



UNIVERSITI TEKNIKAL MALAYSIA MELAKA

**EFFECT OF SURFACTANT ON THE SURFACE INTEGRITY OF
STAINLESS STEEL USING EDM**

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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2016

ABSTRACT

This project mainly focused on the effect of surfactant towards the EDM machining characteristics (surface hardness , surface topography and recast layer) of AISI 304 stainless steel by using different dielectric fluid which are deionized water and carbon nanofiber with surfactant and deionized water and carbon nanofiber without surfactant. Two types of surfactants namely Gum Arabic (GA) and PolyvinylPyrrolidone (PVP) were used. The experimental results show that with the addition of surfactant in mixture, it can prevent the agglomeration of carbon nanofiber in the dielectric fluid and also can improve machining efficiency. Thus, it will increase the surface hardness of the material. However, when dielectric fluid used without surfactants were added , the recast layer thickness is extremely high. Further, the recast layer thickness reduces with the increase in the concentration 1:1 for both surfactants which are PVP and also GA.. Besides, when surfactant such GA and PVP were added in dielectric fluid ,less craters were found on the workpiece surface due to discharge distribution effect. For the workpiece under machining process in dielectric fluid with surfactant, more apparent discharge distribution effect is observed. A smoother surface with smaller craters and less microcrack is achieved. Therefore, the improvement of surface finish for workpiece is verified firmly by adding surfactant.

ABSTRAK

Projek ini mengenai kesan *surfactant* kepada ciri-ciri pemesinan (kekerasan permukaan, permukaan topografi dan *recast layer*) *Electric Discharge Machining* (EDM) AISI 304 keluli tahan karat dengan menggunakan air dinyah-ionkan dan karbon nanofiber dengan *surfactant* serta air ternyah-ion dan nanofiber tanpa *surfactant*. Dua jenis *surfactant* iaitu *Gum Arabic (GA)* dan *Polyvinylpyrrolidone (PVP)* telah digunakan. Keputusan eksperimen menunjukkan apabila penambahan *surfactant* dalam campuran ia boleh mencegah pemendapan karbon nanofiber dalam cecair dielektrik dan juga boleh meningkatkan kecekapan mesin. Oleh itu, ia akan meningkatkan kekerasan permukaan bahan. Walau bagaimanapun, apabila cecair dielektrik tanpa *surfactant*, ketebalan *recast layer* adalah tinggi. Di samping itu, ketebalan *recast layer* berkurang apabila nisbah di antara karbon nanofiber dan *surfactant* meningkat ke kepekatan 1: 1 untuk kedua-dua *surfactant* iaitu PVP dan GA.. Selain itu, untuk permukaan topografi pula, apabila *surfactant* seperti GA dan PVP ditambah di dalam cecair dielektrik, kemunculan kawah adalah kurang pada permukaan bahan kerja kerana kesan pengedaran. Apabila *surfactant* digunakan sebagai bahan proses pemesinan dalam cecair dielektrik dengan lebih ketara kesan pengedaran pelepasan diperhatikan. Permukaan licin dengan kawah kecil dan *microcrack* sukar dicapai. Oleh itu, dengan menggunakan *surfactant*, kekasaran permukaan bahan lebih baik.

DEDICATION

To my beloved parent's Suberi bin Said and Hayati binti Narullah and family and not forgotten my supervisor.

ACKNOWLEDGEMENT

It is a pleasure to thank those who made the thesis possible. First and foremost, I would like to show my deepest gratitude to my supervisor Dr. Liew Pay Jun for her encouragement, guidance and support from the initial to the final level. Secondly, deepest gratitude to master student's Raziman Razak for his helps and not forgets my beloved parents. Lastly, I would like to offer my regard and blessing to all of those who supported me in any respect during the completion of this thesis.

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CHAPTER 1

INTRODUCTION

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CHAPTER 1

INTRODUCTION

This chapter gives an introduction upon background, problem statement, objectives, and scope of study ~~in this title.~~

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1.1 Electrical Discharge Machining

~~1.1~~

Electrical Discharge Machining (EDM) can be defined as non-traditional machining process based on removing material from a part by means of a series of recurring electrical discharge that created d by electrical pulse generators at short intervals between a tool called electrode and the part ~~mention before~~ in the presence of

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dielectric fluid. This fluid make it's possible to flush the erode particles from the gap and it important to maintain the flushing continuously (Bergaley, 2013).

