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STUDY OF THE SURFACE INTEGRITY OF THE MACHINED WORKPIECE IN THE EDM OF SKD 11 TOOL STEEL

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(Keywords: Electrical Discharge Machining EDM, SKD 11 Tool Steel, Surface Integrity, Design of Experiment)

This paper represented a comprehensive study which investigated the influence of the machining parameters in EDM to the surface topography, composition of the machined surface and surface roughness of SKD 11 tool steel. The selected EDM parameters were peak current (4, 6, 8 and 16A) and pulse on-time (6, 9, 12 and 15μs). EDM tests on SKD 11 tool steel were conducted on a Sodick 3 axis linear AQ35L EDM die sinking machine, with peak current and pulse on-time varied. The electrode used is copper and produced by lathe machining. The EDMed surface topography and composition of the machined surface was examined with a Scanning Electron Microscope (SEM) Evo 50 and Energy Dispersive X-Ray Spectrometer (EDX). Surface roughness was determined with a Portable Surface Roughness Tester. It is observed from the SEM micrographs that the surfaces generally have a matt appearance formed on the EDMed surface. These various factors increased with the increasing of peak current and pulse on-time. There are no cracks being observed on the EDMed surface since the setting of parameters are considered in a small range and the high carbon and chromium contain of SKD 11 tool steel. There are no significant different in composition of the EDMed surface been observed under different EDM condition compared with non-EDM specimen. It was also found that higher values of peak current and pulse on-time increased the surface roughness. Lower peak current and lower pulse on-time produced a better surface finish. Peak current has a major influence in defining the EDM surface topography and composition of the machined surface. Meanwhile, surface roughness greatly affected by the pulse on-time rather than peak current.

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LIST OF ABBREVIATIONS

EDM	-	Electrical Discharge Machining
DC	-	Direct Current
DOE	-	Design of Experiments
SEM	-	Scanning Electron Machining
EDX	-	Energy Dispersive X-Ray Spectrometer
PSM 1	-	Projek Sarjana Muda Satu
PSM 2	-	Projek Sarjana Muda Dua
t_i	-	Pulse On-time
I_p	-	Peak Current
Ra	-	Central Line Average of Surface Roughness

CHAPTER 1

INTRODUCTION

In this chapter, the introduction, background of problems, statement of problems, objective, scope, importance of the study and the expected result in the study were discussed.

1.1 Introduction

Electrical discharge machining (EDM) or it is also called as spark-erosion machining, is a process that is used to removes material with repetitive spark discharges from a pulsating DC power supply, with a dielectric fluid flowing between the tool and the workpiece [1].

The EDM process of erosion using the electrical discharge was developed in 1770 by an English scientist. The Russian scientists B. and N. Lazerenko adopted the principle and developed a process to control the material removal of conductive materials. In 1952, Charmilles Technology Corporation of Geneva, Switzerland was worked together with Mr. Lazarenko to develop the first industrial economical die-sinking EDM machine. The machine has been introduced in Milan, Italy in 1955. Shortly after, the team was developed a surface finish scale that can be achieved on an EDM machine. The development was also adopted by an organization of engineers in German [2].

The EDM process has become popular and widely used in production technologies in manufacturing field. The recent development of EDM has progressed in the industries of plastic technology due to growing application of EDM process and the demand of the human toward the advance technology era. The EDM can perform better than the other machining method since the application of EDM had increased. The new materials which are hard and difficult to machine but widely used in the modern manufacturing industries such as hastalloy, hardened tool-steel, titanium, carbide and etc can easily been carry out in the EDM [3].

In the review research work, various aspects of EDM on different types of workpieces have been done. In this work, a study focused on the surface topography when machining SKD 11 tool steel by die-sinking EDM was carried. The work also examined the influence of the machining peak current and pulse-on time to the surface roughness, surface topography and composition of the machined surface.

