RELATIONSHIP BETWEEN ELECTRODE SIZE AND MACHINED SURFACE IN THE EDM MACHINING PROCESS

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Report submitted in partial fulfilment of the requirements for the award of the degree of Bachelor of Mechanical Engineering with Manufacturing Engineering

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SUPERVISOR'S DECLARATION

We hereby declare that we have checked this project and in our opinion this project is satisfactory in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering with Manufacturing.

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I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurrently submitted for award of other degree.

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ABSTRACT

Electro-Discharge Machining (EDM) has found widespread application in the fabrication of Micro-Electro Mechanical Systems (MEMS), tool and mold industries and aerospace industries. The machining technique now plays an indispensable role in the fabrication of a wide variety of components. However due to rapid heating and cooling during machining, a thermally affected layer will form on the machined surface. A close inspection reveals the presence of many surface defects such as void, cracks, shallow crater and debris on this layer. Tungsten carbide (WC) with 15% of cobalt content is selected as the workpiece material and the copper tungsten as the electrode in this experiment. The electrodes are consisting in three different sizes are 3mm, 6mm and 8mm of diameter. Since EDM has been shown to be a versatile method for machining difficult-to-work materials, it is believed that the EDM process will open up an opportunity for the machining of tungsten carbide (WC). The aim of this study is to analyzes the machined surface in term of surface roughness that influenced by the different size of electrodes. After completion the experiment process, scanning electron microscope (SEM) will be employed to analyze the surface topography and the surface roughness tester will be used to measure the surface roughness on the machined surface.

ABSTRAK

Electro-Discharge Machine (EDM) telah ditemui secara meluas penggunaannya di dalam pembuatan Micro-Electro Mechanical Systems (MEMS), industri alat dan acuan, dan industri aeroangkasa. Pada masa kini, teknik memesinnya memainkan peranan yang penting di dalam pembuatan pelbagai komponen. Walaubagaimanapun pemanasan serta peyejukkan yang cepat semasa operasi pemesinan dijalankan akan mengakibatkan terbentuknya satu lapisan di atas permukaan ini. Satu penyemakan hampir telah mendedahkan bahawa banyak kecacatan hadir di atas lapisan ini seperti lopak, keretakan, kawah cetek dan puing. Tungsten karbida (WC) dengan 15% kandungan kobalt dipilih sebagai bahan kerja dan tungsten tembaga sebagai elektrod dalam eksperimen ini. Elektrod ini terdiri daripada tiga saiz yang berbeza iaitu 3mm, 6mm, dan 8mm. Semenjak EDM menunjukkan satu kaedah yang serba boleh untuk memesin bahan kerja yang sukar, ia dipercayai boleh membuka peluang untuk memesin tungsten karbida (WC). Kajian ini adalah bertujuan untuk menganalisis permukaan yang dimesin dalam istilah kekasaran permukaan yang dipengaruhi oleh pengunaan saiz elektrod yang berbeza. Selepas eksperimen siap dijalankan, mikroskop pengesanan elektron (SEM) akan digunakan untuk menganalisis topografi permukaan dan penguji kekasaran permukaan akan digunakan untuk mengukur kekasaran permukaan yang dimesin.

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t_i	Pulse on-time
t_0	Pulse off-time
R_a	Surface roughness
I	Intensity
A	Current

LIST OF ABBREVIATIONS

EDM	Electro-discharge machine
MEMS	Micro-Electro Mechanical Systems
WC	Tungsten Carbide
SEM	Scanning electron microscope
MRR	Material removal rate
DC	Direct current
HAZ	Heat affected zone
ER	Electrode wear

CHAPTER 1

INTRODUCTION

1.1 Project Background

Electrical discharge machining (EDM) is a process that is used to remove metal through the action of an electrical discharge of short duration and high current density between the tool and the workpiece. It has been proven to be especially valuable in the machining of super-tough, electrically conductive materials such as the new space-age alloys. These metals would have been difficult to machine by conventional methods, but EDM has made it relatively simple to machine intricate shapes that would be impossible to produce with conventional cutting tools. This machining process is continually finding further applications in the metal machining industry. Although the application of EDM is limited to the machining of electrically conductive workpiece materials, the process has the capability of cutting these materials regardless of their hardness or toughness [1].

The material used in this experiment is tungsten carbide (WC) with 15% of cobalt content. Tungsten carbide is an important tool and die material mostly because of its high hardness, strength and wear resistance over a wide range of temperature. It has high specific strength and cannot be processed easily by conventional machining techniques. Since EDM has been shown to be a versatile method for machining difficult-to-work materials, it is believed that the EDM process will open up an opportunity for the machining of tungsten carbide. As such, extensive study on the effect of machining

parameters on the machining characteristics in EDM of tungsten carbide should be called for [2].

This experiment will perform at constant parameter of EDM with the different size of electrode and then it will be compare to get fine machined surface in cutting WC. After EDM operation, the scanning electron microscopy (SEM) will be employed to analyze the machined surface. The surface topography reveals that the surface roughness is caused by an uneven fusing structure, globules of debris, shallow craters, pockmarks, voids and cracks [3]. Then, the machined workpiece surface will be measured by using the surface roughness tester to analyze the surface roughness. The surface roughness is influenced by the size, appearance and depth of the electrode discharge [3]. The current also reveal that some of the surface crack distribution is influenced by the machining parameters, the electrode diameter and the material conductivity [3].

1.2 Objective

i) To investigate relationship between the electrode size and machined surface of tungsten carbide (WC) in the EDM machining process.

1.3 Project Scopes

The research scope is limited to:

i) EDM Die Sinking (Sodick AQ55L) will be used for the whole experiment.
ii) Tungsten carbide with 15% of cobalt content is selected as the workpiece.
iii) The parameter that will be set up at the constant rate are pulse duration, peak current, arc gap, duty cycle and intensity.
iv) The surface topography of tungsten carbide (WC) will be examined by using a scanning electron microscope (SEM).
v) The surface roughness of the workpiece will be measured by using a surface roughness tester (Perthometer S2 Mahr).

1.4 Problem Statement

In this experiment, tungsten carbide (WC) will be cut using EDM machine with different sizes of electrode at the constant selected parameter of EDM. The problem might interface in this experiment is when the large of size of electrode is used will attend to more roughness on the machined surface. Therefore this study were implemented to show how the surface roughness can be influenced by the different size of electrode and in order to get fine machined surface.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction of EDM Machining

EDM has been an important manufacturing process for the tooling, mould and die industries for several decades. Currently, it is just as likely to be used for production quantities of aircraft, medical, and electronic parts, as for tooling and prototypes. Turbine disks for aircraft engines, and airfoil shapes for ground-based turbines are among its many current applications, which also encompass die cavities for large automotive body components such as narrow slots, turbine blades, and various intricate shapes [4]. Other major uses of the process include machining carbide stock and producing metal molds and dies for stamping, forging, and jewelry manufacture [5]. The process is finding an increasing industrial use due to the ability of producing geometrically complex shapes as well as its ability to machine hard materials that are extremely difficult to machine when using conventional process. There are two main types of EDM processes [6]:

i. Conventional EDM (Sinker EDM or Ram EDM)
ii. Wire EDM

The ability of EDM to machine hard materials that are extremely difficult to machine has made some researcher to categories and classified the machining processes as shown on Figure 2.1.

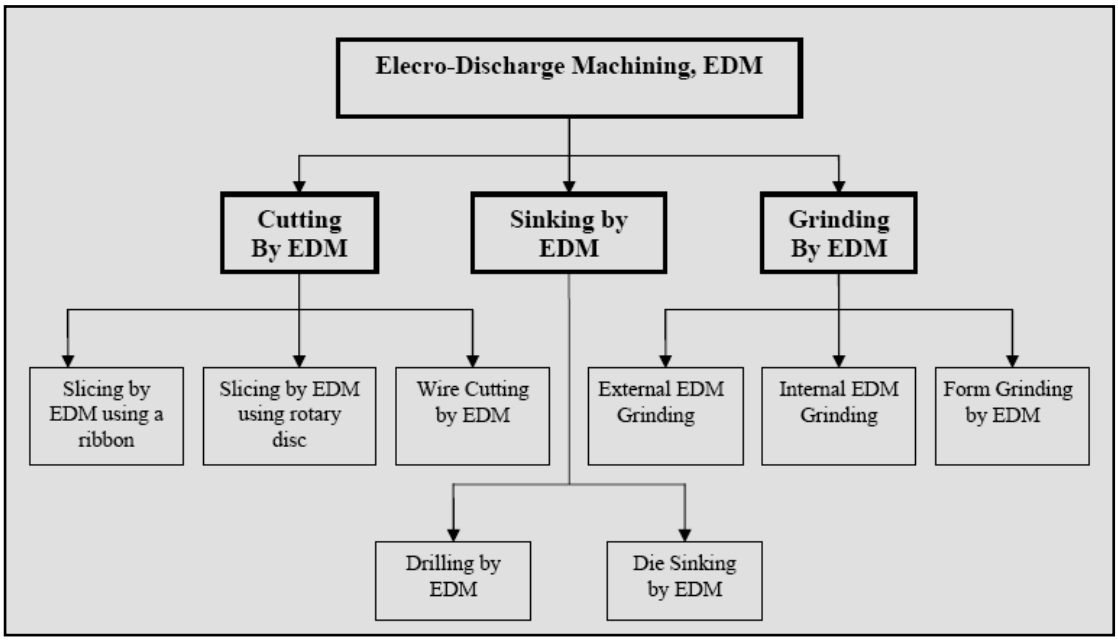


Figure 2.1: Classification of EDM processes [7]

2.2 EDM Process.

EDM machining is accomplished by the action of rapidly occurring electrical discharges, or sparks, which erode small pieces of metal from the workpiece. The cutting tool is an electrode that is shaped to the contour of the required cut. Both of the workpiece and the electrode are submerged in an electrically nonconducting (dielectric) fluid and connected to a dc power supply. The dielectric fluid functions as an insulator, coolant, and medium for flushing away debris from the tool and the workpiece, usually the dielectric fluid is consisting of mineral oil or kerosene,

Then the sparks travel through the nonconductive fluid to reach the workpiece, it were sent from the electrode to the workpiece at a rate of thousands per second, The electrode vaporizes the metal without ever touching the workpiece, which is by necessity made of electrically conductive material.