~~Among the variety of process involves in EDM processes, most widely and successfully applied to the machining of variety of work piece material.~~ The material is removed of means of repetitive spark discharges that cause melting or evaporation of the work piece material and the surface can be characterized by overlapping craters and thermal impact occurs (Nikolaos Cornelia et al., 20062013).

Surface integrity is the nature of the surface condition of work piece after manufacturing processes. It can also be defined as the unimpaired or an enhanced surface condition of a component or specimen which influences its performance. Specialized test were conducted to characterize surface integrity such as surface texture (roughness ~~and lay and lay~~), macrostructure (macrocracks and surface defects) and micro hardness (Dastagiri et al., 2014).

This study will be investigating the effect of surfactant on surface integrity towards the machining characteristics. ~~Some effect of the electrode area, especially on surface roughness and topography.~~ According to Peças et al. (2008), the processing component can increase the EDM ~~and~~ performance of accuracy and complex geometry. EDM polishing is the one that required using low of discharge energy that push a low electrode-piece also known as gap distance. ~~Due to this, small gap will produce; it will cause it difficult to remove the particle.~~

1.2 Problem ~~statement~~ Statement

Electrical discharge machining is a machining process that usually used for hard metals or those that difficult to be machined by using traditional technique.

Normally, kerosene is used as dielectric fluid. However, the used of kerosene may lessen ~~the material removal rate (MRR)~~the responses such as material removal rate (MRR), surface hardness and others since the kerosene has tendered to decompose and deliver carbon during the discharge process. Besides, it also makes a few issues while machining, for example, corruption of dielectric properties, contamination of air and attachment of carbon particles on the work piece~~creates several problems while machining such as degradation of dielectric properties, pollution of air and adhesion of carbon particles on the work piece~~ (Chakraborty et al., 2015).

Therefore, in the recent researches, deionized water has been widely used to replace kerosene as dielectric fluid. In this study, mixture of deionized water and carbon nanofibers (CNF) will be used to determine the surface integrity of AISI 304 stainless steel. However, there is a major drawback in mixing carbon nanofibers into deionized water. CNF tends to agglomerate and this situation might lead to significant reduction of the machining efficiency. Therefore, the usage of surfactant is introduced in the mixture contains CNF. –The surfactant might improve the dispersibility of CNF in the dielectric fluid and thus improve the EDM machining efficiency.

~~However, the use of deionized water is difficult to observe the austenite phase and intensity of micro-cracks in the white layer of the sample. Hence, to overcome this problem, surfactant was added in deionized water because of the incredible electrical conductivity of carbon nanofiber likewise diminishes the protecting quality of the dielectric liquid and builds the flash whole separation between the anode and work piece. (Liew et al., 2013). Carbon nanofibers were somewhat held fast to the work piece surface, particularly when a high centralization of carbon nanofibers was used. There is a bidirectional material movement between the terminal and the work piece surface, including carbon nanofibers in the dielectric liquid at a suitable fixation is useful for keeping the material relocation.~~

1.3 Objectives

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The main objectives of this project are:

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1. To investigate the effect of surfactant on the surface integrity (surface ~~hardness, roughness, and surface topography~~ topography, and recast layer) after EDM process.
2. To compare the machining performance of stainless steel under various dielectric fluids (~~deionized water,~~ deionized water with carbon nanofiber, deionized water with both carbon nanofiber and surfactant Gum Arabic and Polyvinylprrolidone).

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1.4 1.4 Scope of studyStudy

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This project will be conducted using die sinking electrical discharge machine. AISI 304 stainless steels will be used as a work piece material. Besides, the electrode that will be used is copper electrode. There are three different types of dielectric fluid will be used, namely ~~deionized water,~~ deionized water with carbon nanofiber, deionized water with both carbon nanofiber and surfactant. The surfactant that will be used is Gum Arabic (GA) and polyVinylPyrrolidone (PVP) ~~PolyVinylPyrrolidone (PVP) and Gum Arabic (GA)~~. Some parameter involve to conduct this experiment are voltage (V), peak current, pulse on time (μ sec) and pulse off time (μ sec). The output variables are ~~white layer (recast layer), surface topography, heat affected zone on stainless steel, surface hardness, roughness, and surface topography, and recast layer on machine surface.~~ of machined surface.

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CHAPTER 2

LITERATURE REVIEW

Literature review is used as a reference, to give information and guide based on the journal, book and other sources on the internet. Some issues will be explained in this chapter according to the title of effect of surfactant on the surface integrity of stainless steel using EDM.

