



**Faculty of Manufacturing Engineering**

**COMPARATIVE STUDY FOR MATERIAL REMOVAL RATE, SURFACE  
FINISH AND ELECTRODE WEAR RATE ON DIE SINKING EDM**

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**MASTER OF ENGINEERING IN MANUFACTURING INDUSTRIAL ENGINEERING**

**2013**

**COMPARATIVE STUDY FOR MATERIAL REMOVAL RATE, SURFACE FINISH  
AND ELECTRODE WEAR RATE ON DIE SINKING EDM**

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**A thesis submitted in fulfillment of the requirements for the degree of Master of  
Engineering in Manufacturing Industrial Engineering**


**Faculty of Manufacturing Engineering**

**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

**2013**

## DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged.

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## APPROVAL

I hereby declare that I have read this dissertation/report and in my opinion this dissertation/report is sufficient in term of scope and quality as a partial fulfillment of Master of Manufacturing Engineering (Industrial Engineering)

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## **DEDICATION**

Special thanks I dedicate to all people that help me in completing my final year project especially to my supervisor, Dr. Shajahan Bin Maidin, my beloved family and my wife for supporting me.

## ABSTRACT

The electrical discharge machining (EDM) is one of non conventional machining process where the erosion of the work piece take place based on the thermal energy between the electrode and the work piece. Two different work piece materials were machined using die sinking EDM to study the characteristics of each material using copper electrode. Two different work piece materials were used, aluminum and copper and the dimension for each is 100 mm length, 50mm width and 6mm thick. The Sodick CNC EDM die sink will be used as the main equipment in this project. To get the best result, the selections of parameters play a main role in producing good surface finish quality, high removal rate (MRR) and less electrode wear ratio (EWR). High electrode wear ratio (EWR) and the lower material removal rate is some of the problems in EDM machine that will decrease machining productivity. There are four different pulse current that will be tested (8, 12, 16 and 20 ampere) with four pulse on time in micro second (50, 100, 150, and 200) and the reference voltage and pulse on time are kept constant 22 Volt. There are sixteen engrave will be formed in each sample. Dielectric fluid is used is kerosene and the polarity or machining type is positive. At the end of this study the optimal performance parameters will be defined and determining which material gives highest material removal rate, less surface finish as well as the conditions that give less tool wear rate (TWR). The result obtained indicating that the material removal rate MRR and TWR are increased with the increase of current. This is because the higher current means higher and stronger spark that generates or melt more material from the work piece. The result shows that pulse duration has a little effect on the MRR. But regarding the tool wear ration TWR the results show a decrease of the TWR along with the increase of pulse duration this is because of the presence of carbon layer that precipitated on the surface of the electrode and the thickness of this layer increased with the increase of pulse duration and in turn decrease the TWR. Regarding the comparative study, the result showed that aluminum has higher MRR compared with copper, this is due to the fact that aluminum has lower melting point compared with copper. And regarding the TWR, the results showed that the copper has little amount of tool wear when machined using copper electrode, this is because the copper has higher thermal conductivity compared to aluminum who has higher TWR when machined using same copper electrode. The higher thermal conductivity means more thermal energy this work piece can carry and also means more facilitating the thermal energy will be diffused which maintain the tool wear.

