FULL FACTORIAL AND EXPERIMENTAL INVESTIGATION ON SURFACE INTEGRITY OF STAINLESS STEEL IN WEDM OPERATION

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the requirements for the award of the degree of
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SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project and in my opinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering with Manufacturing Engineering.

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STUDENT'S DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

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Special thanks to my parents on their support and cares,

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ABSTRACT

Surface integrity generally can be described by its topological, mechanical, and metallurgical. Since the defects produced from different machining can affect the performance of component, experiments always will be conducted to understand the effect of changing operating parameters before new machining strategies are accepted. In this study, surface integrity was characterized by surface roughness and microhardness of stainless steel 304. The objectives of the project are investigating wire cut EDM parameters effect on surface roughness, and microhardness of stainless steel. Five cutting parameters selected to study their effects on surface integrity which are wire speed, wire tension, on time, off time, and peak current. The results show the relationship between parameters and surface roughness, and parameters and microhardness. The graph is being plotted using Minitab.

ABSTRAK

Permukaan integriti secara umum dapat dijelaskan oleh topologi, mekanik dan metalurgi. Kerana kecacatan yang dihasilkan dari mesin yang berbeza boleh mempengaruhi prestasi komponen, percubaan akan selalu dilakukan untuk mengetahui pengaruh perubahan parameter sebelum strategi mesin baru diterima. Dalam kajian ini, integriti permukaan ditandai dengan kekasaran permukaan dan microhardness dari stainless steel 304. Tujuan projek ini adalah untuk menyiasat kesan EDM parameter iaitu kekasaran permukaan, kekerasan dan struktur permukaan stainless steel. Lima parameter dipilih untuk mempelajari pengaruh mereka pada permukaan integriti iaitu kelajuan wayar, ketegangan wayar, masa wayar aktif, masa wayar tidak aktif, dan masa maksimum. Keputusan analisis menunjukkan hubungan antara parameter dengan kekasaran permukaan, dan parameter dengan kekerasan permukaan. Graf akan dilukis menggunakan Minitab.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

In statistics, a full factorial experiment is an experiment whose design consists of two or more factors, each with discrete possible values or "levels", and whose experimental units take on all possible combinations of these levels across all such factors. A full factorial design may also be called a fully-crossed design. Such an experiment allows studying the effect of each factor on the response variable, as well as the effects of interactions between factors on the response variable.

Using this full factorial, we will investigate surface integrity of Stainless steel 304. Stainless steel is defined as a steel alloy with a minimum of 10.5 or 11% chromium content by mass. Stainless steel does not stain, corrode, or rust as easily as ordinary steel, but it is not stain-proof. It is also called corrosion-resistant steel or CRES when the alloy type and grade are not detailed, particularly in the aviation industry. There are different grades and surface finishes of stainless steel to suit the environment to which the material will be subjected in its lifetime. Stainless steel is used where both the properties of steel and resistance to corrosion are required.

Specialized test were conducted to characterize surface integrity of this material such as surface texture (roughness and lay), macrostructure (macrocracks and surface defects), microstructure (microcracks and plastic deformation), and microhardness. Surface integrity is the nature of the surface condition of workpiece after manufacturing processes. It can also be defined as the unimpaired or enhanced surface condition of a component or specimen which influences its performance.

The machine that will used in this project is EDM which is sometimes called "spark machining" because it removes metal by producing a rapid series of repetitive electrical discharges. These electrical discharges are passed between an electrode and the piece of metal being machined. The small amount of material that is removed from the workpiece is flushed away with a continuously flowing fluid. The repetitive discharges create a set of successively deeper craters in the work piece until the final shape is produced. There are two primary EDM methods: ram EDM and wire EDM. In a typical ram EDM application, a graphite electrode is machined with traditional tools. In wire EDM a very thin wire serves as the electrode.

1.2 PROJECT BACKGROUND

Surface integrity is the nature of the surface condition of workpiece after manufacturing processes. It can also be defined as the unimpaired or 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), macrostructure (macrocracks and surface defects), and microhardness. In this project, the focus will be on surface roughness and microhardness test.

Stainless steel is defined as a steel alloy with a minimum of 10.5 or 11% chromium content by mass. Stainless steel does not stain, corrode, or rust as easily as ordinary steel, but it is not stain-proof. It is also called corrosion-resistant steel or CRES when the alloy type and grade are not detailed, particularly in the aviation industry. There are different grades and surface finishes of stainless steel to suit the environment to which the material will be subjected in its lifetime. Stainless steel is used where both the properties of steel and resistance to corrosion are required.

There are several factors should be seen to machined surface integrity which is wire speed, wire tension, tool wear, tool materials and geometry. That is why researchers from many institutions will run experiments to determine which factors contribute in good performance of stainless steel.