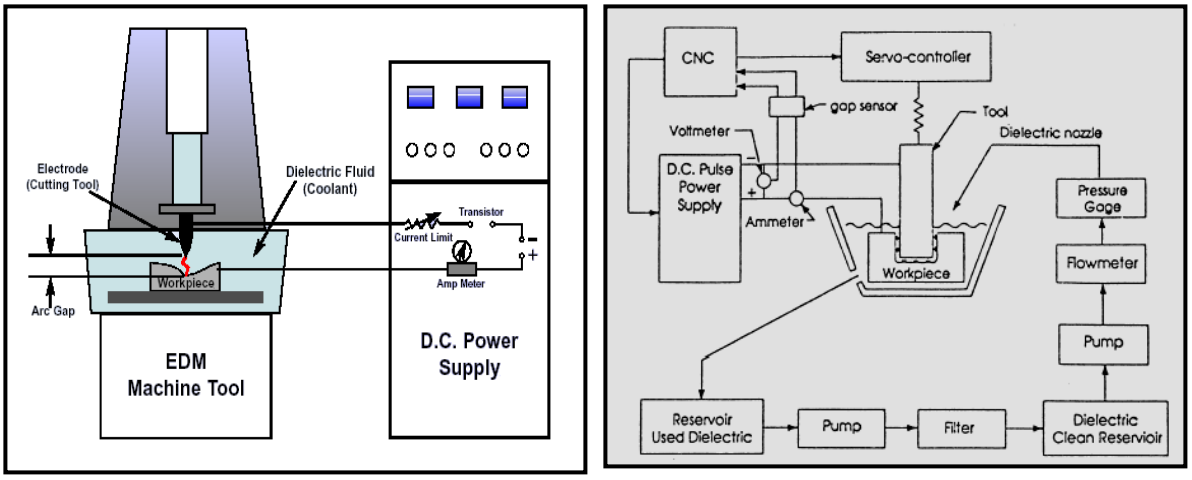
Although rates of metal removal are slower with electrical discharge machining than with other commercial machining methods, the slower removal produces better surface finishes. Higher rates of metal removal are known to produce rougher finishes that have a molten and resolidified (recast) structure with poor surface integrity and low fatigue properties [4].

Generally the EDM-die sinking is used to produce blind cavities [6]. When blind cavities are required, a formed electrode is machined to the desired shape. Then, by means of electrical current the preformed electrode surrounded by dielectric fluid, reproduced its shape in the workpiece. A powerful spark causes pitting or erosion of the metal on both the anode (+) and cathode (-). This process is also called spark machining or spark erosion machining. The EDM process involves a controlled erosion of electrically conductive materials by the initiation of rapid and repetitive spark discharges between the electrode and workpiece which is separated by a small gap.

Figure 2.2 showed the EDM is accomplished with a system comprising two major components [8]:

i. Machine tool
ii. Power supply

The machine tool holds a shaped electrode, which advances into the work material and produces a high frequency series of electrical spark discharges. The sparks are generated by a pulse generator, between the tool electrode and the work material, submerged in a liquid dielectric, leading to metal removal from the work material by thermal erosion or vaporization.



(a) (b)

Figure 2.2: The (a) Illustration and (b) Schematic of Basic EDM System [8]

2.3 Design Considerations for EDM

In this topic the user should follow the design consideration for their guideline for run a better any EDM works. The general design guidelines for electro-discharge machining are as follows: [9]

i) Parts should be designed so that the required electrodes can be shapes properly and economical.
ii) Deep slots and narrow opening should be avoided.
iii) The surface finish specified should not be too fine for produce the economic production.
iv) To achieve a high production rate, the bulk of material removal should be done by conventional processes (roughing out).

2.4 Machining Parameter in EDM Die Sink

In EDM, the variables parameters are have great effects to the machining performances results especially to the material removable rate (MRR), electrode wear

rate and surface integrity. There are two major groups of parameters that have been discovered and categorized [8]:

i) Non-electrical Parameters
   - Injection flushing pressure
   - Rotational of speed electrode

ii) Electrical Parameters
   - Peak current
   - Polarity
   - Pulse duration
   - Power supply voltage

There is no present EDM technology that can eliminate all redeposition, of material, although the pulse-type power supply is efficient and effective for minimizing remelt and recast and also for protecting the workpiece from heat-related deterioration [10]. There are some important parameters can be considered that affect the machining surface produce such as:

i) DC voltage
   - This is determined by the width of gap between the electrode and the workpiece. A higher voltage creates a current and spark across wider gap.

ii) Current (A)
   - The erosion rate varies with current, as does electrode wear. As the amount of current goes up, so does the workpiece erosion rate. Different electrode materials demonstrate different rates of erosion. For example, copper electrode erodes at a constant percentage of the workpiece material. Graphite, on the other hand, wears more rapidly upon an increase in current but its wear rate then declines and remains nearly constant.

iii) On-time (pulse time or t_i):

- The duration of time (µs) the current is allowed to flow per cycle. Material removal is directly proportional to the amount of energy applied during this on-time. This energy is controlled by the peak current and the length of the on-time.

iv) Off-time (pause time or t_0):

- It is the duration of time (µs) between the sparks (that is to say, on-time). This time allows the molten material to solidify and to be wash out of the arc gap. This parameter is to affect the speed and the stability of the cut. Thus, if the off-time is too short, it will cause sparks to be unstable.

v) Arc gap (or gap):

- It is the distance between the electrode and the part during the process of EDM. It also called as spark gap.

vi) Duty cycle:

- Duty cycle is a calculated percentage equal to on-time divided by total time for the complete on/off cycle. Modem EDM power supplies control duty cycle and on-time, but not off-time. While on and off times are usually constant, duty cycle control allows machine flexibility to adjust these times to meet special situations such as a section or particle of material not as conductive as the overall workpiece.

vii) Intensity (I):

- It points out the different levels of power that can be supplied by the generator of the EDM machine. (I) represents the mean value of the discharge current intensity.

2.4.1 Electrode

All EDM electrode materials must possess certain properties in order to perform economically in any application in the machining [11]. The main property of electrode is electrical conductivity, however, other application depending to the material workpiece used. The function of an electrode is to transmit the electrical charges and to erode the work piece to the desired shape.

Commonly the material of electrode are made of tungsten, copper tungsten, silver tungsten, yellow brass, chrome plated materials, zinc alloys, tungsten carbide, copper, graphite, etc [11]. Copper electrodes have been used primarily in resistance capacitance circuits where higher voltages are employed. Graphite electrodes are commonly used in application requiring little tool wear and high material removal rate. Brass electrodes are mainly used in pulse type circuits because of their good machinability. Table 2.1 shows the details of electrode material selection.

However the material selection should be done carefully because the quality surface finish is largely influenced by the electrode selection material. Different electrodes have their own effect on machining characteristics. Some electrode have a high MRR but the other else have different characteristic depends on what material and tool used [11].

Electrode Material	Form	Wear ratio in finishing	Wear ratio in roughing	Relative cost	Machinability Rating
Graphite	Block,rod, tube,bar	5 : 1	To 100:1	Low	Excellent
Copper	Bar,rod,sheet,wire, tube,forging,stampings	1:1	2:1	Medium	Good
Copper-graphite	Blocks,rods	2:1	4:1	Medium	Fine
Brass	Same as copper	0.7:1	2:1	Low	Good
Zinc alloys	Cast, die casting	0.7:1	2:1	Low	Good
Steel	All forms	1:1	2:1	Low	Excellent
Copper tungsten	Bar,flats,shim stock,rod,wire,tube	3:1	8:1	Medium	Fair
Silver tungsten	Sintered	8:1	12:1	High	Fair
Tungsten	Wire,rod,ribbon	5:1	10:1	High	Poor

Table 2.1: Types of electrode material for EDM [11]

Based on the table above, copper tungsten is the best choice and widely used as an electrode material in EDM machining tungsten carbide workpiece. This material has good properties such as high dimensional accuracy, very good resistant, high melting point temperature and etc [2]. Very good resistant, that's mean the surface of the electrode will not be eroded easily, thus keeping the workpiece dimensional accuracy to a high level [2]. Copper tungsten also has good finishing surface produce that can give minimum defection to the machined surface than other electrode such as copper and brass [11].

2.4.2 Flushing Pressure

Flushing is important because it removes eroded particles from the gap for efficient cutting. Flushing also enables fresh dielectric oil flow into the gap and cools both the electrode and the workpiece. Improper flushing causes erratic cutting, thus prevents the electrode from cutting efficiently. It is then necessary to remove the attached particles by cleaning the workpiece. Dielectric fluid is used as flushing to assist in the removal process of particles from the work area hence giving better surface finish [12].

There are five types flushing fluid system EDM such as pressure flushing, suction flushing combine pressure and suction flushing, jet flushing, and pulse flushing [6].

2.4.3 Dielectric Fluid

Basic characteristics required for dielectric used in EDM are high dielectric strength and quick recovery after breakdown [12]. The dielectric fluid acts as an insulator between the electrode and the mold cavity. The selection of dielectric fluid will be based on the insulation properties of the fluid. Air is not a very good insulator but water based dielectric is the best. However, water has a few drawbacks such as [8]:

i. It causes rust especially to electrode and workpiece or machine itself.

ii. The electrical discharge separates the water into pure hydrogen and pure oxygen. In other words it is a very explosive pair.

Therefore, kerosene is good compromise then water based dielectric [8]. Where it has no rust problem and no dangerous gasses are produced with kerosene. The suitable dielectric is based on the type of materials and the processes that are made and used. Most dielectric media are hydrocarbon compounds known as kerosene, and water. The machines are equipped with a pump and filtering system for the dielectric fluid.

