SURFACE INTEGRITY OF MILD STEEL IN DIE-SINKING ELECTRICAL DISCHARGE MACHINE (EDM)

MUHAMAD HANIFFAH BIN GHAFAR

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

Faculty of Mechanical Engineering
University Malaysia Pahang

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UNIVERSITI MALAYSIA PAHANG

FACULTY OF MECHANICAL ENGINEERING

I certify that the project entitled "*Surface integrity of mild steel in Electrical Discharge machine (EDM)"*is written by *Muhamad Haniffah bin Ghafar*. I have examined the final copy of this project and in our opinion; it is fully adequate in terms of scope and quality for the award of the degree of Bachelor of Engineering. I here with recommend that it be accepted in partial fulfilment of the requirements for the degree of Bachelor of Mechanical Engineering with Manufacturing Engineering.

En Akhtar Razul Razali ....

Examiner Signature

SUPERVISOR'S DECLARATION

We hereby declare that we have checked this project report 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 Engineering.

Signature : ....
Name of Supervisor : Mr. Mohamed Reza Zalani Mohamed Suffian
Position : Supervisor
Date : 6 DECEMBER 2010

STUDENT'S DECLARATION

I declare that the work in this thesis entitled surface integrity of mild steel in Die-sinking Electrical Discharge Machining (EDM) is the works of my own project accept as cited in references. The thesis has not been accepted for any degree and is not concurrently submitted for award o other degree.

Signature : ………………………….

Name : Muhamad Haniffah bin Ghafar

ID Number : ME07016

Date : 3 November 2010

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ABSTRACT

A comprehensive study of the surface integrity of the machined workpiece in the electrical discharge machining (EDM) of mild steel (AISI 1020) is presented in this thesis. Copper Electrode was used as a tools in this research. EDM is a thermal process that uses spark discharge to erode electrically conductive materials, it's primarily used for hard metals that very difficult to machine with traditional techniques. EDM tests on a mild steel workpiece were conducted on a sodick AQ55L (ATC) EDM Die-Sinking Machine. The surface Roughness tester Series Mahrsurf XR 20 is used to measure Ra and the surface microstructure was examined with a metallurgical microscopes. The EDM machining parameters those were used were peak current, IP (9A and 18A), discharge voltage (90V and 120V), servo voltage, SV (20V and 60V), pulse on-time (100µs and 300µs) and pulse off-time (500µs and 700µs). The full factorial design of experiment (DOE) from STATISTICA software was used to generate the arrangement of the experiment parameter and the software was used to analyze the effect of each parameter on the machining characteristics. From the analyzed result, peak current, IP and the pulse on-time have significant effect to the Surface Roughness, Ra. The lower values of these two parameters the lower Surface roughness, Ra observed. From the observation on the metallurgical microscopes, it is found there are clearly EDM damaged layer on the workpiece, distinguished by the width and length of microcrack and craters, especially at high peak current, IP and pulse on-time. The surface roughness, damaged layer and micro-cracks seem to decrease when the peak current and pulse on-time were set at very low values.