1.2 Background of Problems

EDM technology is one of the most advanced technologies since it has many advantages over conventional machining processes. For the conventional machining, the processes run manually by the operators. Sometimes, this affects the quality problem, waste of time, extra manpower, uneconomic and etc. Moreover, the materials that were electrically conductive cannot be cut, even though of its hardness due to rapid the tool wears, cutting speed, current and so on. The surface finish formed was not good enough and it is inability in generating complex shape. Meanwhile, the development of EDM process had solved the criteria problem that occurred. In this work, an investigation of the machining parameters (peak current and pulse-on time) to the surface roughness, surface topography and the composition of the machine surface was carried out.

1.3 Statement of Problem

This research study focused on the following question:

(a) What is the most consequence of machining parameters (peak current and pulse-on time) that influence the surface roughness, surface topography and composition of the machined workpiece surface?

1.4 Objective

The objective of the project was to analyze the influence of peak current and pulse-on time to the surface roughness, surface topography and composition of the SKD 11 tool steel by using copper electrode.

1.5 Scope

This research focused primarily on the surface roughness, surface topography and the composition of the machined surface in the die-sinking EDM by using SKD 11 tool steel. The machining parameters are peak current and pulse-on time. Other responses such as the microstructure, white layer thickness and surface crack density were not covered in this project.

1.6 Important of the Study

Through this study, it helped in investigated the influence of the machining parameters (peak current or pulse-on time) to the surface roughness, surface topography and composition of the machined workpiece (SKD 11) surface. Further, this project helped to minimize various criteria of machined surface integrity for EDM industry.

1.7 Expected Result

The result had shown the effect of operating parameters of EDM on the machined workpiece surface indicated that the peak current and pulse on time had a direct relationship with surface roughness, surface topography and composition of the SKD 11 tool steel by using copper electrode. By applied DOE method on this experiment; the influence of peak current and pulse-on time to the surface roughness; surface topography and composition of the SKD 11 tool steel were investigated.

CHAPTER 2

LITERATURE REVIEW

In this chapter, the theory related to the study was discussed in detail. Moreover, the previous research and study were also summarized.

2.1 EDM

The acronym EDM is derived from Electrical Discharge Machining. EDM is among the earliest non-traditional manufacturing process, having an inception 50 years ago in a simple die-sinking application. Anyone who has ever seen what happens when a bolt of lightening strikes the ground will have a fair idea of the process of EDM. The EDM process we know today started with the observations of Joseph Preistly in 1770. He noticed that electrical discharges had removed material from the electrodes in his experiments. This is also known as electro-discharge erosion (Figure 2.1). In the 1940's, Soviet researchers had developed a machining process, which was formed the foundation for modern EDM [4].

EDM is a non-conventional metal removal machining method that utilizes the use of an electrode to machine the desired shape into a workpiece under carefully controlled conditions. It is a machining method primarily used for hard metals or those that would be impossible to machine with traditional techniques [5]. However, EDM only works with materials that are electrically conductive. Generally, those materials used are ferrous alloys. EDM can cut into small or odd-shaped angles, intricate contours or cavities in prehardened steel without the heat treatment to soften and re-harden them as well as exotic metals such as titanium, hastelloy, kovar, and inconel [6].

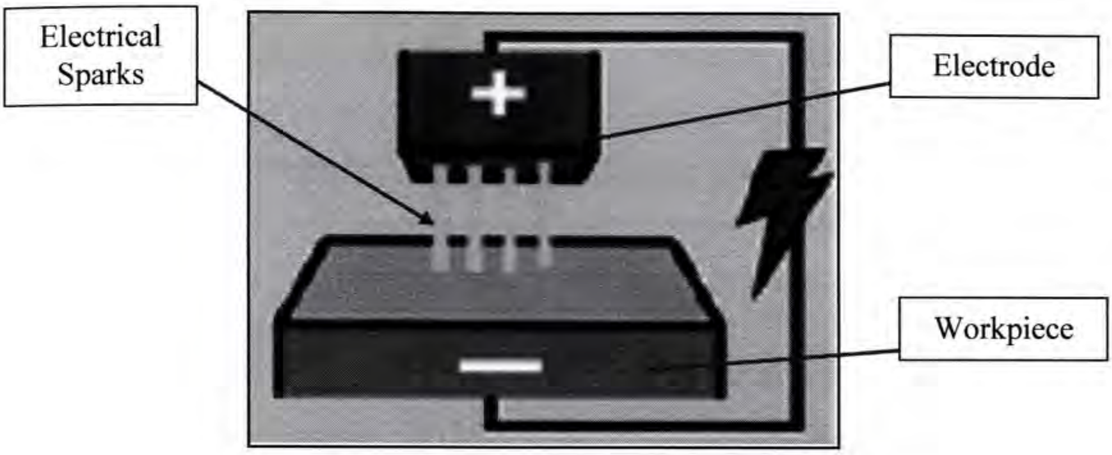

Figure 2.1: Electro-discharge erosion [6].