The functions and properties of dielectric fluid are [6]:

i. Remain electrically non-conductive until the required breakdown voltage is reached (i.e.: should have high dielectric strength)

ii. Act as an insulator until the potential is sufficiently high.

iii. Breakdown electrically in the shortest possible time once the breakdown voltage reached

iv. Carrying away the swarf particles (materials, decomposition products, hydrogen, carbon, bubbles)

v. The pressurized fluid flushes out the eroded gap particles and remove the particles from the fluid by causing the fluid to pass through a filter system

vi. The fluid cool the eroded particle between the workpiece and the electrode

vii. To form a dielectric barrier for the spark between the workpiece and the electrode

viii. Provide an effective cooling medium

ix. Good degree of fluidity

x. Be cheap and easily available

2.5 Tungsten carbide

Tungsten carbide (WC-Co) with 15% cobalt content will be used as a material workpiece in this project. Increasing the cobalt content in this material will increase the hardness of the WC-Co. Table 2.2 shows the composition and properties of WC-Co materials with increasing cobalt content.

Actually WC-Co has a compressive strength greater than any other metal or alloy and is three times more rigid than steel. Abrasion resistance is up to 100 times greater

than steel. Thermal expansion is less than one-half that of steel, and tungsten carbide resists thermal shock and oxidation temperatures up to 1200°F (648.89°C) [13].

Composition of Tungsten Carbide		Density,	Rockwell Hardness,	Vickers Hardness	Transverse Rupture
% of WC	% of Co	g/cm^3	R_A	kg/mm^2	Strength, psi
100	-	15.7	92-94	1,800-2,000	43,000-71,000
97	3	15.1-15.2	90-93	1,600-1,700	142,000-170,400
95.5	4.5	15.0-15.1	90-92	1,550-1,650	170,000-199,000
94-94.5a	5.5-6	14.8-15.0	90-91	1,500-1,600	277,000-256,000
94-94.5b	5.5-6	14.8-15.0	91-92	1,600-1,700	199,000-227,000
91	9	14.5-14.7	89-91	1,400-1,500	213,000-270,000
90	10	14.3-14.5	88.5-90.5	1,350-1,450	220,000-277,000
89	11	14.0-14.3	88-90	1,300-1,400	227,000-284,000
87	13	14.0-14.2	87-89	1,250-1,350	241,000-298,000
85	15	13.8-14.0	86-88	1,150-1,250	256,000-312,000
80	20	13.1-13.3	83-86	1,050-1,150	284,000-369,000
75	25	12.8-13.0	82-84	900-1,000	256,000-384,000
70	30	12.3-12.5	80-82	850-950	-

Table 2.2: Composition and Properties of WC-Co Materials with Increasing Cobalt Content [13]

2.6 Machining Characteristics

2.6.1 Surface Integrity

The EDM is a material removal process where removes the work material by a series of electrical sparks between the workpiece and electrode. These sparks generate craters on the surface, recast layers and heat affective zones on the subsurface of the EDMed workpiece. Surface integrity describes the mechanical, metallurgical, topological, and chemical conditions of the surface region (i.e., heat affected zones, microhardness, microcracks, residual stresses, surface roughness, tool/carbon material diffusion) [14]. EDM surfaces are quite complicated. Study on the effects of EDM machining on surface integrity of EDMed surfaces have been documented by many researchers [1, 15, 16,]. If uncontrolled, the thermal changes may cause cracks in the top layer and residual stresses in the underlying base layers [17].

2.6.2 Surface Layer

Actually the surface cracking occurs on the recast layer of the machined workpiece. Usually the EDM process creates three types of surfaces layers. The top surface contains a thin layer of spattered material that formed from the molten metal and small amount of electrode material [6]. Underneath this surface is the recast or white layer, which is caused by the current from EDM process that melts the material. Because of the thermal changes, it heats up the underlying surface and alters the metallurgical structure. This layer is formed because some of the molten material has not been removed and rapidly quenched by dielectric fluid. The third layer is the heat affected zone (HAZ), which is affected by the amount of current applied. In this layer, the material has been heated below the melting point of the material as in the recast layer. The HAZ may alter the performance of the workpiece material. Figure 2.3 shows the HAZ and recast layers.

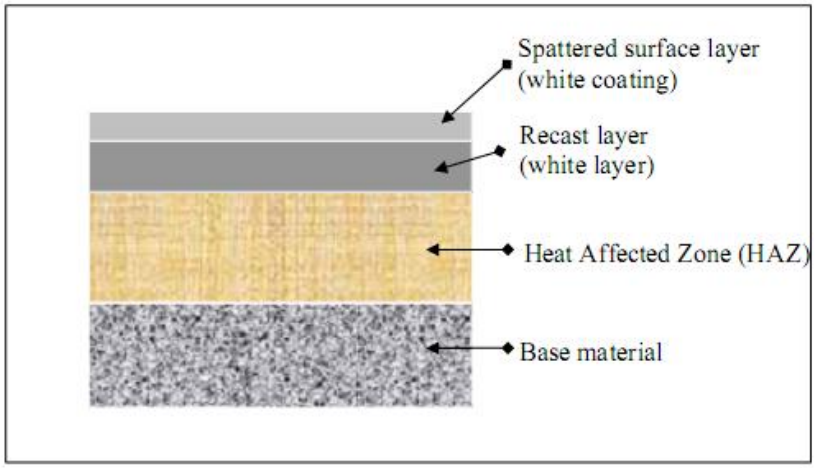


Figure 2.3: Surface layers in EDMed workpiece [6]

2.6.3 Surface Roughness

One the most important parameter of surface topography or surface finish is surface roughness. The factor can affect the surface roughness is because more molten material is being removed from the spark gap. It is happen because the higher energy discharge pulse produces from the electrode tool in the dielectric liquid and its will affect in contact of surface finish and also dimensional accuracy of the machined surface. The distinctive morphology of a surface which has undergone EDM machining, is due to the enormous amount of heat generated by the discharges, which causes melting and vaporization of the material, followed by rapid cooling [19, and 20]. The surface topography presented the surface roughness is caused by an uneven fusing structure, globules of debris, shallow craters, pockmarks, voids and cracks [18]. Basically the surface roughness is influenced by the size, appearance and depth of the electrode discharge [18]. The parameter used for surface roughness is R_a (μm) which is the arithmetic mean of the departures of the roughness profile from the mean line.

2.6.4 Surface Cracking

. Observation of the machined surface, and the sample sections, reveals that the surface cracks are often micro-cracks. These cracks were formed at exceedingly high thermal stresses prevailing at the insert surface as the latter was cooled at a fast rate after the discharge [1]. The high magnification microscope shows that cracks exist in the white layer; initiating at its surface, and traveling down perpendicularly towards the parent material. In the vast majority of cases the cracks terminate within the white layer, or just on the interface of the white layer and the parent material. Only rarely do the cracks penetrate the entire white layer thickness to extend into the parent material [18].

CHAPTER 3

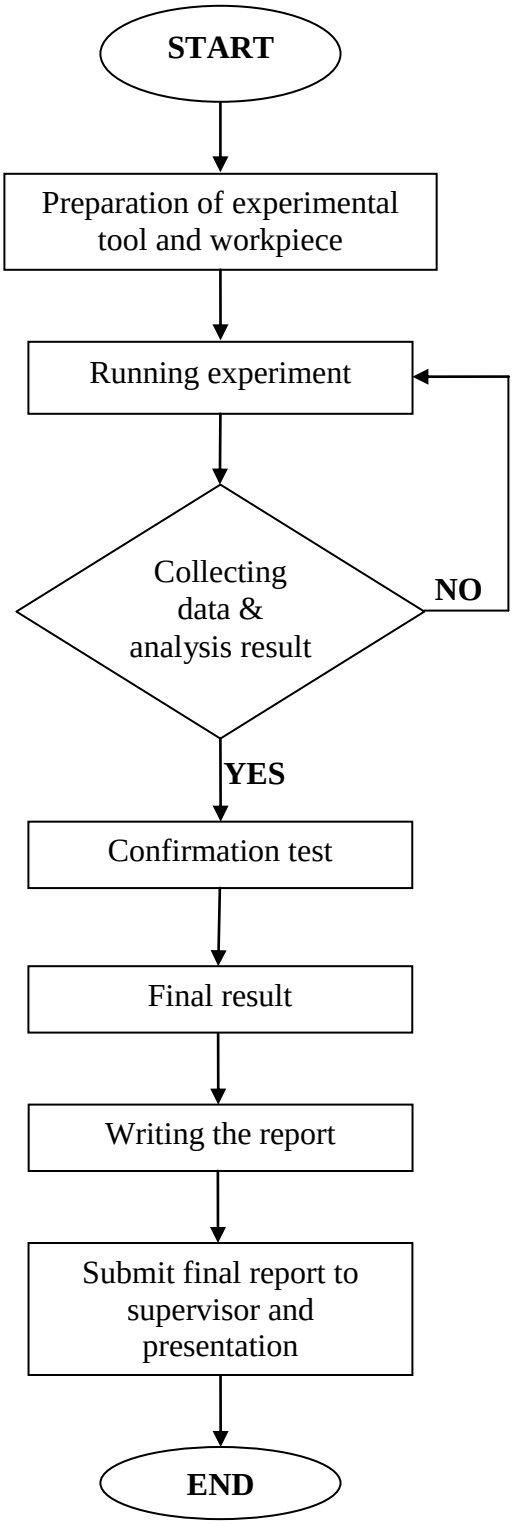
METHODOLOGY

3.1 Introduction

There are many processes involve in this project such as searching information, experimental, analysis and discussion. Those processes are described in this chapter according to the flow chart. In the past chapter (literature review), every data and information were gathered together and being analyzed according to the objectives and scope of the project. The main point of the research is about the electrode and the surface cracking in EDM machining. There are based on journals and books as the references and the legal sources such as internet and manual instruction of the machine. Every information being analyzed to get the overall idea of this project and understand the objectives and scopes from the reading and studying the journals and books.

In this chapter will describe about overall progress from the beginning until the end of this project. There are four main processes involve in this project that starts with experimental, collecting the data, analyze the result and lastly confirmation test. As shown in the Gantt chart and flow chart in Appendix A1, A2 and B, this chapter will explain more detail about the processes above.