ABSTRAK

Sebuah kajian menyeluruh integriti permukaan benda kerja iaitu mild steel (AISI 1020) menggunakan Electik nyahcas mesin (EDM) disediakn dalam tesis ini. Elektroda Tembaga digunakan sebagai alat pemotong dalam kajian ini. EDM adalah proses thermal yang menggunakan percikan pembuangan untuk mengikis bahan konduktif secara elektrik, ini terutama digunakan untuk logam keras yang sangat sulit untuk mesin dengan teknik tradisional. Ujian EDM pada benda kerja dilakukan pada Machine Die-Sinking sodick AQ55L (ATC) EDM. Para Kekasaran permukaan tester Seri Mahrsurf 20 XR digunakan untuk mengukur Ra dan struktur mikro permukaan diperiksa dengan mikroskop metalurgi. Parameter pemesinan EDM yang dipilih arus puncak, IP (9A dan 18A), voltan nyahcas (90V dan 120V), voltan servo, SV (20V dan 60V), tempoh hidup denyutan (100µs dan 300µs) dan tempoh mati denyutan (500µs dan 700µs). Rancangan faktorial lengkap eksperimen (DOE) daripada perisian STATISTICA digunakan untuk menghasilkan susunan parameter percubaan dan perisian yang digunakan untuk menganalisis pengaruh setiap parameter pada ciri-ciri pemesinan. Dari hasil analisis oleh perisian Statistica, menunjukkan bahawa puncak Lancar, IP dan Pulse On-waktu berpengaruh signifikan terhadap Kekasaran Permukaan, Ra. Hal ini dapat diamati, nilai-nilai yang lebih rendah daripada dua parameter ini, kekasaran permukaan yang lebih rendah, Ra akan didapati. Dari pengamatan di mikroskop metalurgi, ditemui ada jelas lapisan rosak EDM pada benda yang dikerjakan, dibezakan dengan lebar dan panjang microcrack dan kawah, terutama pada quality Puncak Lancar, IP dan Pulse On-bila masa. Kekasaran permukaan, lapisan rosak dan mikro-retak nampaknya menurun ketika puncak arus dan tempoh denyutan hidup yang ditetapkan dengan nilai yang sangat rendah.

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LIST OF SYMBOLS

MRR	Material Removal Rate
IP	Peak Current
SV	Servo Voltage
t_i	Pulse On-time
t_o	Pulse Off-time
Ra	Coefficient for Surface Roughness
SS	Statistical Significant
df	Degree of Freedom
p	probability
F	Function

LIST OF ABBREVIATIONS

EDM	Electrical Discharge Machine
HAZ	Heat Affected Zone
CNC	Computer Numerical Control
NC	Numerical Control
AISI	American Iron and Steel Institute
DOE	Design of Experiment
ANOVA	Analysis of Variance

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

S.H.Lee et al. state that Electrical discharge machining, commonly known as EDM, is a process that is used to removed metal through the action of an electrical discharge of short duration and high current density between the tool and the workpiece. There are no physical cutting forces between the tool and the workpiece. This machining process is continually finding further applications in the metal machining industry. It is being used extensively in the plastic industry to produce cavities of almost any shape in the metal moulds. 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 and toughness. The machine used in this study is a sodick AQ55L (ATC) EDM machine and material used is AISI 1020 grade mild steel.

1.2 IMPORTANCE OF RESEARCH

The importance of this research is stated below:

1. Improve the surface finish quality of the metal that being cut by Electrical discharge machine (EDM).
2. To find the parameter that might be the main factor of defect during cutting by EDM.
3. To improve the surface finish especially for dies and mould for plastic industries application.

1.3 PROBLEM STATEMENT

EDM machines process operation are based on cutting the workpiece or material without any contact or stress subjected to the workpiece. From this operation, the workpiece not have any effect on the microstructure of the bulk workpiece material. From the EDM process, the problem that maybe observed is on the surface of the workpiece. Criterions those are observed and reduced by EDM machine process are:

1. Damaged layer of the workpiece.
2. Number of grains and microcracks.
3. Large craters on the workpiece.
4. The workpiece surface roughness.

All of the problems above occurred when the current and pulse durations of EDM parameters increase. The difference between craters and microcracks are stated below:

1. Craters are shallow depression.
2. Microcracks are cracks that require a magnification of 10x or higher to be seen by the naked eye. Cracks might be occurring at external or internal of material (S.Kalpakjian, 2006).

1.4 OBJECTIVE OF THE RESEARCH

The objectives of this project are stated below:

1. To evaluate the microstructure defect of mild steel operated by Die-sinking Electrical-discharge machine (EDM).
2. To analyze the surface roughness of mild steel when perform on various parameters machining.
3. To find the optimum parameters machining for reduce the defect of the layer surface for quality surface finish.

1.5 SCOPE OF THE PROJECT

Scope of this research is based on objectives that had been notified before and there are several scopes that will be carrying out with the result of this research:

1. Evaluate the microstructure defect of the mild steel (AISI 1020), the defect damaged layer, microcracks and craters observed by using the metallurgy microscope.