1.3 PROBLEM STATEMENT

Some people may ask what is the important of surface integrity that need to make a research on surface integrity. The answer is because the extent of the defects depends on the interactions of the mechanical and thermal energy produced on the workpiece material properties. The defects produced from different machining procedures can significantly affect the performance component. Therefore, it is critical for industries to know and understand the effects of changing operating parameters before new machining strategies are accepted.

1.4 PROJECT OBJECTIVES

The objectives of the project are:

1. Investigating EDM parameters effect on surface roughness of stainless steel 304.
2. Investigating EDM parameters effect on microhardness of stainless steel 304.

1.5 SCOPE OF PROJECT

The purpose of this project is to determine the surface integrity of stainless steel 304. Surface integrity is included surface roughness, and surface hardness. The machine used to cut the material is wire-cut Electrical Discharge Machining (EDM). Surface integrity characterizations conducted where surface roughness measured using a perthometer or stylus profiler machine, and micorhardness measured using Vickers Hardness test.

1.6 SUMMARY

From this chapter 1, the background of the study has known. The next chapter will put several literature of the scope of the project in order to achieve the objectives for this project

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter will review some literature about metal cutting process focused on Electrical Discharge Machining operation. In machining operation, some information about cutting tool and cutting condition is included. Several overviews about characterization on surface integrity also provided to get some view about the project.

2.2 METAL CUTTING OPERATION

Metal cutting operations form the basis of manufacturing processes. Final products are often made by machining primary shapes to size. The study of metal cutting is of vital importance and forms the basis of the scientific approach to solving problems of machining. Principles of metal cutting are very helpful in increasing the rate of production in all workshops, for example turning, milling, shaping, planning, broaching, and jig boring.

In all these operations, the components are produced by removing material in the form of chips with the help of a cutting tool. In most operation, a wedge-shaped tool is constrained to move against the workpiece. In orthogonal cutting, the tool moves at right angles to the direction of relative cutting motion between the tool and the workpiece.

2.2.1 EDM machine

EDM (Electrical Discharge Machining) is a non-traditional concept of machining which has widely used to produce dies and molds. It is also used for finishing parts for aerospace and automotive industry and surgical components (Serope Kalpakjian, Steven R. Schmid. 2004). EDM is sometimes called "spark machining" because it removes metal by producing a rapid series of repetitive electrical discharges. These electrical discharges are passed between an electrode and the piece of metal being machined. The small amount of material that is removed from the workpiece is flushed away with a continuously flowing fluid. The repetitive discharges create a set of successively deeper craters in the work piece until the final shape is produced. There are two primary EDM methods: ram EDM and wire EDM. The primary difference between the two involves the electrode that is used to perform the machining.

In a typical **ram EDM** application, a graphite electrode is machined with traditional tools. The now specially-shaped electrode is connected to the power source, attached to a ram, and slowly fed into the workpiece. The entire machining operation is usually performed while submerged in a fluid bath. The fluid serves the following three purposes:

a) flushes material away
b) serves as a coolant to minimize the heat affected zone (thereby preventing potential damage to the workpiece)
c) Act as a conductor for the current to pass between the electrode and the workpiece.

In wire electrical discharge machining (**WEDM**), also known as wire-cut EDM and wire cutting, a thin single-strand metal wire, usually brass, is fed through the workpiece, submerged in a tank of dielectric fluid, typically deionized water (Todd, Allen, Alting. 1994). Wire-cut EDM is typically used to cut plates as thick as 300mm and to make punches, tools, and dies from hard metals that are difficult to machine with other methods. The wire, which is constantly fed from a spool, is held between upper and lower diamond guides (Elman C. Jameson. 2001).

The guides, usually CNC-controlled, move in the *x*–*y* plane. On most machines, the upper guide can also move independently in the *z*–*u*–*v* axis, giving rise to the ability to cut tapered and transitioning shapes (circle on the bottom square at the top for example). The upper guide can control axis movements in *x*–*y*–*u*–*v*–*i*–*j*–*k*–*l*–. This allows the wire-cut EDM to be programmed to cut very intricate and delicate shapes. The upper and lower diamond guides are usually accurate to 0.004 mm, and can have a cutting path or kerf as small as 0.12 mm using Ø 0.1 mm wire, though the average cutting kerf that achieves the best economic cost and machining time is 0.335 mm using Ø 0.25 brass wire. The reason that the cutting width is greater than the width of the wire is because sparking occurs from the sides of the wire to the work piece, causing erosion. This "overcut" is necessary, for many applications it is adequately predictable and therefore can be compensated for (for instance in micro-EDM this is not often the case). Spools of wire are long—an 8 kg spool of 0.25 mm wire is just over 19 kilometers in length. Wire diameter can be as small as 20 micrometres and the geometry precision is not far from +/- 1 micrometre (Elman C. Jameson. 2001).