3.2 Flow Chart of Methodology



3.3 Experimental Setup

The experimental will be conduct by Sodick AQ55L-CNC die sinking machine to perform the machining on the workpiece. The condition of this experiment is shows in Table 3.1.

Working parameters	**Description**
Workpiece	Tungsten carbide with 15% of cobalt content (40mm x 15mm x 10mm)
Electrode	Copper tungsten electrode with the diameter of 3mm, 6mm, and 8mm.
Dielectric	Kerosene
Depth of cut (mm)	0.5
Voltage (V)	100
Peak current (A)	64
Pulse duration (μs)	12.8
Duty factor	0.5

Table 3.1: EDM condition

After completion the EDM machining process, a scanning electron microscopy (SEM) will be used to detect any appearance on the machined surface. Each sample of machined surface will be analyzed at 2500× magnification photo using the SEM. Then the surface roughness tester will be employed to measure the surface roughness of the machined surface. The comparison between SEM photographs and surface roughness will be made to shown the relation that influenced the surface finish by using the different size of electrodes.

3.3.1 Electrode Material

In this experiment copper tungsten is used as an electrode material. This copper tungsten electrode are consist of 3mm, 6mm and 8mm of diameter. The specification of this electrode is given in the Table 3.2.

Specification	Value
Density (g/cm³)	15.2
Electrical resistively (μΩ/Cm)	5.5
Coefficient of expansion ($^{o}C^{-1}$)	0.0005
Composition	75% Tungsten, 25% Copper
Diameter Tolerance (mm)	+/- 0.1

Table 3.2: Specification of electrode material

3.3.2 Workpiece Material

The workpiece chosen for this experimental is tungsten carbide (WC-Co) with 15% of cobalt content. The properties of the tungsten carbide are given in Table 3.3.

Properties	Value
Density (g/cm³)	15.1
Melting point (°C)	2597
Tensile strength (kg/mm²)	179
Compressive strength (kg/mm²)	410
Toughness (kg/mm²)	50

Table 3.3: Workpiece material properties

3.4 Machine and Equipment

The following equipments were used in this experimental works:

1) EDM die sinking (Figure 3.1)

Brand: Sodick EDM die sinking
Model: AQ55L
No of axis: 3 axes (X,Y and Z)

This machine is going to use to conduct the electro discharge machining process in hole making on the WC-Co as workpiece.

Figure 3.1: EDM Die Sinking- Sodick AQ55L

2) Scanning electron microscopy (SEM) (Figure 3.2)

Brand: Zeiss
Model: EVO 50

SEM is employed to examine the surface cracking on machined surface after the experimental is done.

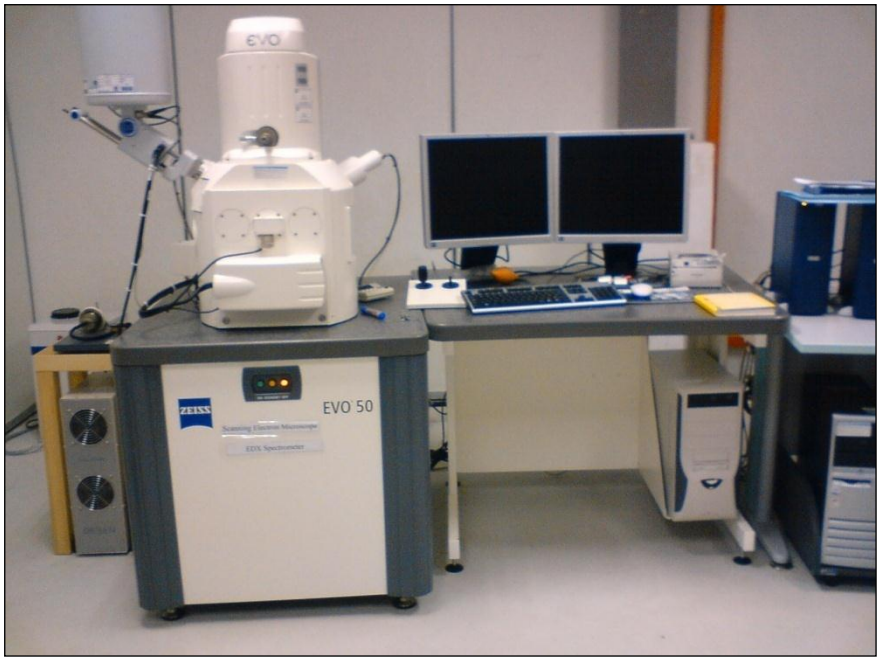


Figure 3.2: Scanning electron microscope

3) Surface roughness tester (Figure 3.3)

Brand : Perthometer S2 MAHr

The surface roughness tester is used to measure the surface roughness of the machined workpiece surface.

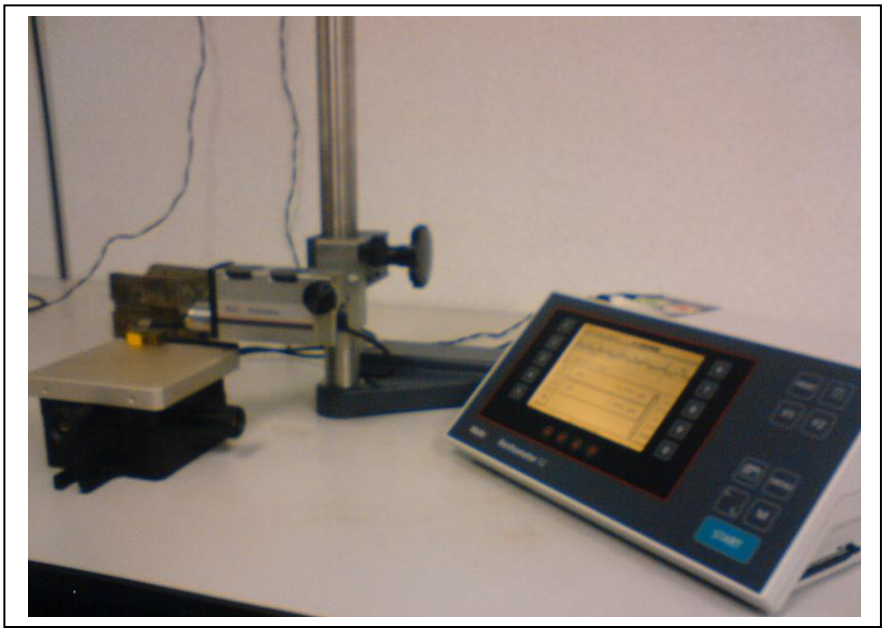


Figure 3.3: Surface roughness tester

3.5 Data

1) The Table 3.4 is used to record the surface roughness after measured by the surface roughness tester (Perthometer S2 Mahr). This measurement will be taking in 3 times on each machined surface. Then the average will be calculated to show distinguish between the surface roughness on the machined surface after using 3 different size of electrode used.

No. of Sample	Surface Roughness, Ra (µm)			Average
	a	b	c	
1				
2				
3				

Table 3.4: Sample of table for the data collection

After the result is obtained from the experiment, the graph will be build to shown the relationship between the machined surface in term of surface roughness and the different size of electrodes. Then the comparison between SEM photograph and the data from the surface roughness will be made to shown the relationship between them.

CHAPTER 4

RESULT AND DISCUSSION

4.1. Introduction

There are 2 types of result are obtained from the experiment such as SEM photograph and the data from surface roughness measurement. Then the graph will be build to make the comparison between the SEM photo and the surface roughness measurement.

4.2. Scanning Electron Microscope (SEM) Photograph

The EDM machining process is characterized by the use of high local voltages and temperatures which cause erosion and vaporization of the material. The surface roughness is influenced by the size, appearance and depth of the electrode discharge. The surface topography presented in Figure 4.1, 4.2 and 4.3 reveals that the surface roughness is caused by an uneven fusing structure, globules of debris, shallow craters, voids and cracks. These machined surfaces are taken in 2500x magnification by using scanning electron microscope (SEM).

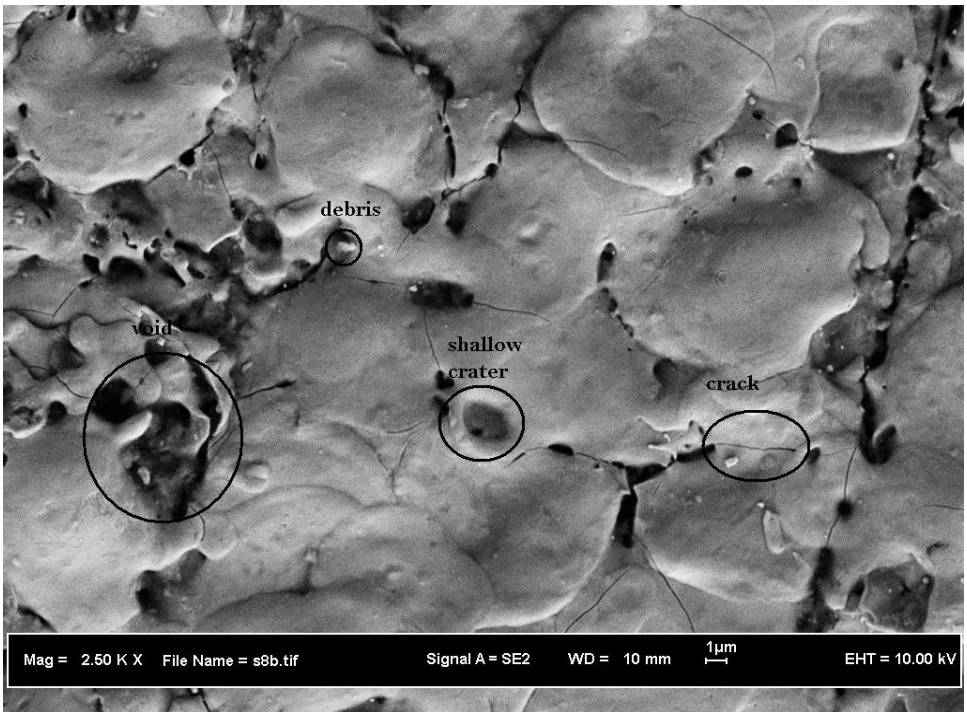


Figure 4.1: Surface topography after 8mm diameter electrode used on tungsten carbide

