UNIVERSITI TEKNIKAL MALAYSIA MELAKA

ELECTRICAL DISCHARGE MACHINING (EDM) OF REACTION BONDED SILICON CARBIDE (RB-SiC)

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

by

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DECLARATION

"I declare that this is my own work except for excerpts and summaries of each every one of them was me explain the source".

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APPROVAL

"I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Bachelor of Engineering Manufacturing (Process)".

Signature : ……

Name : DR. LIEW PAY JUN

Date : ……...

ABSTRAK

Electrical discharge machining (EDM) adalah satu proses pemesinan pembuatan bukan tradisional di mana pembuangan bahan-bahan kerja itu dilakukan dengan mencapai percikan bunga api yang tinggi antara bahan kerja dan elektrod yang direndam dalam cecair dielektrik . Proses ini biasanya digunakan untuk memotong bahan yang lebih keras dengan ketepatan dimensi yang lebih tinggi, membuat lubang mikro dan lubang yang dalam. Objektif kajian ini adalah untuk membandingkan kesan penambahan serbuk karbon nano dan mikro terhadap Reaction Bonded Silicon Carbide (RB-SiC) dan untuk mengkaji kesan kepekatan serbuk karbon terhadap *material removal rate (MRR), tool wear ratio (TWR), surface roughness (Ra)* dan *spark gap*. Kepekatan serbuk dan saiz akan diambil sebagai parameter pembolehubah dalam proses ini. Dalam kajian ini, model mesin EDM SODICK AQ35L digunakan. *MRR* dan *TWR* dikira sebelum dan selepas pemesinan sementara *spark gap* dan *surface roughness* dikira selepas pemesinan. Kaedah korelasi telah digunakan di dalam projek ini. Berdasarkan kepada empat ciri-ciri, serbuk karbon nano (40 nm) menunjukkan keputusan yang baik berbanding dengan serbuk karbon mikro (200-300 µm). Pada ketika ini, zarah yang kecil memberikan kesan yang besar kepada keputusan. Tambahan pula, dengan menambah serbuk karbon, keputusan telah ditingkatkan berbanding tanpa menambah serbuk karbon.

ABSTRACT

Electrical discharge machining (EDM) is a non-traditional manufacturing machining process where the material removal of the workpiece is done by achieving the high frequency of sparks between the wokpiece and the electrode which immersed in the dielectric fluid. This machining usually used to machine harder materials with higher dimension accuracy, making micro holes and deep holes. The objectives of this study are to compare the effect of addition of micro and nano carbon powder on RB-SiC by using EDM die sinking and to study the effects of the powders on material removal rate (MRR), tool wear ratio (TWR), surface roughness (Ra) and spark gap. Concentrations of powder and size of particles are used as the variable parameters in this process. In this study, EDM machine model SODICK AQ35L is used. MRR and TWR are calculated before and after machining while spark gap and surface roughness are calculated after machining. Correlation method has been applied to this project. Based on the four characteristics, nano carbon (40 nm) powder shows good results compared to the micro carbon powder (200-300 µm). At this point, small particles gave large effects to the results. In addition, by adding carbon powders, the results have been improved compared when no adding carbon powder.

DEDICATION

For my beloved father, mother, sister and brothers, their endless support in term of motivation, support and caring as well throughout the whole project.

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LIST OF ABREVIATIONS, SYMBOLS & NOMENCLATURE

Al	-	Aluminium
C	-	Carbon
CNC	-	Computer Numerical Control
Co	-	Cobalt
Cr	-	Chromium
Cu	-	Copper
DC	-	Direct Current
EDM	-	Electrical Discharge Machining
I_o	-	Maximum Current
I_p	-	Peak Current
Mo	-	Molybdenum
MRR	-	Material Removal Rate
Ni	-	Nickel
OHNS	-	Oil Hardening Non-Shrinking
Ra	-	Surface Roughness
RB-SiC	-	Reaction Bonded Silicon Carbide
SEM	-	Scanning Electron Microscopy
Si	-	Silicon
SiC	-	Silicon Carbide
t	-	Machining Time
T_{off}	-	Pulse Off-Time
T_{on}	-	Pulse On-Time
TWR	-	Tool Wear Ratio
V	-	Machining Voltage
V_o	-	Open Circuit Voltage
W_b	-	Weight of Workpiece before Machining
W_a	-	Weight of Workpiece after Machining
W_{tb}	-	Weight of Electrode before Machining

W_{ta}	-	Weight of Electrode after machining
δ	-	Spark Gap

CHAPTER 1
INTRODUCTION

This chapter presents the background of the study. This study investigates the comparison between nano carbon powder (40nm) and micro carbon powder (200-300 µm) on the semi-conductive material, silicon carbide (SiC) by using Electrical Discharge Machining (EDM). The background of the study covers the history and the process flow of Electrical Discharge machining (EDM). Besides that, the problem statements followed by the objectives and scope of the study are included. Throughout this chapter, the organization of the report is explained.