The wire-cut process uses water as its dielectric fluid, controlling its resistivity and other electrical properties with filters and de-ionizer units. The water flushes the cut debris away from the cutting zone. Flushing is an important factor in determining the maximum feed rate for a given material thickness. Along with tighter tolerances, multiaxis EDM wire-cutting machining center have added features such as multiheads for cutting two parts at the same time, controls for preventing wire breakage, automatic self-threading features in case of wire breakage, and programmable machining strategies to optimize the operation (Todd, Allen, Alting. 1994).

Wire-cutting EDM is commonly used when low residual stresses are desired, because it does not require high cutting forces for removal of material. If the energy/power per pulse is relatively low (as in finishing operations), little change in the mechanical properties of a material is expected due to these low residual stresses, although material that hasn't been stress-relieved can distort in the machining process. The workpiece may undergo a significant thermal cycle, its severity depending on the technological parameters used. Such thermal cycles may cause formation of a recast layer on the part and residual tensile stresses on the workpiece.

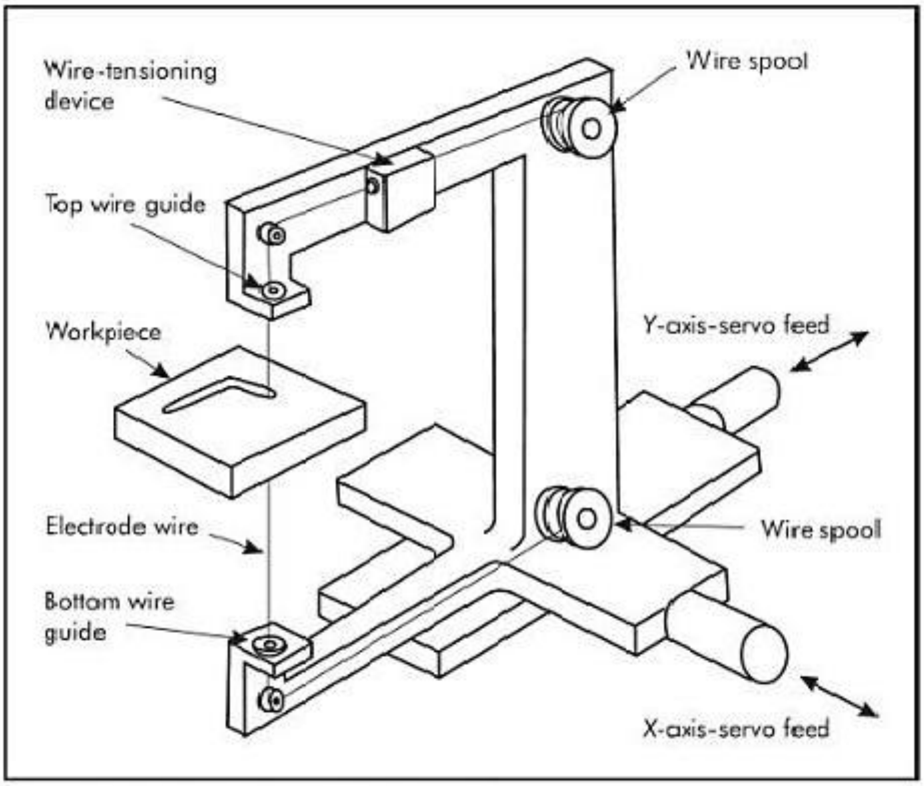

Figure 2.0: Basic wire-cut EDM machine (Elman C. Jameson. 2001)

2.2.2 Workpiece materials

Stainless steel is defined as a steel alloy with a minimum of 10.5 or 11% chromium content by mass. Stainless steel does not stain, corrode, or rust as easily as ordinary steel, but it is not stain-proof. It is also called corrosion-resistant steel or CRES when the alloy type and grade are not detailed, particularly in the aviation industry. There are different grades and surface finishes of stainless steel to suit the environment to which the material will be subjected in its lifetime. Stainless steel is used where both the properties of steel and resistance to corrosion are required (Serope Kalpakjian, Steven R. Schmid. 2004).

Stainless steel differs from carbon steel by the amount of chromium present. Carbon steel rusts when exposed to air and moisture. This iron oxide film (the rust) is active and accelerates corrosion by forming more iron oxide. Stainless steels contain sufficient chromium to form a passive film of chromium oxide, which prevents further surface corrosion and blocks corrosion from spreading into the metal's internal structure.

Stainless steels find use in a very wide variety of applications. Some typical examples are consumer goods, architecture, building & construction. More common applications are balustrades, column wraps, roofing and guttering, signage, curtain wall supports, light poles, elevator doors and public seating. 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 (Material Books. 2001).

