UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Electrical Discharge Machining Of AISI 304 Stainless Steel Using Mixture of Deionized Water And Carbon Nanofiber With Surfactant

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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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Manufacturing Process) (Hons.). The member of the supervisory is as follow:

………………………………

(Dr. Liew Pay Jun)

ABSTRAK

Fokus utama projek ini adalah untuk mengkaji tindak balas *surfactant* terhadap ciri-ciri seperti (kadar pengurangan bahan, kadar pengurangan alat dan kekasaran permukaan) yang dihasilkan melalui proses *Electrical Discharge Machining (EDM)* terhadap keluli tahan karat AISI 304 menggunakan campuran air dinyah-ionkan dan karbon nano fiber dan dicampurkan *surfactant*. Terdapat dua jenis *surfactant* yang telah digunakan iaitu *Gum Arabic (GA)* dan *PoliVinylPyrrolidone (PVP)*. Hasil kajian menunjukkan bahawa kehadiran *Surfactant* kedalam campuran air dan karbon nano fiber mampu untuk mencegah kemendapan karbon nano fiber, dan mampu untuk meningkatkan tahap efisien cecair elektrik dan seterusnya, mampu untuk menjana lebih kadar pengurangan bahan. Apabila PVP digunakan, kadar pengurangan alat menunjukkan kadar pertambahan, tetapi, apabila GA digunakan, kadar pengurangan alat berkurang walaupun kadar konsentrasi GA bertambah. Hasil kajian juga menunjukkan GA merupakan *surfactant* yang lebih stabil berbanding PVP dan mampu memastikan karbon nano fiber tidak akan termendap di dalam cecair elektrik. Kadar pengurangan bahan apabila menggunakan GA mampu mencapai hingga 70-80% lebih baik berbanding PVP. Cecair elektrik yang menggunakan karbon nano fiber dan GA pada kadar konsentrasi 1:2 telah menghasilkan kekasaran permukaan yang lebih baik berbanding cecair elektrik lain.

ABSTRACT

This project mainly focused on the effect of surfactant towards the machining characteristics (material removal rate, electrode wear rate and surface roughness) of Electrical Discharge Machining of AISI 304 stainless steel using mixture of deionized water and carbon nanofiber with surfactant as dielectric fluid. Two types of surfactant namely Gum Arabic (GA) and PolyVinylPyrrolidone (PVP) were used. The experimental results show that the addition of surfactant can prevent the agglomeration of carbon nanofiber in the dielectric fluid, and improve the efficiency of machining and thus, increase the material removal rate. The electrode wear however, increase as the concentration of PVP surfactant increased in the dielectric fluid, but decreases as the concentration of GA surfactant increased. The results also shows that GA is a better surfactant compared to PVP since it is more stable and ensure the optimum dispersion of carbon nanofiber in the dielectric fluid. When GA was used as surfactant, the material removal rate improved up to 70-80% compared to when PVP was used in the dielectric fluid. The surface roughness however shows some irregularities. The surface roughness for mixture using both GA and PVP was highest at concentration of carbon nanofiber to surfactant of 1:1, but it decreases at concentration 1:2. The surface roughness then increased at concentration of 1:3. The lowest surface roughness obtained from the mixture of carbon nanofiber and GA at concentration of 1:2.

DEDICATION

To my beloved parents, sister and brothers, and not forgotten my supervisor.

ACKNOWLEDGEMENT

First of all, praised to ALLAH S.W.T for have given me the strength and courage to finished this project. I would like to express my deepest gratitude towards my project supervisor, Dr. Liew Pay Jun for have guided me from the beginning until the end of this project, and whom without, I will not be able to complete this project with success. Special thanks goes to all of my friends especially Raziman Razak, whom have given me endless advice and helps for me throughout this project. I also would like to thank my beloved parents whom have never stopped encouraging and prays for me since the day I started studying in this university until now and also to all persons that have helped me direct or indirectly towards finishing this project.

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CHAPTER 1

INTRODUCTION

1.1 Electrical Discharge Machining

Electrical Discharge Machining (EDM) is an advanced manufacturing process and has been one of the popular and widely used machining processes in the industry. The material is removed by means of a series of repeated electrical discharges between tool, called the electrode, and the part being machined in the presence of a dielectric fluid (Luis et al., 2005). EDM has been widely accepted and used in manufacturing industry, especially when the parts that will be machined requires high precision or complex shapes or parts that will be machined is categorize under difficult-to-machine materials.

König et al. (1988) states that electro-discharge machining is a reproductive shaping process in which the form workpiece will follow or mirrored from the form of electrode. During the machining process, heat will produced and thermal erosion process takes place. EDM die sinker process was usually performed by submerging workpiece in a dielectric fluid. To prevent any mechanical contact between electrode and workpiece, a gap between them is maintained.