1.1 BACKGROUND STUDY

According to Elman *et al.* (2001), Electrical Discharge machining (EDM) also called spark eroding, spark machining, wire erosion or die sinking where electrical discharge is used to erode electrically conductive materials. According to Benedict *et al.* (1987), EDM is a non-conventional material removal process to machine electrically conductive and any hard materials for example in manufacturing of mould, die, surgical components, and automotive. Considering the EDM die sinking process does not use mechanical energy, the removal rates are not affected by the strengths, toughness and hardness of the material (Lajis *et al*. 2009). This machine has the ability to machine extremely hard materials such as titanium which are hard to machine using other conventional processes. In addition, any complex shapes can be made in high precision value (Lauwers *et al*. 2004).

Based on the English physicist, Priestley *et al.* (1770), EDM is the erosive effect of electrical discharges on many metals. In the research to remove the erosive effect on

electrical contacts, Lazarenko *et al*. (1770) from the Soviet researchers gave the idea to exploit the explosion effects of an electrical discharge and try to develop a machine that can do the process. So, in 1943 they made a spark machining process. They got the name from the fact of progression of the sparks which happened between two electrical conductors submerged in a dielectric fluid.

Nowadays, electrical discharge machining (EDM) is widely used for high precision machining in industry for all types of conductive materials for example metallic alloy, metals, graphite or even ceramics materials of any hardness (Luis *et al*. 2005). Therefore, a comprehensive study about SiC material which is a hard but brittle will be done.

1.2 PROBLEM STATEMENT

Electrical discharge machining (EDM) is a process of machining for hard metals or parts that are difficult to machine such as sharp edge and small hole. The EDM die sinking basically works to the conductive materials due to discharge sparks between the workpiece and electrode. Typically, the process carried out with straight polarity which the tools will reacts as a negative (-ve) charge and the workpiece will reacts as a positive (+ve) charge.

The silicon carbide (SiC) used in this study, however possess a very limited conductivity. In other words, it is difficult to be machined directly by using EDM. Previously, a micro-EDM machine, Panasonic MG-ED82W had been used in the machining of SiC. By adding some carbon nano-fiber into the dielectric fluid, the electrically discharge machinability of RB-SiC had been improved (Liew *et al*. 2013). However, comparison of the powder size has not been investigated yet. Therefore, an experiment using two different sizes of carbon powder will be carried out.

1.3 OBJECTIVE

The objectives of this research are:

(a) To compare the effect of addition of micro and nano carbon powder on Reaction Bonded Silicon Carbide (RB-SiC) by using EDM.

(b) To study the effects of carbon powder concentrations on tool wear ratio (TWR), material removal rate (MRR), spark gap (δ) and surface roughness (Ra).

1.4 SCOPE

The experiments conducted by using EDM die sinking. The material for the electrode was copper. RB-SiC which is a semiconductor material used as a workpiece. Parameters such as concentration and size of both powders were done to get the optimum results for the material removal rate (MRR), tool wear ratio (TWR), surface roughness (Ra), and spark gap. Both powders were mixed in the dielectric fluid and the effect of these powders was studied on the RB-SiC.

1.5 OUTLINES

This report is divided into five parts. The first part is the chapter one. In chapter one, it consist of background of the project, problem statements, objectives of the project, and the scopes of the project. In this chapter, it will literally tell about the background of the electrical discharge machining (EDM) and the problem that need to be investigated. The type of EDM machine used in this project is EDM die sinking.

The second part is the chapter two. Chapter two is about the literature review of the project. Literature review is an evaluation, integrating the previous research together, and explaining on how it integrates into the proposed research problem. This chapter will be referred to the journals, internet resources, books, and previous researches

done on the related topics. Based on the information gathered, this chapter will discuss about the definition of EDM, EDM machining parameters, EDM characteristics, type of electrode, material workpiece, and the measuring equipment.
The third part will cover on the research methodology. This chapter will explain about how this project will be conducted. All possible data collection method and data analysis will be outlined.