## ABSTRAK

Menunaikan Elektrik Pemesinan adalah salah satu proses pemesinan bukan konvensional di mana satu bentuk hakisan dilakukan pada bahan kerja menggunakan tenaga haba di antara elektrod dan bahan kerja. bagi kajian ini CNC EDM Die Sinking dengan tembaga sebagai elektrod penghakis dipilih sebagai alat pemesinan. Di dalam kajian ini juga dua bahan kerja yang belainan telah dipilih iaitu aluminium dan tembaga dengan ukuran lebar 50mm, 100mm panjang dan 6mm tebal diguankan. Di mana perbezaan ciri-ciri kedua-dua bahan kerja yang digunakan akan dikaji. Untuk mendapatkan hasil kerja yang terbaik terhadap bahan kerja Pemilihan parameter memainkan peranan utama. di mana parameter ini akan menentukan kualiti,kekemasan permukaan hakisan pada bahan kerja, kadar hakisan yang tinggi semasa proses hakisan (Material Remover Rate MRR) dan pengurangan kadar nisbah haus pada elektrod semasa proses penghakisan (Tool Wear Rate TWR). Terdapat empat berbeza semasa nadi(Pulse) yang akan diuji (8, 12, 16 dan 20 ampere) dengan empat nadi(Pulse) pada masa di kedua mikro ( 50, 100 , 150, 200 dan) dan voltan rujukan dan nadi pada masa dikekalkan malar 22 Volt. Terdapat enam belas ukiran akan diadakan di setiap sampel. Cecair dielektrik digunakan adalah minyak tanah dan kekutuban atau jenis pemesinan adalah positif. Pada akhir kajian ini parameter prestasi yang optimum akan diberi untuk menentukan bahan kerja yang mana memberikan kadar penghakisan (MRR) yang tigggi,nisbah haus pada elektrod(TWR) yang rendah terhadap kemasan permukaan bahan kerja. Keputusan yang diperolehi menunjukkan bahawa MRR kadar penghakisan bahan kerja dan TWR adalah meningkat dengan peningkatan arus elektrik. Ini kerana apabila arus eleterik meningkat bermakna kekuatan percikan api (Spark) juga meningkat bagi menjana atau mencairkan lebih bahan kerja. Hasilnya menunjukkan bahawa masa denyutan (Pulse) mempunyai sedikit kesan kepada MRR. Tetapi bagi TWR menunjukkan penurunan daripada TWR bersama-sama dengan peningkatan masa denyutan (Pulse) ini adalah kerana kehadiran lapisan karbon yang dicetuskan pada permukaan elektrod dan ketebalan lapisan ini meningkat dengan peningkatan nadi(Pulse) tempoh dan seterusnya mengurangkan TWR itu. Bagi kajian perbandingan, kajian menunjukkan bahawa aluminium mempunyai MRR yang lebih tinggi berbanding dengan tembaga, ini adalah disebabkan oleh aluminium mempunyai takat lebur yang lebih rendah berbanding dengan tembaga. Dan mengenai TWR, keputusan menunjukkan bahawa tembaga mempunyai jumlah TWR yang sedikit. ini adalah kerana tembaga mempunyai kekonduksian yang lebih tinggi berbanding dengan terma aluminium yang mempunyai TWR lebih tinggi semasa proses pemesinan menggunakan elektrod kuprum. Kekonduksian terma yang lebih tinggi bermakna lebih banyak tenaga haba bahan kerja ini boleh membawa dan juga bermakna lebih banyak memudahkan tenaga haba akan diserap yang mengekalkan memakai alat.

## ACKNOWLEDGEMENTS

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

I would like to express my sincere gratitude to all those who have contributed in completing this project especially to my supervisor Dr. Shajahan Bin Maidin for his advice and encouragement. My appreciation is also extended to the technician Mr. Mohammad for his assistance during conducting the experiment and for valuable feedback. Special thanks to my research colleagues for their encouragement and valuable discussions. I would like to thank my wife Amna Omar for her encouragement to carry out this research. Finally, my appreciation goes to Universiti Teknikal Malaysia Melaka (UTeM) for providing the facilities and equipment to accomplish the project.



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# CHAPTER 1

## INTRODUCTION

### 1.0 Overview

This chapter briefly explains the project background, its aim, and objective as well as the scope. Finally, the summary of the project is also provided.

### 1.1 Project background

Many applications nowadays such as aerospace, transportations and medical parts cannot (and in some cases impossible) to be machined using traditional machining processes such as drilling, milling and casting. These applications require close tolerance, high precision and good surface quality Pandy and Singh (2010).

There are many machining process that are listed as advance machining processes such as water jet machining, abrasive water jet machining, laser beam machining, electron beam machining and electrical discharge machining (EDM) Moarrefzadeh and Branch (2012). Suitable advance machine is used according to the conditions and the type of energy to be used to machine and create the desired parts Aghdeab and Abulwahab (2011).

There are two main types of EDM machines, wire cutting EDM and die sinking EDM. The working principle of these machines is based on the thermal energy that occurs by the spark in the gap between the electrode and the work piece where the electrode is connected to the negative terminal whereas the work piece connected to the positive one so that more material removal rate can be achieved Choudh et al.(2010). The main different between those two types are the electrode in wire EDM is small diameter wire (0.25 mm) and its performance cutting

through while the die sinking EDM, the tool takes many shapes so that it has the same desired shape on the work piece.