1.2 Stainless Steel

Carbon steels, alloy steels, and aluminium steels are the most widely used alloy system. These carbon steels are relatively dilute solutions of several elements in the parent matrix. However, stainless steels are more chemically complex steel compared to alloy steels. Stainless steel contains large number of alloying element and thus, broadened the range of possible phases or basic crystal structure (Mcguire, 2008).

According to Washko and Aggen (1990), stainless steel achieved their stainless characteristics through the formation of invincible and adherent chromium-rich oxide surface film. This oxide forms and heals itself in the presence of oxygen. Korkut et al. (2004) states that, due to its exceptional properties such as corrosion resistance and low thermal conductivity, stainless steel was used in many machinery parts requiring high corrosion resistance, and also to fabricate food and chemical processing equipment.

Grzesik (2008) states that, the corrosion resistance properties of stainless steels are resulted from its high chromium content (12- 25%), and 10 – 25% of nickel which resulted in an austenitic structure, which leads to extreme high work-hardening rates. Stainless steel can be categorized or be considered as hard-to-machine material due to its high tensile strength, high ductility, low thermal conductivity, high work hardening rate and abrasive character. Thus, when using conventional cutting process such as turning or milling, high cutting forces will be needed to machine it and which will results in increased of temperatures and the tool wear rates.

1.3 Problem statement

Kerosene was normally used as the dielectric fluid. However, usage of kerosene may reduce the material removal rate since kerosene tends to decompose and produced carbon during discharge process took places. Research has been made in utilizing deionized water as potential replacement for kerosene. Compared to kerosene, deionized water is much better dielectric fluid in terms of high MRR and low electrode wear rate (EWR). Moreover, it significantly improves the surface finish of the parts (Liew et al. 2012). Hence, this study will attempt to determine the machining characteristics (EWR, MRR, and surface roughness) of AISI 304 stainless steel by using mixture of deionized water and carbon nanofiber.

Carbon nanofiber (CNF) will be added into the dielectric fluid to increase the conductivity of the dielectric fluid and to improve the machining efficiency. Liew et al. (2013) states that CNF has the ability to arrange or restructure themselves in the form of micro chains by interlocking to one another and forming bridging networks between electrode and workpiece. Since CNF has excellent electrical conductivity, it may weaken the insulating strength of the dielectric fluid and increase the spark gap distance and thus, will increase the material removal rate (MRR) by increasing the frequency of electrical discharge of the EDM process.

However, there is a major setback in mixing CNF into deionized water. CNF was reported to possess a very strong van der Walls forces, estimated at 500 eV/µm (Inam et al. 2014). Due to this strong van der Walls forces, CNF tends to bundle up or agglomerate at the bottom of the mixture. This situation might leads to significant reduction to the properties of the dielectric fluid and might greatly affect the machining efficiency. Therefore, the usage of surfactant (short form for surface active agent) was introduced in the mixture contains CNF. Introduction of surfactant in the mixture will reduce the van der Walls forces and improve the dispersibility of CNF in the dielectric fluid and thus improve the EDM process efficiency.

1.4 Objectives

The objectives of these studies are:

1. To determine the optimum value of surfactant concentration in the mixture of deionized water and carbon nanofiber for electrical discharge machining of AISI 304 stainless steel.
2. To determine the machining characteristics (electrode wear, material removal rate, surface roughness) of AISI 304 stainless steel in electrical discharge machining (EDM) using mixture of deionized water and carbon nanofiber with surfactant.

1.5 Scope of Study

This report comprised of machining of AISI 304 stainless steel by using EDM die sinking with the mixture of deionized water and carbon nanofiber with surfactant as the dielectric fluid. The process parameter is one of the most important factors in order to determine the output variables, such as surface roughness, material removal rate and electrode wear rate.

The equipment that was used to perform the experiments is a die-sinking EDM machine of type SODICK AQ35L. The dielectric fluid used is mixture of deionized water with carbon nanofiber which length is between 10 – 30 micrometer and diameter of 150 – 200 nanometer with the addition of surfactant. The electrode used is copper.

1.6 Structure of Report

Chapter 1 introduces the electrical discharge machining and the material to be machined which is AISI 304 stainless steel. Chapter 2 is the literature review, which covered the EDM processes, the dielectric fluid used in the process, the properties of materials to be machined and the effect of adding the carbon nanofiber and surfactant into the dielectric solution towards the machining parameters. Chapter 3 is methodology, in which will be discussing about the experimental materials and apparatus, experimental procedure and method of data analysis. Chapter 4 is the results and discussion chapter. Justification will be given with respect to the results obtained from the experimental that have been done. Chapter 5 is the conclusion, which is the summary of this report. Suggestions for future works also are included in this chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 Electrical Discharge Machining (EDM)

Electrical Discharge Machining (EDM) is an advanced manufacturing process which removes parts by melting and evaporating the parts through a series of repeated electrical discharges between the electrode and the part in the presence of a dielectric fluid. EDM is a widely used technique of machining all types of conducting materials especially when involving a high-precision technique (Puertas et al., 2005).