Chapter 4 will focuses on the result and discussion.

Chapter 5 is about the conclusion for this project. It will summarize the results achieved or not based on the objectives. At the end of this chapter, there will also recommendation included as well.

CHAPTER 2
LITERATURE REVIEW

Literature review is an important element in scope studies. In this chapter, it will give all the information about the electrical discharge machining (EDM) die sinking where obtained from the journals, research, books, printed or online articles which are the main sources of the information. In this part, the machining operations, parameters, characteristics measuring equipment and other elements are included. This section acts as a references for the information related according to the topic.

2.1 Electrical Discharge Machining (EDM)

Electrical discharge machining (EDM) is a non-traditional manufacturing process which is remove material from a part by means of a series of repeated electrical discharges (produced by electric pulse generators at short intervals) between the part being machined in the presence of a dielectric fluid and a tool called as electrode (Puertas *et al.* 2003). This machine has been widely used in manufacture automotive, mould, die, surgical components, and aerospace due to its special features of using thermal energy to machine electrically conductive parts for any hardness (Kalpakjian *et al*. 2003).

EDM does not make direct contact between the tool and workpiece during the process. EDM starting in 1770, when an English chemist, Joseph Priestly found the erosive effect of electrical discharges or sparks (Newman *et al*. 2003). In EDM system, there are consists a shaped tool or electrode and the workpiece which are connect to a dc power supply and placed in dielectric fluid (Figure 2.1). When there

is a potential difference between the workpiece and the tool is sufficiently high, the dielectric in the gap is partially ionized. Then a spark will discharge and start to remove a small amount of metal from the workpiece surface (Figure 2.2). Then, the rates of capacitor discharge are repeated between 50kHz and 500 kHz with voltages ranging between 50V and 380V and current between 0.1A to 500A (Serope *et al*. 2001)

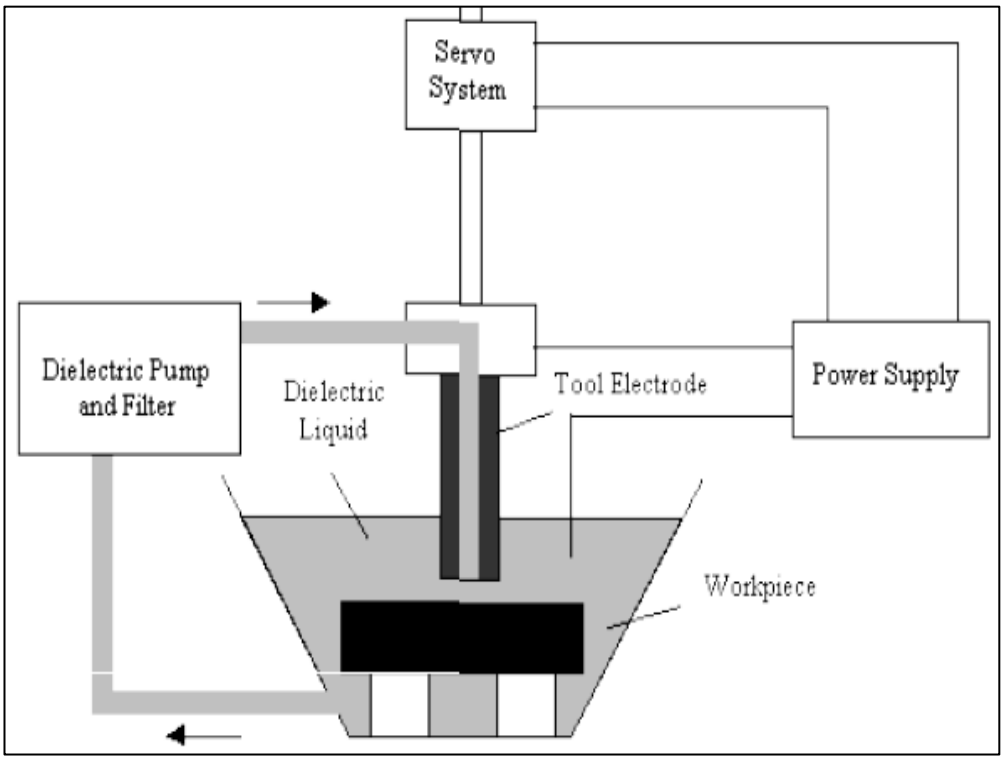

Figure 2.1: Schematic diagram of Electrical discharge machining (EDM) process (Serope *et al.* 2001)

