The effect of power supply current on recast layer in S45C steel using wire EDM

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Abstract. The purpose of this study is to determine the effect of the power supply current on recast layer on S45C steel cutting using wire EDM. In this research, the process of cutting workpiece used Mitsubishi Wire EDM Machine BA-8. Brass wire electrodes used Ø 0.2 mm and work piece material S45C 22 mm. The workpiece was cut into a circle to get 20 mm diameter with EDM wire machine with current power supply value of 4, 5, 6, 7, and 8 amperes. The results showed that the greater the power supply current used to produce thicker recast layer and the greater the hardness value was. The highest thickness value occurred at 8 Ampere power supply current variance of 35 μm. And the highest hardness value also occurred on the variation of 8 Ampere current power supply of 277.3 VHN.

Keywords: current, cutting, EDM, hardness, recast layer

1. Introduction

Wire EDM is one of the non-conventional machining processes [1]. Producing the quality of a good product in Wire EDM is strongly influenced by several factors. Among others are the type of wire electrode, dielectric fluid, and its machining parameters. Some parameters machinery will include: Pulse On Time (Ton), Pulse Off Time (Toff), Servo Voltage (SV), Wire Feed Rate (WFR), and Wire Tension (WT), Power supply current (IP). The machining parameters are determined based on the type of workpiece material and the magnitude of the engine [2-4]. In the process of Wire EDM, machining conditions (such as tool life, material removal rate) and the achievement of good product quality (such as precision and the surface roughness of the workpiece) determine the success of the process of the EDM Wire [1].

On the surface of the workpiece with Wire EDM, cutting results will always be formed recast layer having different mechanical properties of the base metal [5,6]. This inhomogeneity can be used to obtain harder recast layer compared to the base metal. One of the uses of this layer is for the manufacture gear or shaft products which require a hard surface layer and a tough inner layer so that the process of making these products with Wire EDM can avoid surface hardening process which is usually performed after the cutting process with other machines [7,8]. This provides a shorter production time advantage and more cost savings. In addition to the recast layer, on the workpiece, there also will be formed heat affected zone which is a layer of heat material affected by heat during the process of machinery [1]. The recast layer is the piece of the workpiece (parent material) that melts then freezes again and forms a layer on the surface of the workpiece. Recast layer formed under the influence of heat generated by a spark jumps from wire and colored white [1,8,10]. In the process of cutting with Wire EDM, recast layer is a side effect that can not be avoided. Therefore, to create a product such as a gear or an axle, it is necessary to form a hard recast layer.
To achieve the above, the selection of an effective and efficient machinery process is necessary. The selection includes the setting up and using the parameters that are directly related to the formation of a recast. Power supply current is a part of machining parameters that affect the formation of recast layer. In wire EDM, the power supply current value affects the amount of machining parameters that affect the formation of recast layer. In wire EDM, the power supply current value affects the amount of energy used by the wire to cut the workpiece. With the increase in the amount of energy used to cut the workpiece, the current strength gives a higher amount of heat on the surface. The heat will be absorbed deeper so that the heat affected zone is formed also deepened, resulting recast layer is getting thicker and harder. This study aimed to determine the effect of the power supply current to recast layer on using the S45C steel cutting Wire EDM.

2. Materials and Methods
Workpiece materials SC 45 with chemical compositions (%wt): 0.4 C, 0.23 Si, 0.64 Mn, 0.008P, 0.009 S, 0.06 Cr, 0.03 Cu. Hardness: 160 – 220 HB (160 – 220 VHN). Tensile strength: 569 - 686 Mpa. Metal cutting process used the Wire EDM Mitsubishi BA-8. Material S45C. The parameters used in this study was a power supply current (IP) with variations of 4, 5, 6, 7, 8 Ampere. - Pulse time off used 1μs and Wire tension: 7mm. To find out the results of testing, macro recast the Optical Microscope with Tamron macro lens SD In was conducted. The maximum distance of 90m with a comparison test macro 1: 1. The specimen surface to be photographed was flattened and cleaned with a grit paper mounted on a centrifugal sandpaper machine until smooth and shiny. Rubbing paper used grade 400, 600, 800, and 1000. Data retrieval recast layer thickness at three points for each specimen can be seen in Figure 1.

![Figure 1. Thickness Measurement Area of Recast Layer](image)

Microhardness vickers test was used to measure the hardness of the specimen. Hardness testing was conducted to determine the hardness of the surface due to the recast. The tool used was digital micro Vickers hardness tester TH 712. The test forces used were 0.98N with power source AC 220V / 50 – 60 Hz. After the specimen was completed data collection for recast layer thickness, the specimen was then placed on microhardness vickers hardness tester for testing recast layer by taking five points. Hardness distribution data retrieval recast layer is displayed in Figure 2.