Steel and any other advanced material such as ceramic and composite are extremely difficult to be machined using traditional machines as their properties are not suitable, for instance the high hardness and high temperature resistance and stability materials are more easily and economy if they machined by one of non-conventional machines Pradhan et al.(2009).

This project is a comparative study where two samples (100x50x7 mm) of aluminum and copper were machined using die sinking EDM. These two materials were machined using copper electrode. These two different materials have wide use in the industry and applications such as cars, houses, and electronic etc. These two materials are suitable for the EDM machine to be tested as they are electrically conductive and ranged from hardness materials to less hardness. In each sample sixteen engraves form will be machined. The discharge current are as followed (8,12,16,20 and 24 Amp) and for each of discharge current, the current on time will be applied as followed (50,100,150 and 200 micro seconds) and other factors will be constant to know the behavior or the characterize of material in term of MaterialRemoval Rate (gm./min) and Surface Finish ( $R_s$ ) and tool wear ratio (TWR) for each material. MRR and TWR will be measured using formula while the surface finish is measured using surface finish tester.

## **1.2 Aims**

The aim of this project is to undertake a comparative study in term of the characteristics of machining two different materials (aluminum and copper) using Copper electrode by EDM and to find the optimum process parameter for each material

## **1.3 Objectives**

The objectives of this project are to study:



1. To investigate the effect of the parameters such as pulse on time and pulse current on the Material Removal Rate (MRR), Surface Finish ( $R_s$ ) and the Tool Wear Rate (TWR).
2. To determine the optimal parameters that result in high MRR and lower tool wear ratio.
3. To conduct a comparative study between copper and aluminum using copper electrode EDM.

#### **1.4 Scope**

This project is limited to machining parameters on electrical discharge machining like pulse on time, pulse off time and discharge voltage. The scope should be limited in this project due to low cost and time. The project intends to investigate non iron content materials such as borosilicate, composite etc. The important factors such as discharge current, voltage, pulse on time and pulse off time will be monitored and recorded to know how these factors effect on the MRR and surface finish of each work piece material. The project will investigate how these parameters affect the MRR and the surface finish ( $R_s$ ) of each work piece material.

However, due to the limited capability of the EDM machine at the lab which does not enable machining of non iron content, the project will study and utilize aluminum and copper. Beside that there is only a copper tool that is used as electrode in the workshop. This is also including calculation of the machining characteristics like material removal rate. Beside that this project is going to be conducted to gain deep understanding and knowledge about the electrical discharge machining.

#### **1.5 Summary**

This chapter has discussed briefly the aims and objectives, the scope of the project. This chapter is as a fundamental for the project and act as a guidelines for the project. Generally, this project consists of five chapters. Chapter two will describe EDM in detail and the literature review of the test on the EDM machine and how it works. Chapter three is about Introduction to Machining Processes & Experimental. Chapter four is the Methodology which explains the approaches and methods used in performing the project. Chapter 5 consists of the results and conclusion.

## **CHAPTER 2**

### **LITERATURE REVIEW**

#### **2.1 Introduction**

Literature review was done to have broad idea of what other researchers have done in this field. The literature review is used as a guide to do the analysis and gives more information about the EDM and the idea to perform the test. Literature review was done by reading many articles, books and journal papers. Furthermore, articles and internet websites is used as main source to get the information needed to guide and to carry out the experiment. The history and the type of EDM machine, the limitation of the EDM machine and as well as the process and the working principle are explained in this chapter.

#### **2.2 Literature Review**

Many research have been conducted using EDM machine and for each experiment or research the input parameters are different, for instance the pulse on time, pulse off time, voltage and the current that are used to machine electrically conductive material are different from those which are used to machine non electrically conductive material. Due to the work piece material has to be conductive, the current used and the other parameters are high. The literature review section will be divided into two main sub contents based on the type of the work piece material in term of the capability of electric conductivity.

#### **2.3 History of Electrical Discharge Machine (EDM)**

The EDM story started in 1943 and during the Second World War where the Soviet government had problem in maintenance of automobile engine the problem caused by the spark between the tungsten electrical contacts. There was two scientists Boris and Natalya

Lazarenko who asked by the government to investigate the problem. When they started the investigation and fix the problem they noted that the spark become more uniform and predictable compared with if they are in the air. That time they had the idea for using the spark for erosion purpose Lazarenko B.R (1943). After that, Lazarenkos develop the erosion by using uniform spark then the process of erosion more understudied and start machining hard material such as tungsten or tungsten in 1950's Germer, L.H and Haworth, F.E. (1949).

