained by averaging the surface roughness values of 5mm measurement length.

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3.3.4 Cutting Speed (CS)

The measure of cutting length divided by machining time gives us cutting speed:

Cutting Speed = Cut length / Machining time

3.3.5 Sparking Gap (Gap)

Sparking gap or also known as overcut. Sparking gap is measured by using a Vertical Beam Optical Comparator:

Spark gap = (kerf width – wire diameter) ⁄ 2

3.3.6 Material Removal Rate (MRR)

The volume of the material removed per minute will give us the material removal rate (MRR). Material removal rate can be determined as follows:

Volume = spark gap x cut length x work piece thickness
Mass = work piece density x volume
MRR = mass / machining time

3.4 Research Procedure

The following four machining parameters are chosen as input parameters:

a) Open circuit voltage (V)
b) Pulse duration (µs)
c) Wire speed (mm/s)
d) Flushing pressure (kg/cm^2)

Wire Electro-Discharge Machining performance on DF2 tool steel in this research project is measured by material removal rate (MRR) and surface finish (Ra).

Design of experiment using Taguchi method was employed with two levels and four factors experiment. The total experiments required are $2^4 = 16$ experiment runs. The experiment design will include all the combination factors at two levels.

<u>The flow of the experiment is as follows:</u>

i) Start
ii) DOE Taguchi
iii) Run experiments
iv) Analysis of results
v) Determine the machine's optimum setting
vi) Confirmation test
vii) Final result
viii) End of experiment

3.5 Experimental Set-up

3.5.1 Machine Tool

The experiments were carried out on a WEDM machine (NEEM Technologies) at the Computer Numerical Control Laboratory of Manufacturing Engineering Department, Kepala Batas Community College, Penang, Malaysia.

Specifications of the WEDM machine:

- Design : Fixed column, moving table
- Table size : 440 x 650 mm
- Max. workpiece height : 200 mm
- Max. workpiece weight : 500 kg
- Main table traverse (X, Y) : 300, 400 mm
- Auxiliary table traverse (u, v) : 80, 80 mm
- Wire electrode diameter : 0.25 mm (Standard)
- Generator : ELPULS-40 A DLX
- Controlled axes : X Y, U, V simultaneous / independent
- Interpolation : Linear & Circular
- Least input increment : 0.0001mm
- Least command input (X, Y, u, v) : 0.0005mm
- Input Power supply : 3 phase, AC 415 V, 50 Hz
- Connected load : 10 KVA
- Average power consumption : 6 to 7 KVA

3.5.2 Work Piece Material

The DF2 cold work tool and die steel plate of 310mm x 100mm x 10mm size has been used as a work piece material for the present experiment. DF2 is a general purpose oil-hardening tool steel is a versatile manganese-chromium-tungsten steel suitable for a wide variety of cold-work applications. Its main characteristics include: good machinability, good dimensional stability in hardening, good combination of high surface hardness and toughness after hardening and tempering. These characteristics combine to make it suitable for the manufacture of tooling with good tool-life and high production economy.

3.5.3 Preparation of Specimens

DF2 tool steel plate of 310mm x 100mm x 10mm size is mounted on the WEDM machine tool and specimens of 30mm x 5mm x 10mm size are cut.

3.5.4 Experimentation

Following steps were carried out during the machining of DF2:

1. The work piece was mounted and clamped securely onto the work table of the WEDM machine.

2. Setting for a work coordinate system was done on the work piece by fixing a datum point. With reference to the work coordinate system, the programmed cutting operation was carried out.
3. Straight cuts of 50 mm length were made by programming the machine.

Precautionary measure taken during experiments:

1. Each experiment was conducted three times in each of the trial due to reduce experimental set up error.
2. Each set of experiments was carried out at room temperature.
3. Specimens were cleaned with acetone before taking measurements.

3.6 Experimental Equipments

The equipments involved in this study are as follows:

a. WEDM machine – NEEM Technologies

b. Surface Roughness Tester - Mitutoyo

c. Vertical Beam Optical Comparator – Mitutoyo

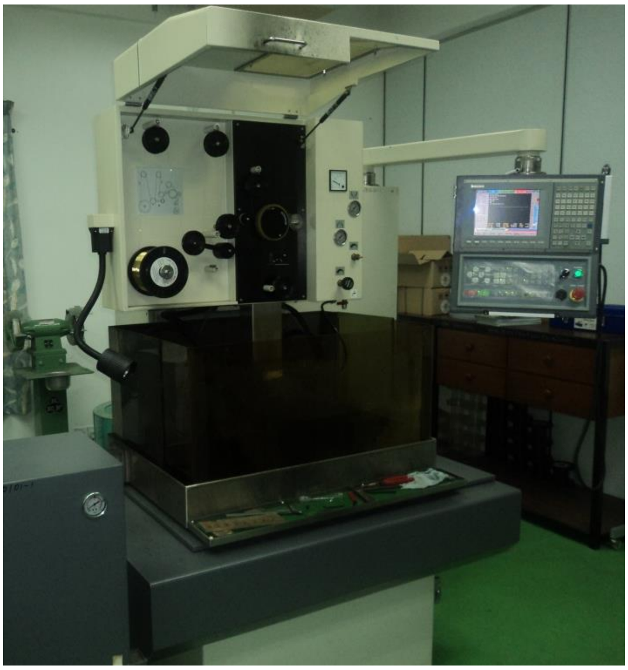

Figure 3.1: WEDM – NEEM Technologies

Figure 3.2: Vertical Beam Optical Comparator – Mitutoyo

Figure 3.3: Surface Roughness Tester - Mitutoyo