2.1 Electro Discharge Machining

According to Kumar et al. (2015), electrical discharge machining (EDM) is a non-traditional machining that controlled by a metal removal process that usually used as cutting tool to cut (erode) the hard work piece to produce the desired shape of product. The metal-removal process is the process where it applies pulsating (ON/OFF) electrical charge of high frequency of current through the electrode to the work piece.

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Khan et al. (2014) claims that removing material primarily turns to electrical energy into thermal energy through a series of spark between work piece and electrode in a dielectric fluid. The thermal electric is consumed by generating high plasma eroding the material.

EDM is a process whereas it used to evacuate the metal through the action of an electric discharge in short duration and also high current density between the work piece and tool. EDM can machine the hardened material into simple intricate shapes that is difficult to be machined using conventional cutting tool. In EDM the electric spark is set up between work pieces and cutting tool that separated by dielectric fluid that usually flowing through a small gap (Lee et al., 2003).

The dielectric fluid with pressure flow sideways over the metal through the gap between the electrode and work piece, thus dielectric fluid will take away the debris of solidified melted metal (Vinoth et al., 2015).

Based on Bergaley et al. (2013), EDM is a procedure to make the holes, external shapes, profiles or cavities in presences of electrically conductive work piece by methods for the controlled use of high-frequency of electrical discharges to vaporize the work piece material in specifically area. That means it should control pulse of direct current that occur between work piece also known as anode and electrode which is cathode (Habib, 2009).

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2.2 Principle of EDM

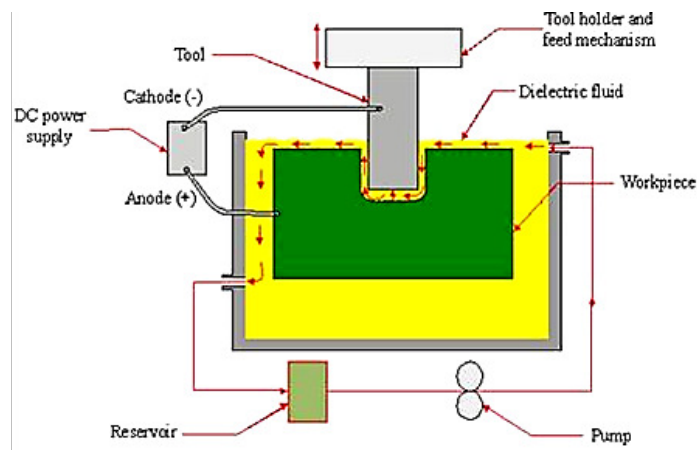


Figure 2.1 : EDM process (Mohd Abbas *et al.*, 2007)

Figure 2.1 shows the electro discharge machining (EDM). In EDM, a potential difference is connected between the tool and work piece. Both the tool and the work piece are to be a conductor of electricity and are immersed in dielectric medium such as kerosene or deionized water. The gap between tool and work piece are maintained. Depending upon connected between potential difference and the gap between work piece and tool, an electric field would build up. Usually the tool is connected to the negative terminal and work piece is connected to the positive terminal (Moarrefzadeh, 2012).

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Vinoth et al. (2015) state that, no physical contact between the electrode and the work piece in the material removal process. In case if there are contacts between work piece and electrode sparkling will stop, the material will not remove. Thus, the basic principle of EDM is that only one spark occurs at a time.

In EDM operation, a high voltage is connected over the limited hole between the electrode and the work piece. The high voltage induces an electric field in the insulating dielectric that is available in the narrow gap between electrode and work piece. This reason directing particles suspended in the dielectric to a mass at the purposes of the most grounded electrical field. At the point potential difference between the electrodes a work piece is adequately high, the dielectric breaks down and a transient spark discharges through the dielectric fluid evacuating little of measure of material from the work piece surface (Sivaroa, 2014).

The dielectric or flushing liquid also known as ionized during course of the discharge. During positive charge ions strike the cathode, the temperature rises up so high. It cause material melt or vaporised formed tiny drops of molten metal which are flushed out as “chipping” into dielectric (Jahan et al., Wong, & Rahman, 2012).

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2.2.1 EDM Process Advantages and Disadvantages

Advantages:

The advantages of EDM are:

1. Cavities with thin walls and fines structures are possible to machine because there is no contact between electrode and work piece hard geometry in general in possible to machine
2. Although the removal rate is related to the melting point of the metal being machining, the use of electrical discharge machining is not affected by the hardness of the work.
3. Electrical discharge machining is burr free.