2.2.3 Types of wire cut

The main demand of modern manufacturing industry is the development of improved machine tools, cutting tools, and production processes. The cutting tool is one of the important elements of any machining operation.

Different types of tools are used for various type of cutting jobs. Cutting needs vary and making tools for different cutting needs is indeed a tough job. A large variety of tool materials have been developed but none of them is suited to all cutting needs and can be considered superior from all angles. Selection of cutting tool material and geometry of the cutting tool calls for a good knowledge of the material to be machined, production rate required, rigidity of the setup, accuracy and surface finish of the components.

Wire cutting, a thin single-strand metal wire, usually brass has been used in this investigation. It is instead typically used to cut plates as thick as 300mm and to make punches, tools, and dies from hard metals that are too difficult to machine with other methods (Todd, Allen, Alting. 1994).

The electrode in wire-cut EDM is a spool of wire ranging from 0.001 to 0.016 in (0.04 to 0.041mm) diameter and from 2 to 100 lbs. (0.90 to 45.36kg) in weight. The length of wire on a spool can provide over 500 hours of unattended machining time. The electrode of the wire-cut machine travels continuously from a supply spool to a take-up spool so that it is constantly being renewed (Stephen F. Krar, Arthur Gill. 1998).

When this type of electrode is used, the wear on the wire does not affect the accuracy of the cut because new wire is constantly being fed past the workpiece at rates from a fraction of an inch to several inches per minute. Electrode material should have the following characteristics:

a) A good conductor electricity
b) A precision uniform diameter
c) A high melting point
d) A high tensile strength
e) Good thermal conductivity
f) Produce efficient metal removal from the workpiece.

2.3 CUTTING PARAMETERS

Machining has a great many variables to deal with and your best way to understand the do's and don'ts of a given machine are to find out the windows. In any manufacturer of machining, the information for a given type and hardness of a material were provided

2.3.1 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 produce fine finish surface (Mike Lynch, 2001).

2.3.2 Wire speed

Wire speed is the rate at which the wire is passed through the workpiece. Generally, a faster wire speed is used for roughing and a slower wire speed is used for finishing. During roughing, the wire will usually be under influence of a great deal of power (electricity) as material is blown away as quickly as possible. This results in a great deal of pitting on the wire itself and, if taken to extreme, will cause wire breakage. You can relieve much of this pressure by increasing the speed of the wire as it passes through the part.

For, finishing the above-mentioned pressure is nonexistent. For finishing passes, the wire speed can be reduced to conserve wire (Mike Lynch, 2001).

2.3.3 Wire tension

The wire tension is the amount of pulling force applied to the wire as it is driven through its cutting motions. The tension is cause by the amount of restriction that the wire is given by the tension roller at the top of the wire threading area. The pinch rollers just above the wire bin pull the wire from the wire roll at the top of the machine. The tension roller restricts the wire in a way that permits the tension to be adjusted accurately. The wire tension affects how tight the wire is. During roughing operations, it is wise to have a relatively low wire tension to avoid placing undue stress in the wire. For finishing, the wire tension should be quite high to allow a straight wall on the workpiece (Mike Lynch. 2001).

2.3.4 On time

On time currents controls the length of time that electricity is applied to the wire per spark. Depending on the machine-tool builder, there are various techniques to control on time. Usually, there is a series of numbers that specify the various on times available. The lower number, the shorter the on time. As the name implies, on time is used to control the amount of time per spark power is applied to the wire. As the on time is increased, the tendency is toward faster machining. Usually the on time for roughing is higher than the on time for finishing (Mike Lynch, 2001).

2.3.5 Off time

Off time controls the length of time per spark that the electricity is turned off to the wire. Off time is very important because it is during the off time that the particles are flushed away from the machining area. Without off time, the particles will not be flushed and double burning of the particles will occur. Increasing the off time will generally mean slower cutting, but part finish and accuracy are improved (Mike Lynch, 2001).

2.4 SURFACE INTEGRITY

Surface integrity describes not only the topological (geometric) features of surfaces and their physical and chemical properties but their mechanical and metallurgical properties and characteristics as well (Serope Kalpakjian, Steven R. Schmid. 2004). Surface integrity is an important consideration in manufacturing operations because it influences such properties as fatigue strength, resistance to corrosion and service life (Che-Haron, C.H., Jawaid. 2005).

Several surface defects caused by and produced during component manufacturing can be responsible for inadequate surface integrity. These defects usually are caused by a combination of factors such as defects in the original material, the method by which surface is produced, and the lack of proper control of the process parameters.

The major surface defects are (Serope Kalpakjian, Steven R. Schmid. 2004):

a) Crack maybe external or internal; crack require a magnification of 10x or higher to be seen by the by naked eye are called microcrackers.
b) Cracks are shallow depressions.
c) Heat affected zone is the portion of a metal which is subjected to thermal cycling without melting.