2. The surface quality that was investigated in this experiment was surface roughness using the perthometer machine.

3. Determine the major factor of parameter that influences the defect on the surface workpiece using the STATISTICA software.

4. Find the optimum machining parameter of EDM by using the STATISTICA software.

1.6 PROJECT FLOW CHART

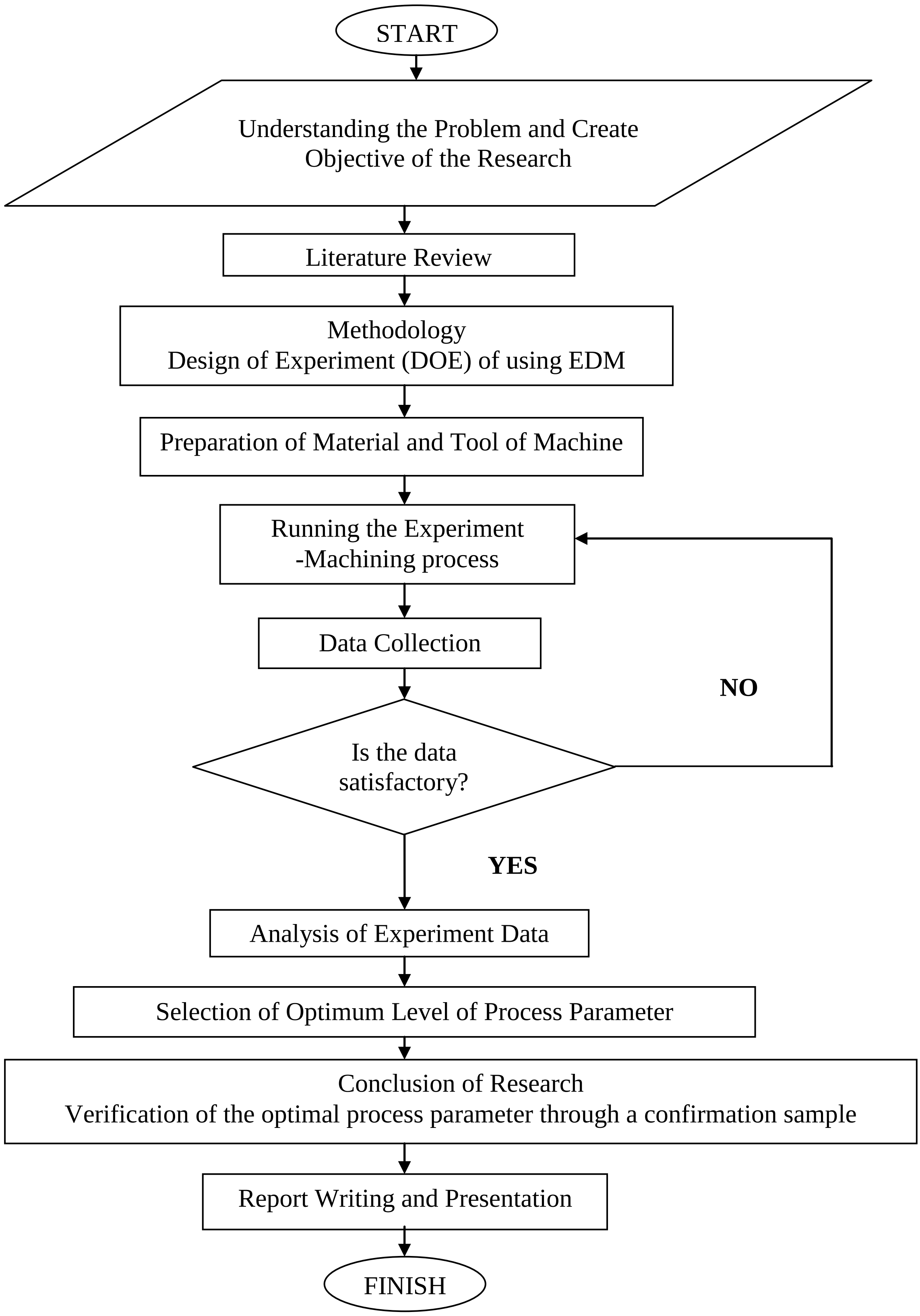

Figure 1.1: Project Flow Chart

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The origin of electrical discharge machining (EDM) dates back to 1770 when English scientist Joseph Priestly discovered the erosive effect of electrical discharges. During the 1930s, attemptswere made for the first time tomachine metals and diamonds with electrical discharges. Erosion was caused by intermittent arc discharges occuring in air between the tool electrode and workpiece connected to a DC power supply. These processes were not very precise due to overheating of the machining area and may be defined as “arc machining” rather than “spark machining” (S.Kumar, 2009).

The basic process in EDM is carried out by producing controlled electric sparks between a tool (electrode) and the workpiece, both of which are immersed in a dielectric fluid. The electric spark raises the surface temperature of both the electrode and workpiece to a point where the surface temperatures are in excess of the melting or even boiling points of the substances. Metal is thus primarily removed in the liquid and vapour phases (C.H. Che Haron, 2001).

The EDM machines are divide by two types which is Die-sinking EDM and the Wire-cutting EDM but for this study has covered the die- sinking EDM machined. It is being used extensively in the plastic industry to produce cavities of almost any shaped in metal moulds. Besides make the cavities of mould, it also widely used for production of dies for forging, extrusion, die casting and injection moulding. Example of production parts, especially in the aerospace, automobile and electronic industries. Other applications include deep, small diameter holes using tungsten wire as the electrode, narrow slots in parts cooling holes in superalloy turbine blades, and various intricate shapes also can perform by the EDM machine (S.Kalpakjian, 2006). From explanation above, there are some of advantages of EDM machining:

(i) May produce a complex shape that is difficult to be produced with conventional cutting tool.
(ii) No direct contact between the tool and workpiece. Therefore, delicate sections and weak material can be machined without any distortion and burrless.
(iii) May operate very small workpiece without any damage cause of excessive cutting tool pressure.
(iv) Also may operate on the extremely hard material to very close tolerance and have high accuracy of cutting (G.F.Benedict, 1987).