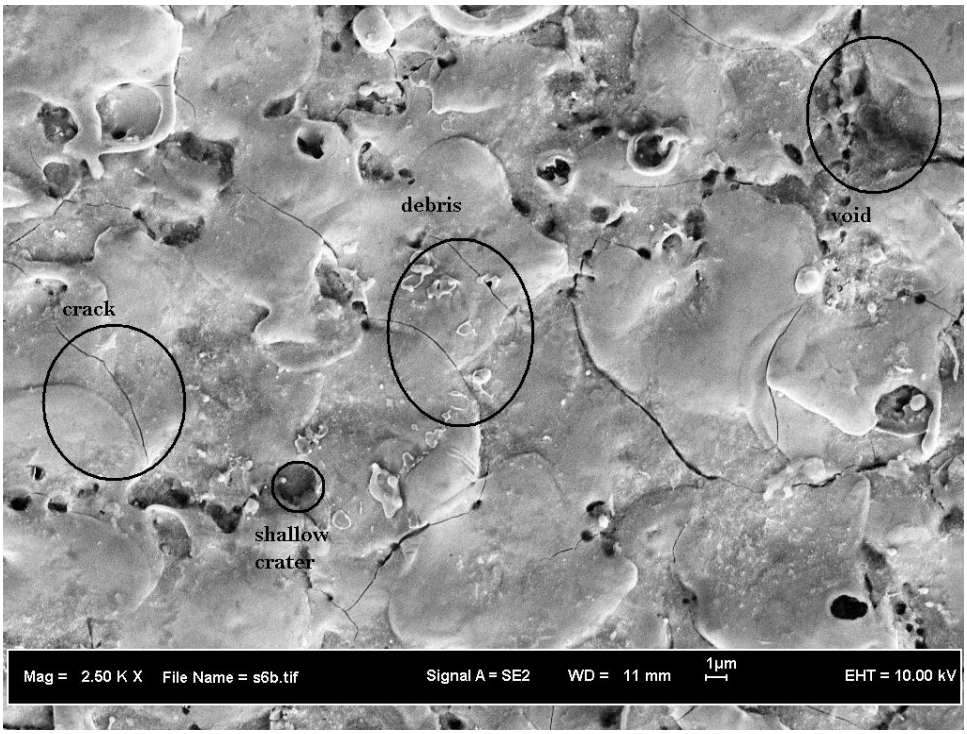


Figure 4.2: Surface topography after 6mm diameter electrode used on tungsten carbide

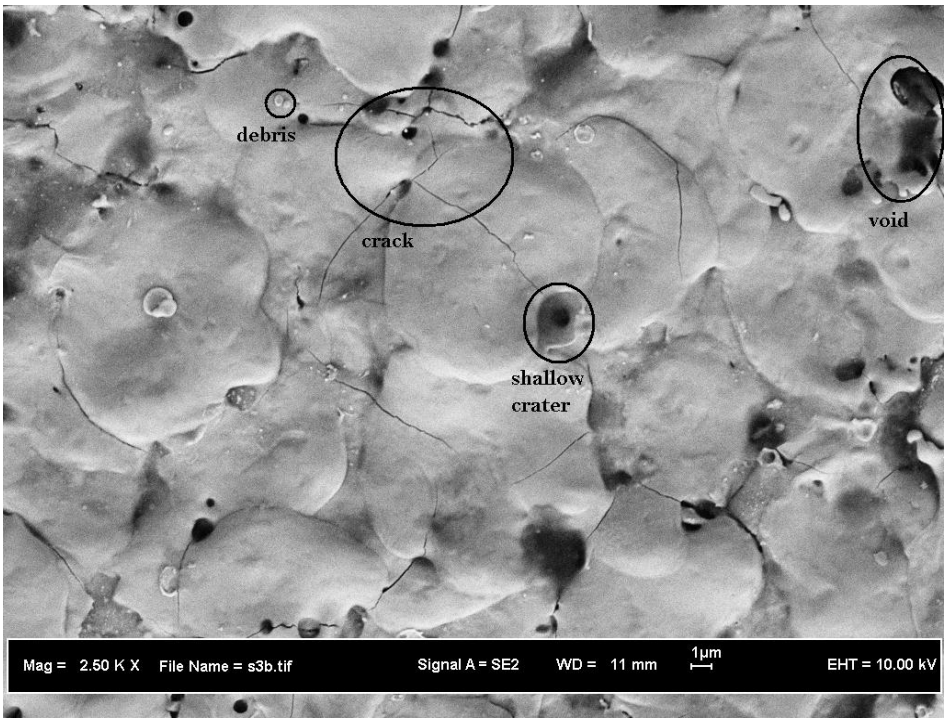


Figure 4.3: Surface topography after 3mm diameter electrode used on tungsten carbide

Observation of the surface topography show in Figure 4.1 is attended to more roughness than the surface as shown Figure 4.2 and Figure 4.3. This is because machined surface of Figure 4.1 reveals that the void, debris, shallow crater, and cracks are more appear on this surface than other two machined surfaces as shown in Figure 4.2 and 4.3. Also for machined surface of Figure 4.2 is attended to more defection than a machined surface of Figure 4.3. The defection are form on the machined surface is because the entrapped gases escaping from the re-deposited material It was found that local melting and evaporation of the workpiece material occurred during and after an electrical discharge and its expulsion took place with gas evolution. This defection is almost influence the roughness on the machined surface.

4.3. Surface Roughness Measurement

The machined surface in nine specimens was measured in three times to collect the data of surface roughness by using the surface roughness tester. Then the average

was taken for the result and the analysis was made as shown in the graph Figure 4.6. This graph was constructed to show the relationship between the machined surface and different electrode sizes used. The Table 4.1 is shown the data was recorded after surface roughness measurement.

4.3.1. Initial Result

(a) Electrode diameter 8mm

No. of Specimen	Surface Roughness, Ra (µm)			Average
	a	b	c	
1	1.825	1.772	1.138	1.57833333
2	1.036	1.879	1.28	1.39833333
3	1.764	1.829	1.247	1.61333333

(b) Electrode diameter 6mm

No. of Specimen	Surface Roughness, Ra (µm)			Average
	a	b	c	
1	0.528	0.692	0.521	0.58033333
2	0.768	0.524	0.674	0.65533333
3	0.61	0.537	0.55	0.56566667

(c) Electrode diameter 3mm

No. of Specimen	Surface Roughness, Ra (µm)			Average
	a	b	c	
1	0.381	0.397	0.317	0.365
2	0.324	0.426	0.377	0.37566667
3	0.348	0.374	0.353	0.35833333

Table 4.1: Table (a), (b) and (c) is about the data from surface roughness of the machined surface with the different size of electrode.

From the measurement of surface roughness reveals that machined surface using 8mm diameter of electrode is attend to more roughness than the machined surface using 6mm and 3mm diameter of electrode. The machined surface using 6mm diameter of electrode is also attend to more roughness than a machined surface of machining using 3mm diameter of electrode. Then the average was taken to show the different reading of 3 sizes of electrodes to make for the final result as shown in Table 4.2.

4.3.2. Final Results of Surface Roughness

Electrode Diameter (mm)	Surface Roughness, Ra (µm)			Average
	1	2	3	
8	1.5783	1.3983	1.6133	**1.53**
6	0.5803	0.6553	0.5656	**0.6004**
3	0.365	0.3756	0.3583	**0.3663**

Table 4.2: Average surface roughness of 3 sizes of electrodes

The graph in Figure 4.4 was constructed to show more clearly about the effect on the machined surface in term of surface roughness that influenced by the different size of electrode. The data to build this graph is obtained from the average of the final result

in the Table 4.2. As shown in this graph the trend line of the surface roughness is increase when the bigger electrode size used. The plotted area of machined surface using 8mm electrode shows the highest, the 6mm electrode is at the middle, and the lowest is 3mm electrode. The result is same as in the Table 4.2, which is for surface roughness for machined surface using 8mm, 6mm, and 3mm of electrode is 1.53µm, 0.6004µm and 0.3663µm.