The EDM system consists of a shape tool or wire electrode, and the part. The part is connected to a power supply. The basic concept of EDM is the machine uses an electrode to erode a workpiece using electrical sparks (Figure 2.1). The electricity flows through the electrode in the form of a square wave attacking the points of least resistance on the workpiece. This "Zap" happens every time the current is switched on the square wave. Then, the current is switched off to allow the debris to be flushed away. This process happens over and over many times a second as the electrode is slowly advanced deeper and deeper into the cut. Actually, the electrode never touches the workpiece because the actual cutting is being done by the spark gap between the electrode and the workpiece.

Sometimes, to create a potential difference between the workpiece and tool, the workpece is immersed in a dielectric (electrically non-conducting) fluid which is circulated to flush away debris. However, the cutting pattern is usually controlled by using the CNC machining. Many EDM machine electrodes can rotate about two to three axis allowing for cutting of internal cavities. This has makes the EDM a highly capable in manufacturing process [7].

2.2 Die-Sinking EDM

It is also known as Sinker EDM, Ram EDM, Vertical EDM and Plunge EDM. The die-sinking process was refined as early as the 1940 with the advent of the pulse generators, planetary and orbital motion techniques, CNC and the adaptive control mechanism. From the vacuum tubes to the transistors and then until the present day solid state circuits, it was not only possible to control the pulse on time but also the pause time or the off time. This made the EDM circuit better, accurate, and dependable, and therefore the EDM industry began to grow [7]. Through sinker EDM, parts can be formed out of even the most rigid materials and formed into very complex shapes.

Sinker EDM is used when parts need tight tolerances or when a tight corner is required. It is a versatile process, allowing for a variety of sized parts from those that can fit in the palm of a hand to parts that weight over 1,000 pounds, and everything in between. Production dies and molds are often made through the sinker EDM process for these reasons as well. Sinker EDM is generally used to produce the blind cavities such as Mobile phone cavities, Speaker grills cavities etc [6].

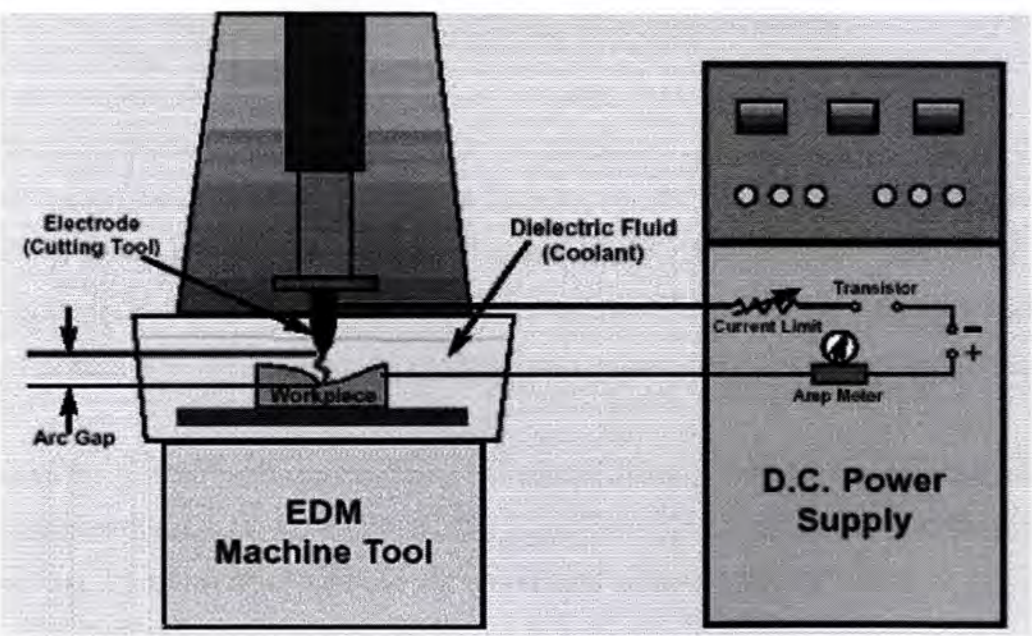

Figure 2.2: Basic EDM System [7].