Among that time the first EDM machine has been made. However, because of the bad quality of the electrode used the machine had some limitations. After 1960 where the advanced material had been discovered and development such as the semiconductor, quick enhancements embarked on the EDM machine. Then the die sinking EDM was widely used and the need to perform new machining such as cutting through which could not be performed by die sinking EDM machine as investigated. This lead to the development of the machine with same working principle instead the electrode was wire. The wire cutting EDM during that time was in the beginning. In 1980's development in the generator design and servo control take place Sato et al. (1985). After that and in the 1990's new method for the EDM machine is developed and the using of this machine strongly increased.

## **2.4 Electrical Discharge Machine (EDM)**

Electrical discharge machine (EDM) is an advanced machine that can perform drilling, grinding or milling. Nowadays modern industries and applications required high precision and high tolerance such as aerospace, transportations, elector component and medical parts. Such requirements cannot be done using traditional machining where high force is used and cannot machine small parts or complex shapes Anand Pandey(2010). Many advanced machine can be used for these special requirement such as water jet machining, electron beam machining, laser beam machining, electrochemical machine and the electrical discharge machine. Also the appearance of advanced material which is too hard leads of using of such machine.

## **2.5 Types of Electrical Discharge Machine (EDM)**

### **2.5.1 Die Sinking EDM**

This project is conducted using die sinking EDM, where both the tool and the work piece are immersed in the dielectric fluid. At the end of machining, the work piece will take the same shape of the electrode shape (this component and the working processes will be discussed in this chapter). The erosion takes place by the sparks where these sparks usually strike one at a time because the mechanism of erosion by spark occurs in different places or zones so that the nearest high zones are eroded first and so on. The different locations in the inter-electrode space have the identical local electrical characteristics which would enable a spark to occur together in all such locations. These sparks happen in huge numbers at random locations between the electrode and the work piece. As the base metal is eroded, and the spark gap subsequently increased, the electrode is lowered automatically by the machine so that the process can continue uninterrupted. Several hundred thousand sparks occur per second, with the actual duty cycle carefully controlled by the setup parameters.

### **2.5.2 Wire Cutting EDM**

Small diameter wire is used as electrode in this machine and the main difference between this machine and EDM is that the wire EDM is used when cutting through is required also the shape of electrode in wire EDM is specified by small diameter wire but in die sinking EDM the electrode may take circular, square, or rectangular.

### **2.5.3 Electrical Discharge Grinding**

The grinding rotates relative to the rotating work piece (no abrasive involved).

#### 2.5.4 Ultrasonic EDM

Ultrasonic EDM is used when high production rate is required. This machine is mainly used to machine difficult to machine materials and high strength temperature resistant alloys. Ultrasonic EDM can be used to machine complex geometries in small batches also the work piece has to be electrically conductive where it is one of the limitations of this machine. The limitation will be discussed later in this chapter. Ultrasonic EDM is used for producing dies for forging extrusion, die casting and injection molding. Ultrasonic EDM can be used to machine extremely hard material and complex geometries where it is impossible to be machined using traditional machines. Also ultrasonic EDM can be used to make stepped cavities Figure 2.1a where square electrode is used and the work piece is moving in x-y in horizontal direction. Also inner cavity can be performed where the electrode is designed with tapered tip which slowly opened and rotated inside the work piece to produce the cavity Figure 2.1b. Spiral cavity also can be machined by using slowly rotating electrode Figure 2.1c.

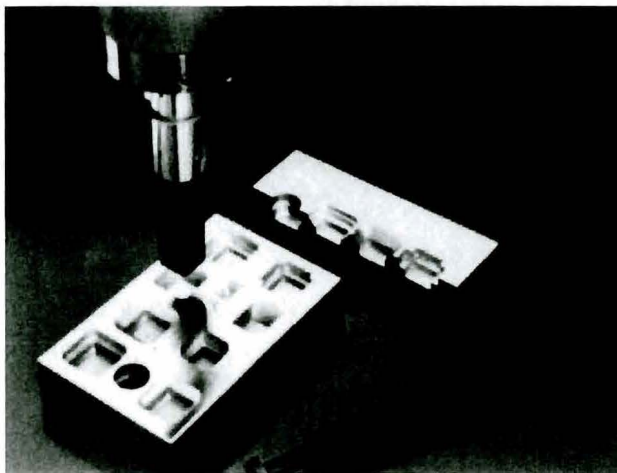


Figure 2.1a: Stepped cavities courtesy of AGIE Ltd.