2.2 SURFACE INTEGRITY

Surface integrity is describes about the topological (geometric) features of surfaces, physical and chemical properties, mechanical and metallurgical properties and their characteristics. Surface integrity is an important consideration in manufacturing operations, because it influences such properties as fatigue strength, resistance to corrosion, and services life, which are strongly influenced by the nature of the surface produced (S.Kalpakjian, 2006).

Several surface defects caused by and produced during component manufacturing can be responsible for inadequate surface integrity. These defect usally are caused by a combination factor, such as (a) defect in the original material, (b) the method by which the surfaces is produced, and (c) the lack of proper control of the process parameter (ex: can result in excessive temperature for this study).

The following is general definition of a major surface defects on the EDM process:

(i) Crack may be external or internal; cracks that require a magnification of 10X or higher to be seen by the naked eye are called microcracks.
(ii) Craters are shallow depressions.

(iii) Metallurgical transformation involve microstructural changes caused by temperature cycling the material; these may consist of phase transformations, recrystallization, alloy depletation, decarburization, and molten and then recast, resolidified, or redeposited material (S.Kalpakjian, 2006).

The EDM process changes not only the surface of the workpiece metal, but also the subsurface. Three layers are created on top of the unaffected workpiece metal. The spattered EDM surface layer is created when expelled molten metal and small amounts of electrode material form spheres and spatter the surface of the workpiece. This spattered material is easily removed. The next layer is the recast (white) layer. The action of EDM has actually altered the metallurgical structure and characteristics in the recast layer. This layer is formed by the un-expelled molten metal solidifying in the crater (S.Kumar, 2009).

The molten metal is rapidly quenched by the dielectric. If this layer is too thick or is not reduced or removed by polishing, the effects of this layer can cause premature failure of the part in some applications. The last layer is the heat-affected zone (HAZ) or annealed layer, which has only been heated, not melted. The depth of the recast layer and the heat-affected zone is determined by the heat sinking ability of the material and the power used for the cut. This altered metal zone influences the quality of the surface integrity (S.Kumar, 2009). Figure 2.1 below show the surface layer of workpiece after EDM machining process.