2.2.1 Principle of Sinker EDM

The illustrations below show the processes that happen during a sinker EDM cycle. The graphs in each the illustrations show the relative values of voltage and current at the point depicted. These represents one EDM cycle that can repeat up to 250,000 times per second. There can be only one cycle occurring at any given time. Once this cycle is identified, the process can start to control the duration and intensity of the on/off pulses to make EDM work for us.

Illustration 1:

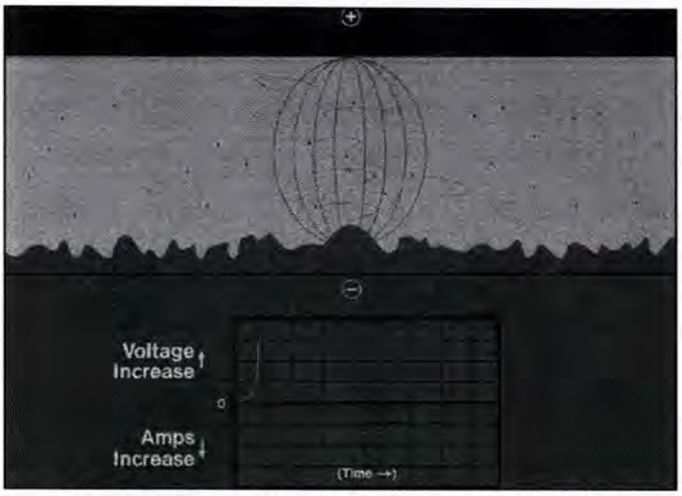

Figure 2.3: The presence of graphite and metallic particles in the fluid [6].

A charged electrode is brought near to the workpiece clamp on the EDM table. The insulating oil which is dielectric fluid is flowed between them. Even though a dielectric fluid is a good insulator, a large enough electrical potential can cause the fluid to break down into ionic (charged) fragments. It allows an electrical current to pass from electrode to the workpiece. The presence of graphite and metallic particles suspended in the fluid can aid this electrical transfer in two ways: the particles (electrical conductors) aid in ionizing the dielectric oil and can carry the charge directly; and the particles can catalyze the electrical breakdown of the fluid. The electrical field is strongest at the point where the distance between the electrode and workpiece is least, such as the high point shown (Figure 2.3). The graph in the illustration shows that the potential (voltage) is increasing, but current is zero.

Illustration 2:

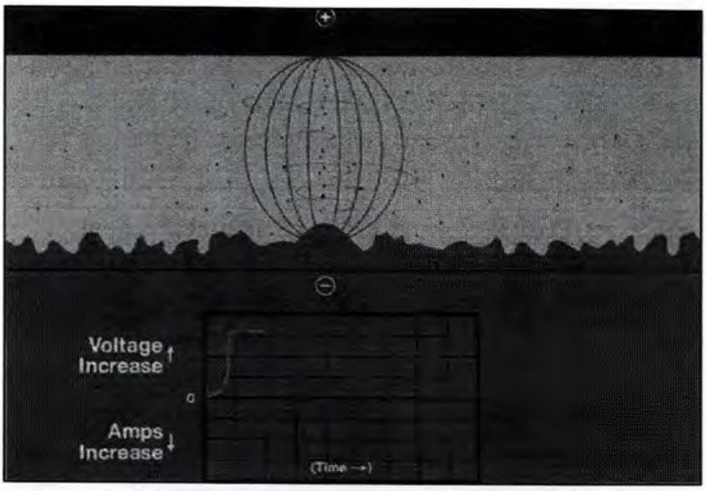

Figure 2.4: Increasing of the number of ionic particles [6].