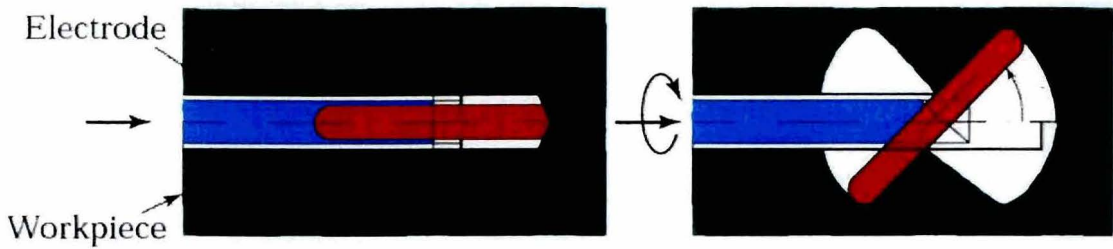


Figure2.1b: Inner cavities Luziesia France

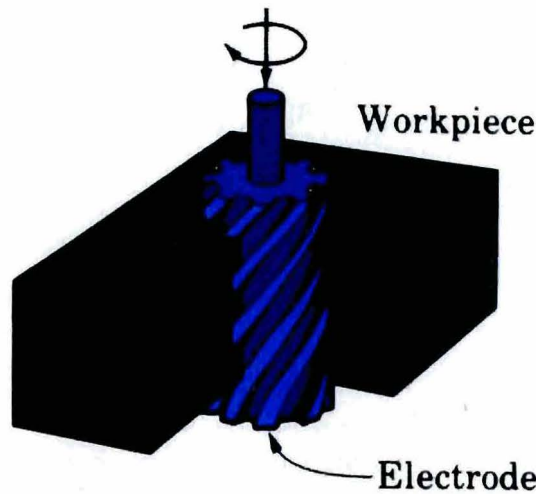


Figure2.1c: Spiral cavity American Machinist

## 2.6 Electrical Discharge Machining Processes

The erosion of the work piece is taking place due to thermal energy generated by EDM machine. Both electrode and work piece are immersed in dielectric fluid (ionized water or kerosene usually used). When the high voltage is applied (300 V) in modulated pulses this cause the free electrons of the tool be subjected to high force which in turn emitting the electrons. These electrons then accelerated toward the work piece via the dielectric fluid. As they are moving quickly from tool to work piece collision with dielectric molecules takes place. Because of this reaction between the free electrons and the molecules more positive ions and electrons will be generated due to the collision. These actions reoccurring again and again till the plasma channel where the temperature approximately 8000 to 10,000<sup>0</sup>C and because of the very low electrical conductivity that the plasma has, this makes the electrons

move from the tool to the work piece whereas the ions move from the work piece to the tool Ali Moarrefzadh (2012).Figure 2.2 illustrates these processes. The movement of the electrons can be seen visually in form of spark Ali Moarrefzadh (2012).

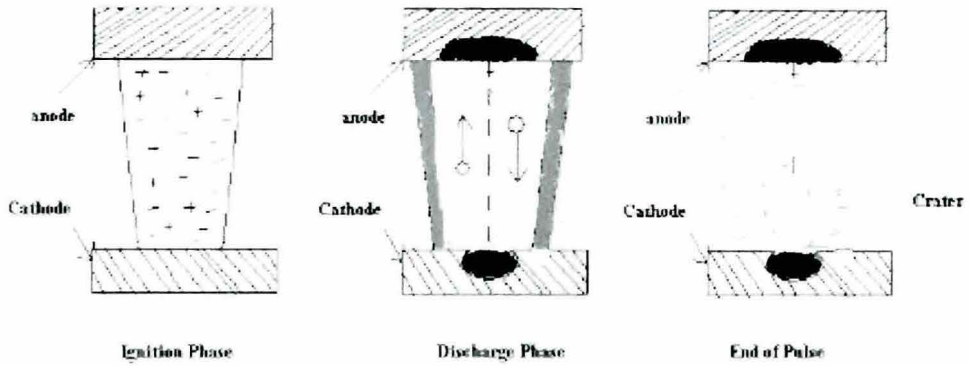


Figure 2.2: The processes of EDM König and Klocke (1997)