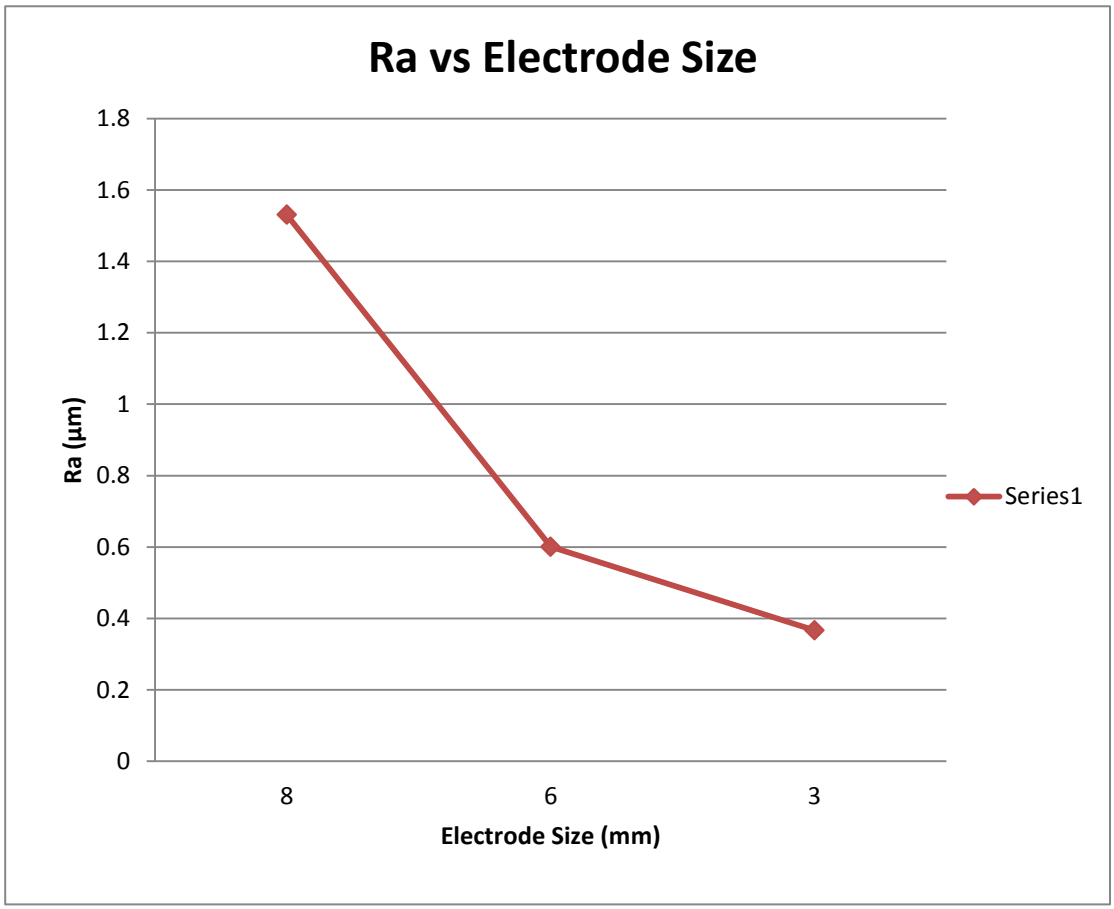


Figure 4.4: Graph of surface roughness versus electrode diameter

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1. Conclusion

It was found the surface roughness on the machined surface was influenced by the different size of electrode used. This claim is made based on the data from the result obtained of surface roughness test and supported by the SEM photograph. So the relationship can be made between electrode size and machined surface is when bigger electrode used, will increases the surface roughness on the machined surface. The phenomenon is occurring because when bigger electrode use, discharges strike the surface of the sample more intensely, and the resulting worsened erosion effect leads to a deterioration of the surface roughness.

The current results seem to be increase the roughness of machined surface when the pulse-on time increases during the machining process. This is because increasing pulse duration will extends the affected area of the electric spark bombardment of the workpiece and more molten material being removed, and this result in an increased the surface roughness of machined surface. If this molten material is not swept away from the surface by the dielectric material, it will solidify during the cooling process and form a white layer. The effect of this white layer also increases the surface roughness.

The current result also reveals the cracks on the machined surface. Actually the surface crack can be attributed to the presence of thermal stress and tensile stress within the machined surface. The thermal stress is happen because the electrode discharges

bombard the surface of the sample during the machining process. The tensile stress is happen because not all of the material which melts during the machining process is swept away from the component's surface by the dielectric.

Surface finish is important to the quality of the product produce. But the surface roughness occur on the machined surface, it doesn't mean cannot be used directly for its application. This is because each of the material has own properties and beneficial to its application respectively.

5.2. Recommendation

In future work, increasing the number of test and the number of electrode in the EDM machining process will increasing the accuracy of the experiment and optimization of the size of electrode can be made. It is because by adding the parameters in this experiment are almost proportional to the machined surface produce. The suggestions for the future work are such below:

1. The parameters of testing can be add in this experiment such as measure the material removal rate (MRR), electrode wear (ER) and so on.

2. Analyze the affected of machined surface by adding the machining parameters such as measure at the different pulse time, peak current, and spark gap.

3. Analyze the white layer on the machined surface by standard metallurgical procedures using cutting, grinding, polishing, and etching (3% Nital) techniques.

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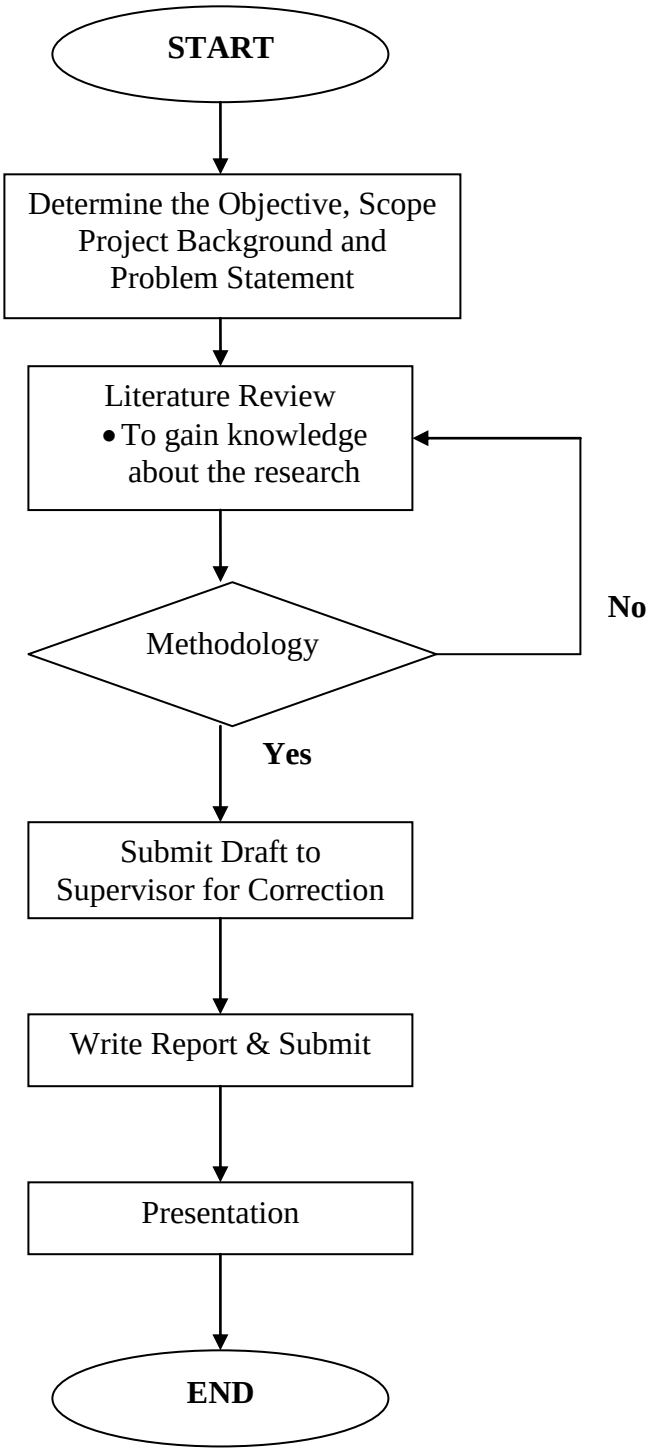
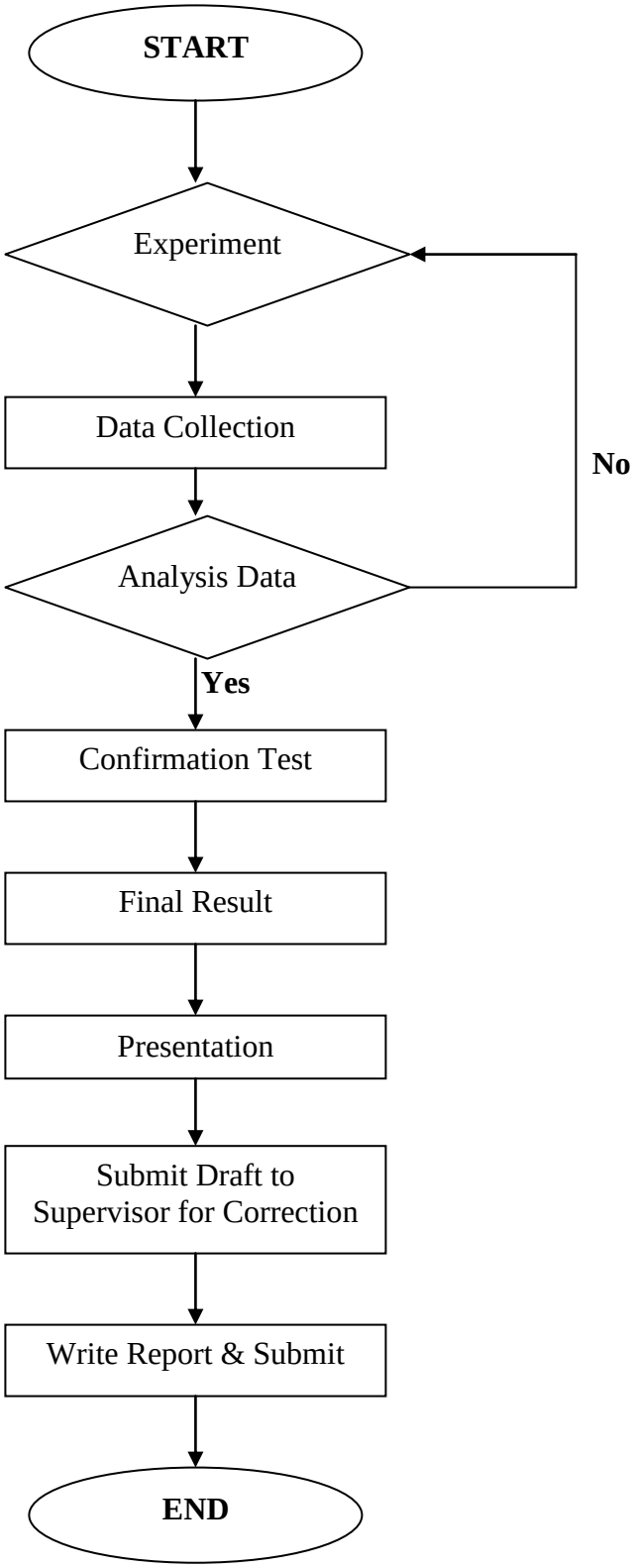
APPENDICES