As the number of ionic (charged) particles increases, the insulating properties of the dielectric fluid begin to decrease along a narrow channel centered in the strongest part of the field. Voltage has reached its peak, but current is still zero (Figure 2.4).

Illustration 3:

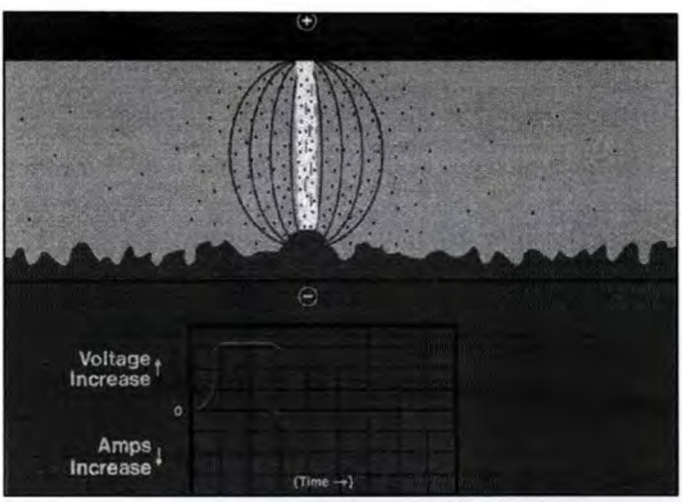

Figure 2.5: Collision happened [6].

A current is established as the fluid becomes less of an insulator, hence collision occurred. The voltage begins to decrease (Figure 2.5).

Illustration 4:

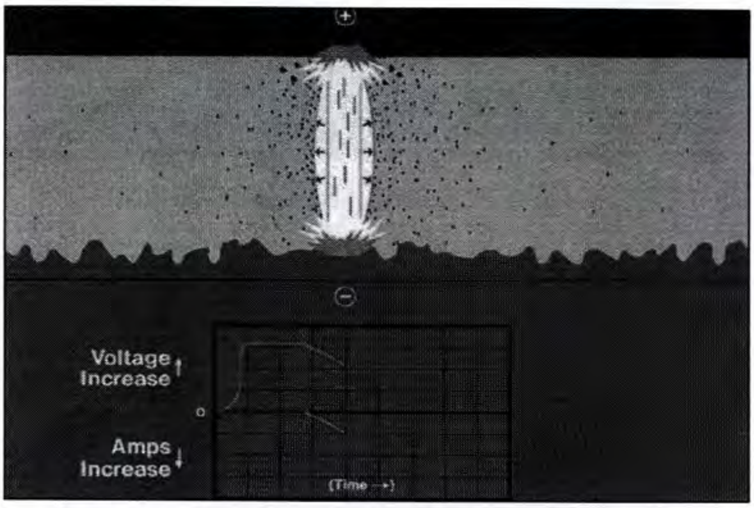

Figure 2.6: Heat generated and discharge channel form [6].

Heat builds up rapidly as current increases and the voltage continues to drop. The heat vaporizes some of the fluid, workpiece and electrode. Then, a discharge channel begins to form between the electrode and workpiece (Figure 2.6).

Illustration 5:

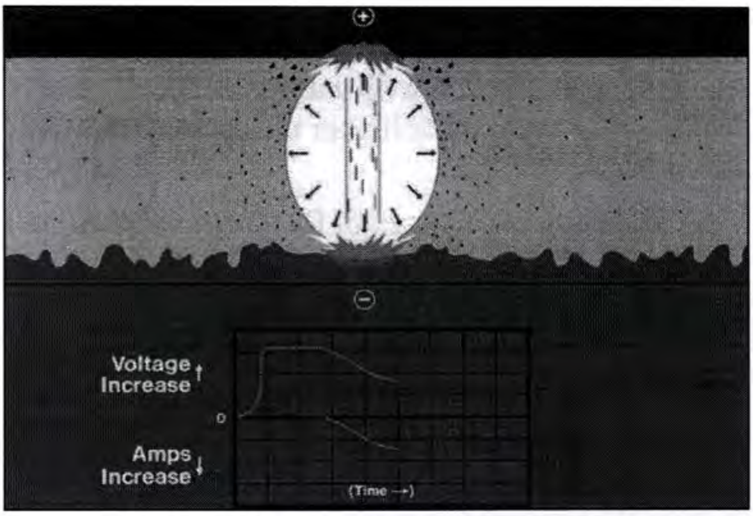

Figure 2.7: Inward expansion of vapor bubble [6].