The spark has a responsibility to erode the work piece material by melting and vaporize the work piece surface Anand Pandey (2010). When the plasma channel is performing its task of melting and vaporizes the work piece material, the pulse on time which is in micro seconds cause a sudden reduction of the plasma temperature and give chance to the debris material to be flushing away by the dielectric pressure.

To make the EDM more stability, every next pulse time occurs at specific zone which is far from the previous erosion zone. Also it is worth to mention that the push off time should not be much long or too short as in case of long this will make the plasma channel that is generated by previous discharge can be de-ionized and the dielectric breakdown strength can be recovered. Also in case of the pulse of time being too short, pulse off time will produce surface roughness and instability in machining Anand Pandey(2010).

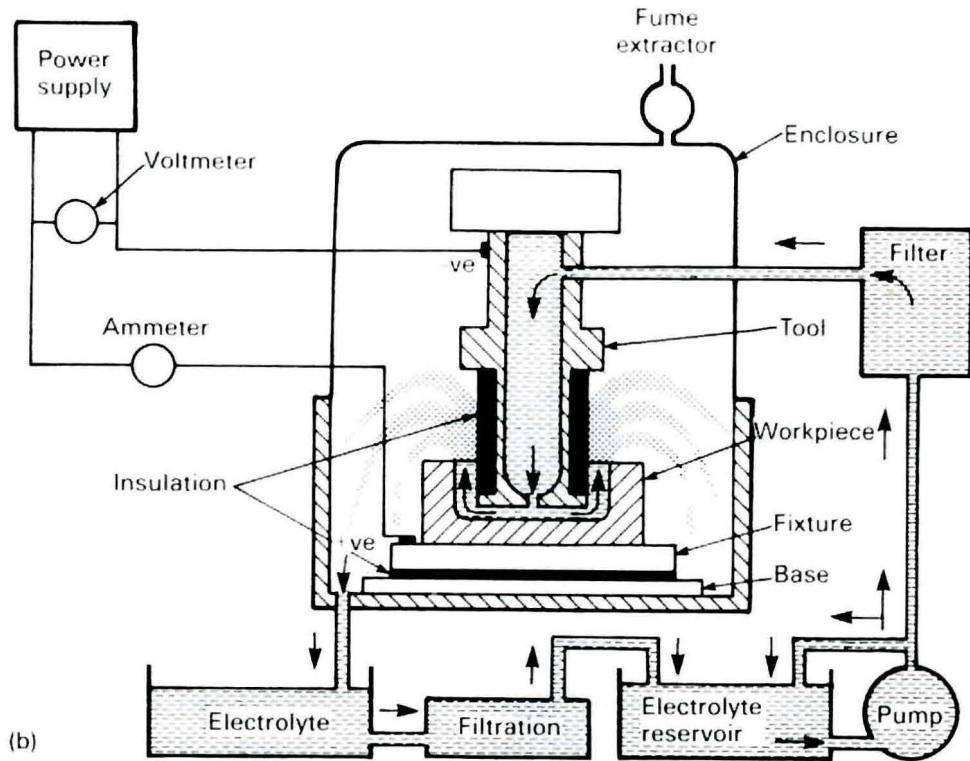


Figure 2.3: The EDM machining processes Ali Moarrefzadeh (2012).

Figure 2.3 shows the EDM processes where the tool acted as a cathode and is immersed in a dielectric fluid, the voltage then is applied approximately 300 volts in modulated pulses. The gap between the electrode and the work piece is controlled and maintained automatically by servo motor. The dielectric fluid breaks down when the temperature reach  $12,000^{\circ}\text{F}$  then the spark generated and erode the work piece material.

## 2.7 Advantages of EDM machine

There are many advantages of using EDM machine compared with other conventional machine and these advantages are:

- a. There is no actual contact between the tool and the work piece, hence no cutting forces act on the work piece where the fragile work piece can be easily machined.