APPENDIX A1: Flow Chart for FYP 1



APPENDIX A2: Flow Chart for FYP 2



APPENDIX B

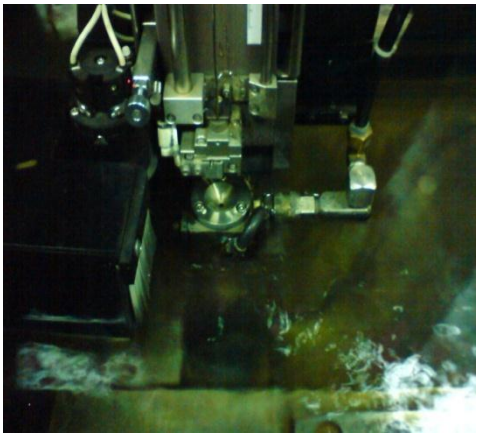
GANT CHART FOR FYP 1

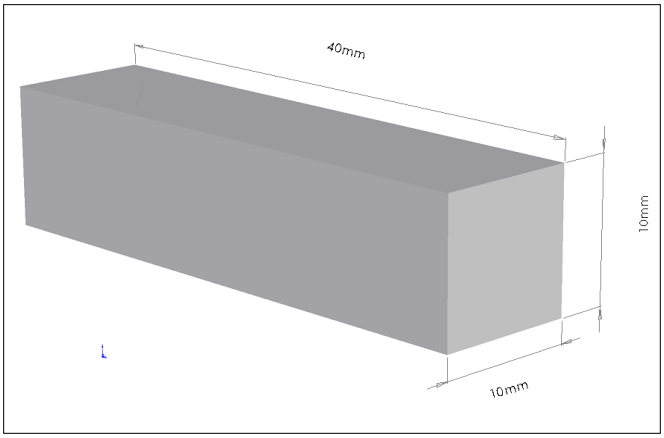
	Project Activities	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15
1	Determine the Objective, Scope	■	■													
	and Project background															
2	Literature Review															
	• Searching for Information of EDM			■	■	■										
	• Determine the Problem Statement						■	■								
3	Methodology								■	■	■					
4	Submit Draft to Supervisor for Correction											■	■			
5	Write Report and Submit													■	■	
6	Presentation															■

GANT CHART FOR FYP 2

	Project Activities	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15
1	Perform Experiment	■	■	■												
2	Data Collection				■	■										
3	Analysis Data						■	■								
4	Confirmation Test								■	■						
5	Final Result										■	■	■			
6	Presentation													■		
7	Submit Draft to Supervisor for Correction													■	■	
8	Write Report and Submit														■	■

APPENDIX C: Machining Progress





(a) (b)

Figure (a) shows the cutting process of the tungsten carbide workpiece by using EDM-wire cut and Figure (b) shows the cutting dimension of this workpiece.

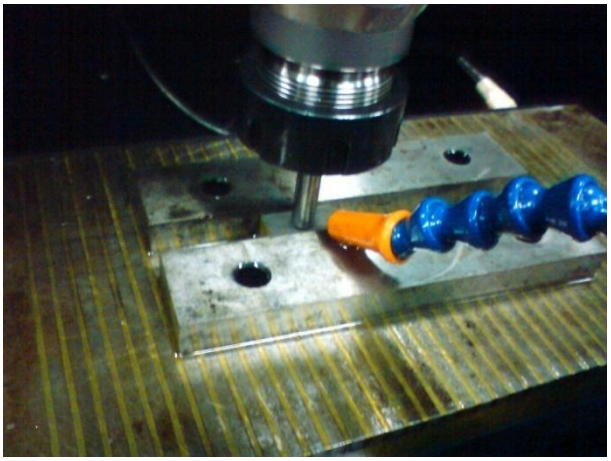
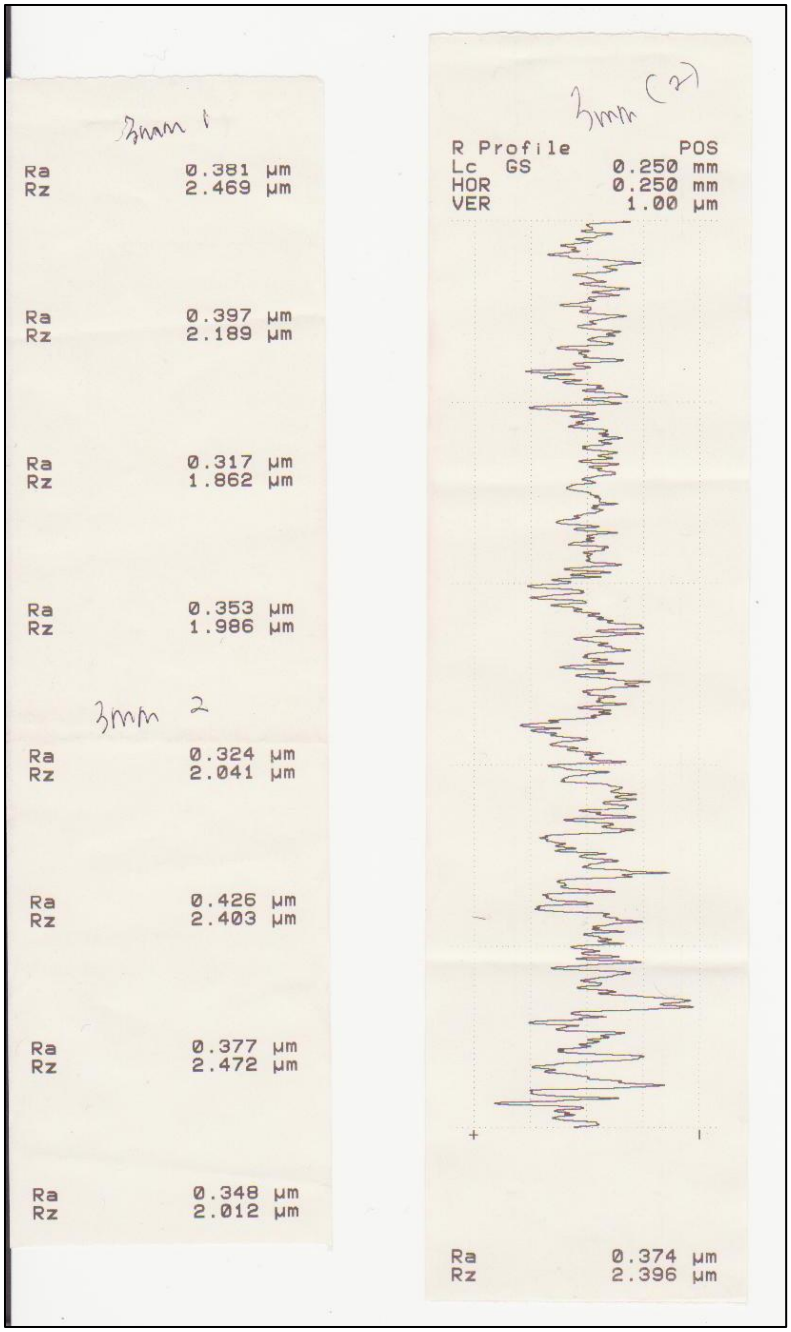
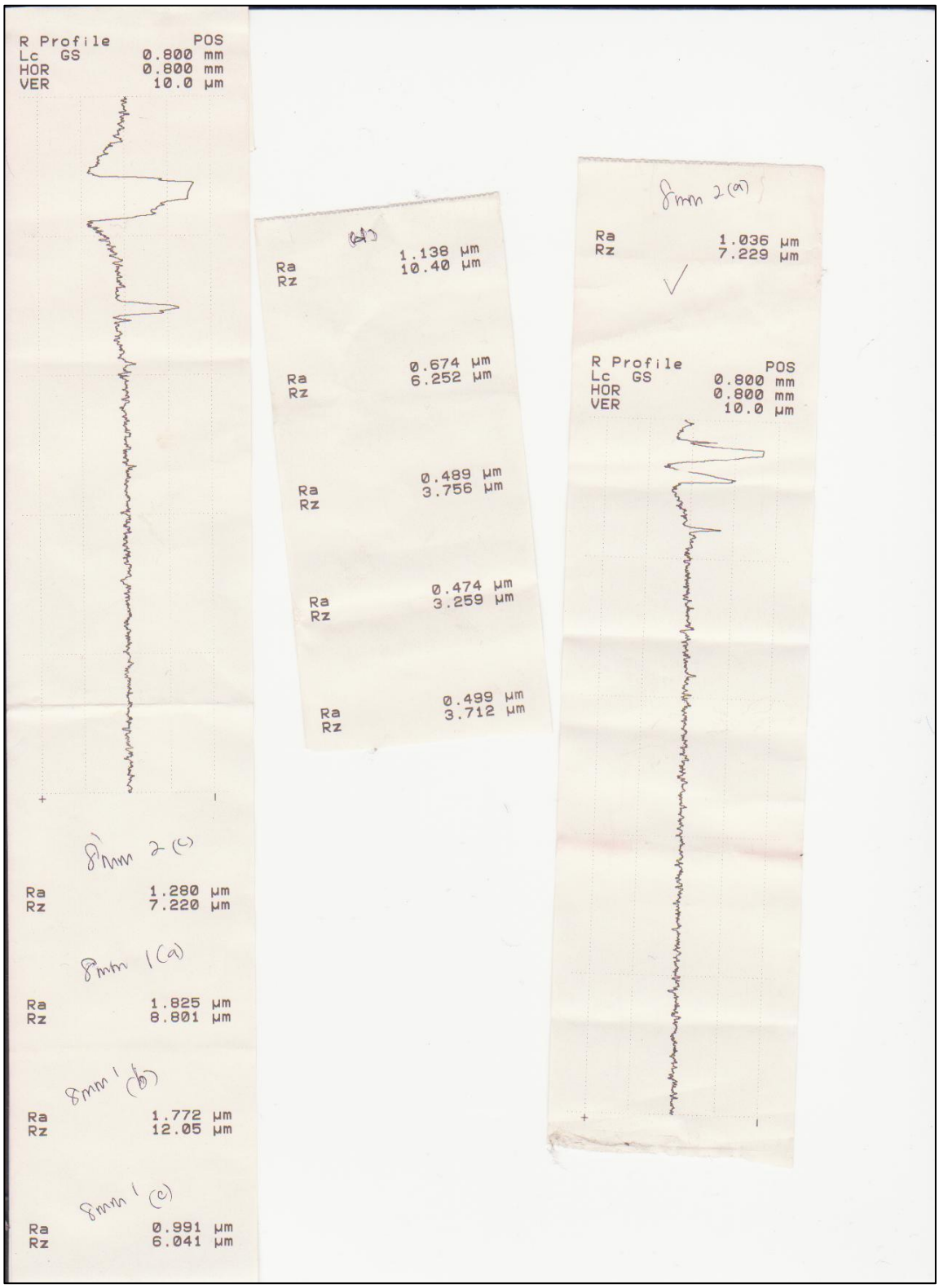


Figure shows the machining process by using EDM die sinking.