König et al. (1988) in its research states that, EDM is a reproductive shaping process in which the form parts being machined will follow the form of tool electrode. This process manipulates the physical phenomenon of material erosion of electrically conductive materials by means of electrical discharges. The thermal erosion process occurs under the influence of heat. A discrete high-frequency electrical discharge (sparks) between tool and workpiece will be generating the required separation energy. A gap (spark gap) is maintained between the electrode and the workpiece to prevent any contact between them which might lead to machining error.

Ho and Newman (2003) states that, the series of electrical discharge which will produce an intense heat, will melt and evaporate the material from tis surface, and thus, removes the materials. This process is completely different compared to the traditional machining process, as chips are not mechanically produced. Normally, the volume of material removed per discharge is normally in the range of 10^{-6} - 10^{-4} mm^3 and the material removal rate (MRR) is normally in range between 2 and 400 mm^3/min depending on the application it required. The accuracy of the part produced form this EDM process is also relatively high since the shape produced are defined from the electrode shape. Figure 2.1 shows the schematic illustration of EDM process.

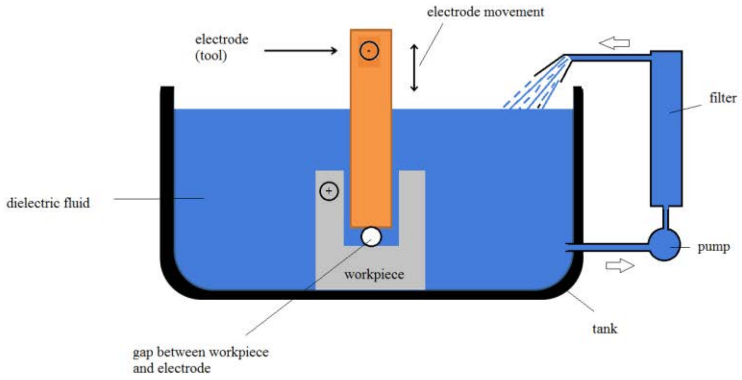

Figure 2.1: EDM Process

2.1.1 Basic Principle of EDM

Basically, EDM system consists of two electrodes which is the tool and the workpiece, which are connected to a power supply and submerged in a dielectric fluid. When there is a significant difference in potential difference between the tool and the workiece, the dielectric will trips and a transient spark discharges through the fluid. The spark discharge will remove a relatively small amount of material (workpiece) from its surface. Usually, the discharge will be repeated at rates between

200 and 500 kHz with the voltage ranging between 50 to 380 V and the currents usually ranging from 0.1 to 500 A (Kalpakjian and Schmid, 2006).

Jameson (2001) states that, no physical contact occur between the electrode and the workpiece for the material removal process, which makes EDM differ from most chip-making machining operations. In case if there is a contact between the electrode and the workiece, sparking will stop and thus, the material will not be removed. Another basic principle of EDM is that only one spark occurs at a time.

As each spark occurs, it will vaporise a small amount of the electrode and the workpiece. When the spark is turned off, the vaporized material will solidify and turns into EDM chip. The EDM chip must be removed from the sparking area in order to produce an efficient machining. The chip or debris is removed by using flushing application.

2.1.2 EDM Process Advantages and Limitations

Advantages:

a) Fragile parts can be machined without distortion because no mechanical work is involved.
b) Holes of desired size can be easily be made in hard and brittle materials.
c) The hardness of the cutting tool is immaterial and the tool need not be harder than the workpiece, because no mechanical contact between tool and workpiece.

Limitations:

a) Only electrically conducting materials can be machined.
b) The process is slow compared to conventional methods.
c) The surface finish is poor because of presence of small craters.
d) Power consumption is more.

2.2 EDM Process Parameter

The real observing and controlling of EDM process has often been built on the identification of different pulses. According to Ho and Newman (2003), there are several pulses in EDM which is arc pulse, open pulse, off pulse, and spark pulse, which are dependent on the ignition delay time. These pulse parameters will directly influence the MRR, surface roughness and accuracy of the workpiece. Hence, the recognition and characterization of the different pulses gives a viable option of observing and controlling the sparking process by measuring the related gap voltage and current.

2.2.1 Pulse Current

Bud (1997) states that, pulse current is the amount of current used in discharge machining, and are measured in units of amperage. In both die-sinking and wire-cut applications, the maximum amount of amperage is determined by the surface area of the cut/removed. The greater amount of surface area, the more power or amperage can be applied. Roughing operations often uses higher amperage, as well as in cavities or details with large surface area.

2.2.2 Pulse On-Time

Lee et al. (2004) states that, the MRR will increase with increasing pulse current but continuous lengthening of the pulse-on duration might not necessarily improve the MRR. In fact, extending pulse-on duration tends to reduce the MRR. As