A vapor bubble tries to expand outward, but its expansion is limited by a rush of ions towards the discharge channel. These ions are attracted by the extremely intense electro-magnetic field that has built up. Current continues to rise; voltage drops (Figure 2.7).

Illustration 6:

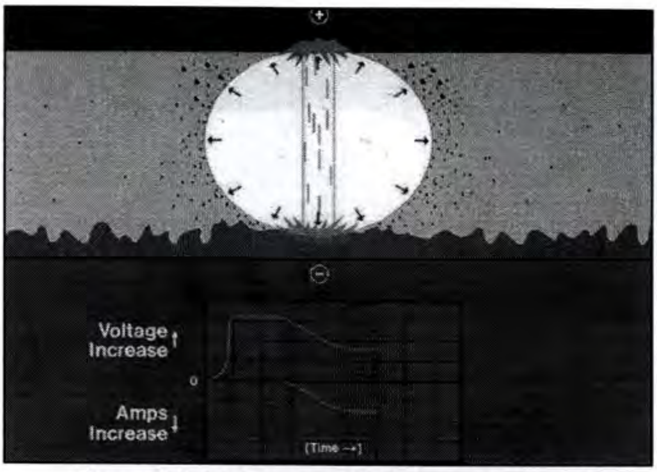

Figure 2.8: Molten state of discharge channel [6].

Near the end of the on-time, current and voltage have stabilized. Heat and pressure within the vapor bubble have reached their maximum and some metal is being removed. The layer of metal directly under the discharge column is in molten state. But it is held in place by the pressure of the vapor bubble. The discharge channel consists now of a superheated plasma made up of vaporized metal, dielectric oil, and carbon with an intense current passing through it (Figure 2.8).

Illustration 7:

Figure 2.9: Vapor bubble collapse [6].

At the beginning of the off-time, current and voltage drop to zero. The temperature decreases rapidly, collapsing the vapor bubble and causing the molten metal to be expelled from the workpiece (Figure 2.9).

Illustration 8:

Figure 2.10: Recast layer formed [6].

Fresh dielectric fluid rushes in, flushing the debris away and quenching the surface of the workpiece. Unexcelled molten metal solidifies to form what is known as the recast layer (Figure 2.10).

Illustration 9:

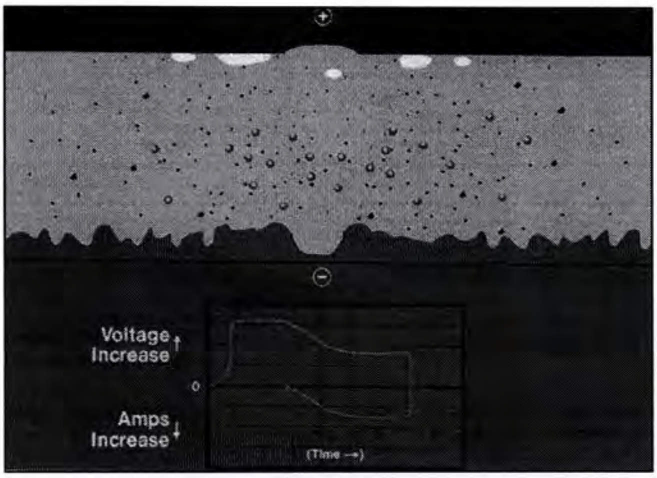

Figure 2.11: Solidification of expelled metal [6].

The expelled metal solidifies into tiny spheres dispersed in the dielectric oil along with bits of carbon from the electrode. The remaining vapor rises to the surface. Without a sufficient off-time, debris would collect making the spark unstable. This situation could create a DC arc which can damage the electrode and the workpiece (Figure 2.11).