Sample of specimen after machining process.

APPENDIX D: Result of Surface Roughness Measurement by using Surface Roughness Tester (Perthometer S2 Mahr)




R Profile POS
Lc GS 0.800 mm
HOR 0.800 mm
VER 10.0 µm
8mm 2 (c)
Ra 1.280 µm
Rz 7.220 µm
8mm 1 (a)
Ra 1.825 µm
Rz 8.801 µm
8mm 1 (b)
Ra 1.772 µm
Rz 12.05 µm
8mm 1 (c)
Ra 0.991 µm
Rz 6.041 µm
(b)
Ra 1.138 µm
Rz 10.40 µm
Ra 0.674 µm
Rz 6.252 µm
Ra 0.489 µm
Rz 3.756 µm
Ra 0.474 µm
Rz 3.259 µm
Ra 0.499 µm
Rz 3.712 µm
8mm 2 (a)
Ra 1.036 µm
Rz 7.229 µm
R Profile POS
Lc GS 0.800 mm
HOR 0.800 mm
VER 10.0 µm

6mm 1

Ra 0.528 µm
Rz 3.421 µm

Ra 0.692 µm
Rz 4.696 µm

Ra 0.521 µm
Rz 3.742 µm

6mm 2

Ra 0.768 µm
Rz 4.708 µm

Ra 0.524 µm
Rz 4.261 µm

Ra 1.126 µm
Rz 6.940 µm

Ra 1.196 µm
Rz 7.503 µm

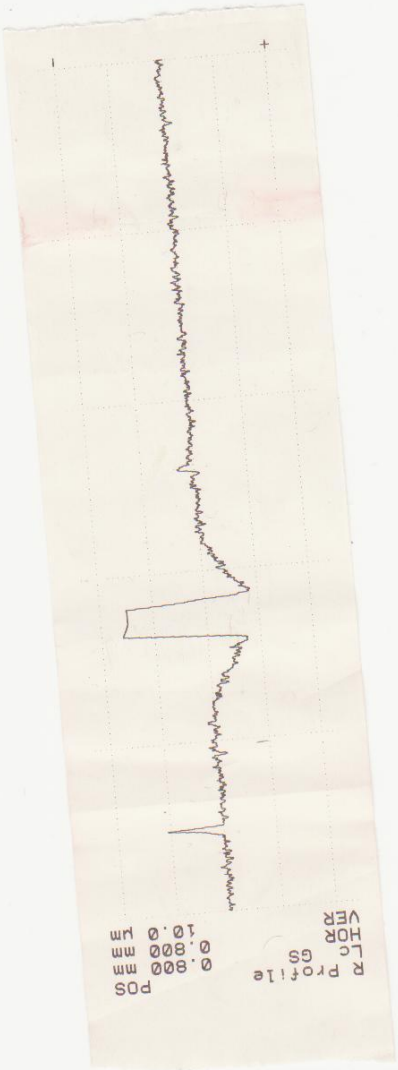
Ra 1.218 µm
Rz 7.405 µm

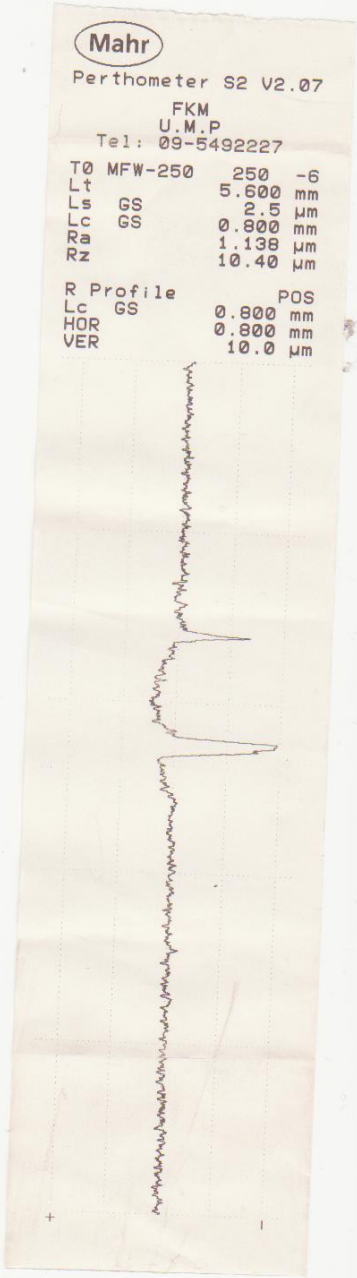
6mm 3

Ra 0.610 µm
Rz 4.110 µm

Ra 0.537 µm
Rz 3.495 µm

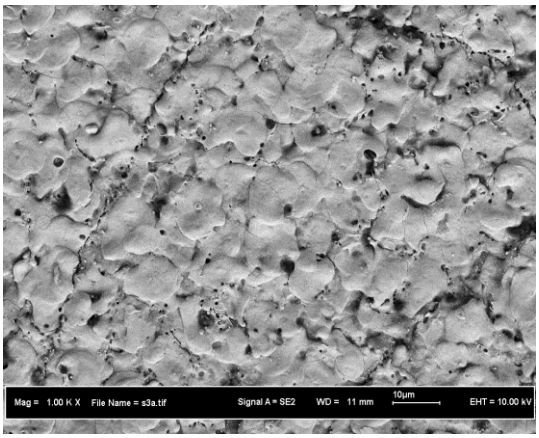
Ra 0.550 µm
Rz 3.499 µm



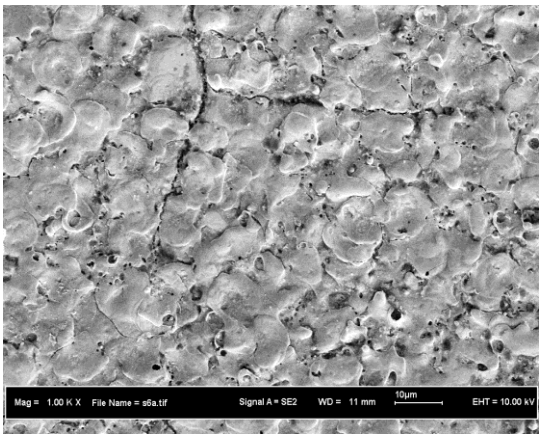


APPENDIX E: SEM Photograph.

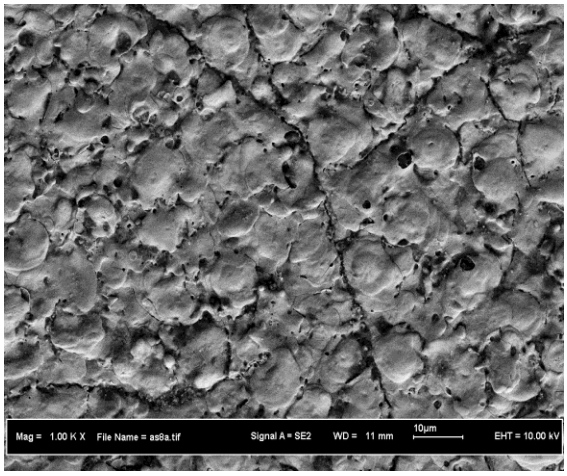
1000x Magnification



Machined surface after
using 3mm diameter electrode



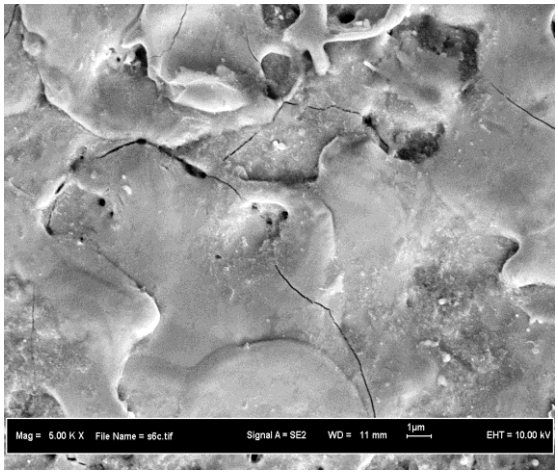
Machined surface after
using 6mm diameter electrode



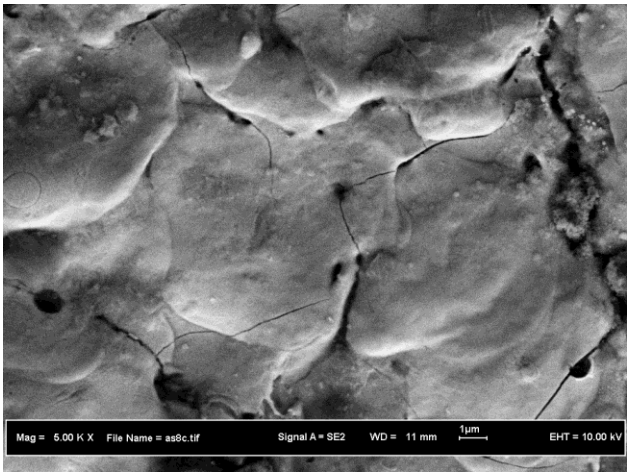
Machined surface after using 8mm diameter electrode

5000x Magnification

Machined surface after
using 3mm diameter electrode



Machined surface after
using 6mm diameter electrode



Machined surface after using 8mm diameter electrode