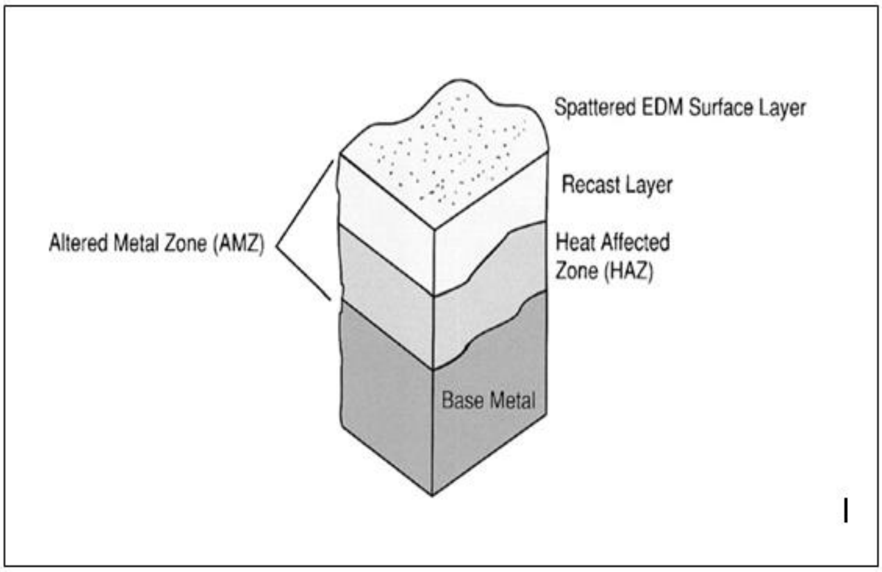

Figure 2.1: Surface Layers after Electrical Discharge Machining
Source: S.Kumar, 2009

2.3 ELECTRICAL DISCHARGE MACHINE (EDM)-DIE SINKING

Electrical discharge machining (EDM) process also known as nontraditional processes are defined as the process where the tool does not contacts the workpiece, it also referred to as spark machining, spark eroding, burning, die-sinking or wire erosion, is a manufacturing process to make the profile shape of an object (workpiece) is obtained using electrical discharges (spark). The material removal from the workpiece occurs by a series of rapidly recurring current discharges between two electrodes, separated by a dielectric liquid and subject to an electric voltage. One of the electrodes is called tool-electrode (tool or electrode) and the other one is called workpiece-electrode (workpiece).

2.3.1 Principle of Operation

The principle of electrical-discharge machining (EDM) is based on the erosion of metals by spark discharges. It also called electrodischarge or spark erosion machining. The basic EDM system consists of a shaped tool (electrode) and the workpiece connected to a DC power supply and placed in a die-electric fluid (electrically non-conducting). The power supply generates an electrical potential between two parts (S.Kalpakjian, 2006).

The electrode and workpiece are positioned in such away that a small gap is maintained between the two. To provide a controlled amount of electrical resistance in the gap, an insulating (dielectric) fluid is flooded between the electrode and workpiece. When pulse electricity is delivered to the electrode and the workpiece, an intense electrical field is created at the point where surfaces provide the narrowest gap. As the result of this field, naturally occuring microscopic contaminants suspended in the dielectric fluid begin to migrate and concentrate at the strongest point in this field. Simultaneously, negatively charged are emitted from the workpiece are emitted from the workpiece. Together these contaminants and particles result in the formation of high-conductivity bridge across the gap (G.F.Benedict, 1987).

As the voltage between the electrode and the workpiece increases at the beginning of the pulse, the temperature of the material making up the conductive bridge increases. A small portion of the dielectric and charged particles in conductive bridge vaporized and ionized resulting the formation of a spark channel between the two surfaces. When the potential difference between the tool and the workpiece is sufficiently high, the die-electric breaks down and a transient spark discharge through the fluid, removing a very small amount of metal from the workpiece surface (S.Kalpakjian, 2006).