Limitation:

The main limitation of EDM:

1. This procedure can be just being utilized in electrically conductive materials;
2. Material removal rate is low and the procedure general is moderate contrasted with conventional machining procedures;
3. Unwanted erosion and over cutting of material can happen;
4. Rough surface finish when at high rates of material removal.

(Sivarao, 2004)

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2.3 Parameter of EDM

2.3.1 Pulse On Time

According to Singh et al. (2012), pulse on time is the time during the machining procedure. It can control the machining has become faster while the pulse on time is increasing.

The white layer thickness is mostly controlled by the pulse on duration, and that it increments pulse on duration increments, and if cracks appears they would be micro-cracks and exist in the white layer (WL); beginning at its surface and going down oppositely towards the parental material (Lee et al., 2013).

When pulse on time increase, the discharge energy of the plasma channel and the period of transferring of this energy into the electrodes increase. This phenomenon leads to the formation of a bigger molten material crater on the workpiece which results in a higher surface roughness (Dastagiri & Kumar, 2014).

2.3.2 Pulse Off Time

Singh et al. (2012) claims that, a pulse off time defined as a time which re-ionization of the dielectric fluid takes place. An insufficient off time leads the uneven cycling and retraction of the advancing of servo by slowing down the process. Pulse off time also known as the time required to returns of insulation in working gap or deionization of dielectric fluid in the discharge duration. At the point when pulse off time is short, it will bring about the probability of arcing is high because of dielectric in the gap between work piece and electrode can't be flushed away appropriately regardless it remain a release crevice (Li et al., 2008).

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2.3.3 Voltage

Kumar et al. (2014) claim that when the voltage increases spark also increase, and because of this, bigger however shallower craters are trapped at higher voltage because of expansion of the plasma divert in the release whole.

When the pulse voltage is removed, the super-heated molten cavities explode roughly into the dielectric fluid and cool quickly. Dielectric fluid between electrode gaps twirled because of forced vortex made by the rotating tool electrodes. The debris created after releasing took after the streamlines of the vortex inside of the between electrode gap just before solidification, possibly having sufficiently high temperatures to integrate with one another and the tool electrode (Ekmekci et al., 2013).

Wu et al. (2009) stated that the distinctive in the middle of electrode and workpiece gets to be bigger when a more drawn out crossing over time of neutrals particles and ions is brought on by the increment of gap voltage. The electrical release period likewise turns out to be longer, decreasing the effectiveness of EDM. The electrical discharge period also becomes longer, reducing the efficiency of EDM.

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2.3.4 Peak Current

Peak current is the amount of current which flows during the on time. High peak current will produce rough surfaces. Low peak current will create a fine finish surface (Mohd Abbas et al., 2007).

The high pulsed current brought about frequent cracking of dielectric fluid, creating more melt expulsions and bigger tensile stresses. These impacts brought about poor surface finish. At higher peak current, the effect of discharge energy on the surface

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of work piece gets to be more noteworthy and the resulting erosion leads to the higher in deterioration of surface roughness (Khan et al., 2014).

Lee et al. (2003) said that machined work piece surface composition got to be rowdy as the top stream is high. It has additionally been watched that the profundity likewise been watched that the profundity of the harmed layer and the normal length, width and number of small scale splits increment with the crest current and heartbeat span. The harmed layer and miniaturized scale splits appear to vanish when the peak current and pulse duration are set at low levels.

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2.4 Material of EDM

2.4.1 Stainless Steel

Stainless steel is chosen as the work piece material. Stainless steel varies from carbon steel by the measure of chromium present. Carbon steel rusts when presented to air and humidity. This iron oxide film (the rust) is dynamic and quickens erosion by framing more iron oxide. Stainless steels contain adequate chromium to frame an aloof film of chromium oxide, which averts further surface consumption and squares erosion from spreading into the metal's interior structure. Stainless steel has a variety of uses, for example, in structural engineering, building and constructions and so on. As well, it also has common applications likes roofing, signage, curtain wall support and guttering. Stainless steel rebar is used in bridges, barrier walls and decking to extend the life of critical areas of roadways and marine structures, food and beverage industry, transportation, chemical, petrochemical, oil and gas, pulp and paper industries, and power generation (William and David , 2014).

Stainless steel is selected as engineering materials due to of their excellent corrosion resistance in environments. The corrosion resistance of stainless steel is due to high chromium contents. Austenitic stainless steel has better corrosion resistance than ferritic and martensitic stainless steel (Smith and Hashemi, 2006).

Liu and Gao, (2003) found that , when using stainless steel as workpiece , efficiency of the ultrasonic micro EDM is eight time greater compare to micro EDM.

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