![Figure 2. Hardness Distribution of Recast Layer](image)
3. Results and Discussions

3.1. Recast Layer

Figure 3. Recast layer on current power supply a) 4, b) 5, c) 6, d) 7, e) 8 amperes

From Figure 3, it is known that the value of the recast layer thickness increases with the current power supply value. This is because the power supply current value affects the amount of energy used to cut workpieces wire [7,10]. The increase in the amount of energy used to cut the workpiece gives a higher amount of heat on the surface so that the layer below will undergo a phase change and chemical composition. The thickness of this layer depends on the pulse energy and the duration of the pulse energy [7]. Increasing the pulse current value will boost the pulse energy. The heat will be absorbed more deeply so the heat affected zone is also formed deeper [11]. This results in a thicker recast layer. Heat affected zone is a layer of base metal that is formed due to the influence of heat during the
The recast layer on the workpiece then the data is displayed in graphical form to facilitate the process of analyzing the effect of power supply current parameters on the thickness and hardness of the recast layer.

![Figure 4. Thickness of Recast Layer](image)

Based on Figure 4, graph of the relationship between power supply current to the thickness of the recast layer seen on the power supply current 4 Ampere yields the value of the recast layer thickness 5 μm. For the power supply current 5 Ampere recast layer thickness formed is 17 μm. Recast thickness is increased to 27 μm on 6 Ampere current power supply. In the current power supply 7 Ampere produces recast thickness of 30 μm. The highest recast layer thickness was obtained from the variation of 8 Ampere current power supply with 35 μm thickness.

From Figure 4 it is known that the value of the recast layer thickness increases with the current power supply value. This is because the current power supply value affects the amount of energy the wire uses to cut the workpiece. The increase in the amount of energy used to cut the workpiece gives a higher amount of heat on the surface. The heat will be absorbed more deeply. Thus, the heat affected zone is also formed deeper. This resulted in recast layer thicker. Heat affected zone is a layer of base metal that is formed due to the influence of heat during the cutting process, while the recast layer is the outermost layer of material that comes, melt, and freeze again due to the influence of heat caused by spark jumps from the wire.
3.2. Hardness

![Figure 5. Hardness of Recast Layer](image)

This shows that the higher the power supply current value is, the harder the recast layer is. This can happen due to the higher power supply current values resulting in an increased amount of energy used to cut the workpieces that the amount of heat that occurs on the surface of the higher recast layer. It is also supported by rapid cooling of the dielectric fluid resulting in a harder recast layer.

Based on Figure 5 which shows that segment 1 for current power supply value 4 Ampere produces hardness value equal to 223.6 VHN. The hardness values are increasing with the increasing values of the power supply current. All hardness values in this segment represent the hardness of the recast layer. In segment 2 for the 4 Ampere current power supply value produces a hardness value of 181.2 VHN. Then the hardness value increases slightly by 183.4 VHN on the current power supply value 5 Ampere. Both hardness values are the value of hardness of heat affected zone. The hardness values are increasing with the increasing values of the power supply current. All of the hardness values in this segment represent the hardness value of the heat affected zone. In segment 5 for the 4 Ampere current power supply value produces a hardness value of 213.3 VHN. The value of this hardness increases with the increasing power supply current value although the increase is not significant. All hardness values in this segment are close to the hardness value of the base metal.

From Figure 5 it is also known that in segment 1 and segment 2 (4 Ampere and 5 Ampere) have increased hardness. This is because the layer is melted due to the heat generated by spark jumps and then froze again and with rapid cooling resulted in the layer becomes harder. While in segment 2 (6 Ampere, 7 Ampere, 8 Ampere), segment 3, segment 4 and segment 5 happened to soften, this is because in this layer the heat received is not too big and cooling that happened slowly so that the material is softer. Recast layer is formed due to the rapid cooling of melting material or gas phase by the dielectric fluid because experiencing rapid cooling as the supplying of supply currents will give greater energy cut. This layer is formed by the molten metal solidifies [13]. The molten metal is rapidly cooled (quenched) by a dielectric fluid that violence increased in this layer. HAZ also forms a plastic deflection in the presence of micro and macro strains characterized by the appearance of twinning and slip [14].

**Conclusion**

The thickness of the highest recast layer is obtained from the variation of 8 Ampere power supply current with a thickness value of 35 m. The hardness of the highest recast layer is obtained from a variation of 8 Ampere current power supply with a value of 277.3 VHN hardness. The higher the power supply current value causes the hardness value and the thickness of the recast layer increase.
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