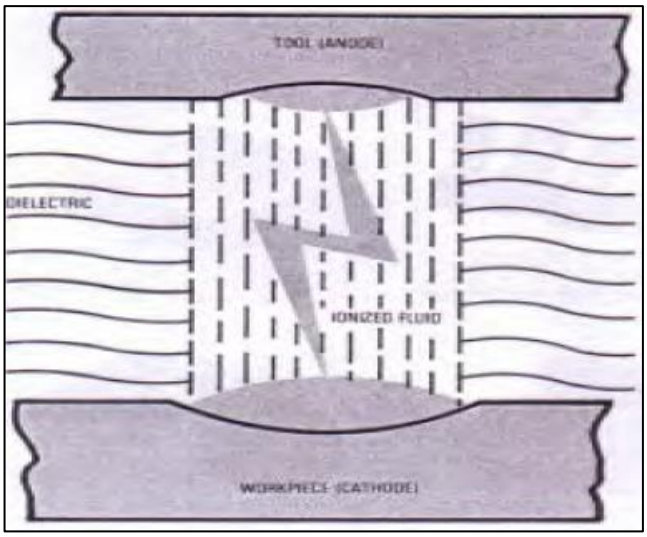

Figure 2.2: Spark discharge remove small particle of metal on workpiece during EDM process (Serope *et al.* 2001)

2.1.1 History of EDM

In 1943 at the Moscow University, Lazarenko discovered the damaging of electrical discharge for constructive use. They made a controlled process of machining difficult to machine metals by vapourising material from surface of metal. The Lazarenko EDM system used the capacitance-resistance type of power supply, which widely used in 1950s and become the successive development in EDM (Newman *et al*. 2003). Besides that, many researches have been done to improve in many aspects such as improvement on surface, material removal rate by using different cutting tool and others (Ojiha *et al*. 2010).

At the same time there also similar claims when three American employees turn up with the notion of using electrical charges to remove broken taps and drills from hydraulic valves. Then, it became the basis for the vacuum tube EDM machine and an electronic-circuit servo system that automatically provided the proper electrode-to-workpiece spacing (spark gap) for sparking, without the electrode contacts the workpiece (Jameson *et al*. 2001).

In 1980s, with the technology of computer numerical control (CNC) in EDM had leaded the tremendous advances in term of enhancing the efficiency of the machining operation. The implementation of CNC technology into the EDM made the machine become so stable with the regular improvement in the process, thus it can be used in a long period of time by monitoring under adaptive control system. EDM process enables machining of any material, which is conductive, regardless of its hardness, strength or shape (Zeid *et al*. 1997)

2.1.2 Types of EDM Machine

Basically, there are two types of electrical discharge machining (EDM). First is the EDM die-sinking and second is the EDM wire-cut.

2.1.2.1 EDM Wire Cut

EDM wire cut was popularized about 1960s' and has been has developed the tool and die, mold and metal working industries. This machine can machining material that is electrically conductive regardless of its hardness such as aluminium, copper, graphite and tool steel. The wire at the machine does not contact the workpiece. So that, there is no physical contacts or pressure imparted on the workpiece compared to other cutting machining such as milling and grinding. Sparks are produced between an accurately position moving wire (electrode) and the workpiece. Direct current is discharged from the wire to workpiece through an insulated dielectrid fluid (water) with a very small gap. The metal removed during the process depends on the desired cutting speed and the surface finish required (Moulton *et al* .2013). Figure 2.3 shows the example of EDM wire cut.

Figure 2.3: Example of EDM Wire Cut (Moulton *et al.* 2013)

2.1.2.2 EDM Die Sinking

Die sinking or sinker EDM is a name for vertical EDM which is taken from the antiquated cavity-making process called hobbing. Hobbing is a process of forcing a pre hardened tool steel shape into the workpiece under a high pressure for example a cold forming process of a cavity for a mold or die. This machining process is called as sinking, die sinking or die, in term of sinker because tool was sunk into the workpiece instead of a hardened hob (Bud *et al*.1997).

RAM EDMing machines also known as vertical EDMs or die sinker and the range of automation and sizes from manual operating table top systems to large CNC ones. Ram EDM components are:

I. Electric power supply
II. Dielectric medium
III. Work piece and tool
IV. Servo control unit

The electric power supply provides series of DC current electric discharges between the workpiece and electrode. Besides, it controls: