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A STUDY ON SURFACE INTEGRITY OF TOOL STEEL AISI H13 AFTER EXPERIENCING ELECTRICAL DISCHARGE MACHINERY PROCESS

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Abstract

Electrical discharge machining (EDM) is the process of applying an electrical charge to cut or shape the work piece. Electrodes will move and cause erosion on the surface of the work piece without contact. This process is widely used in machining complex components and difficult to cut work material as hardened steel. This process generally produces poor machined surface properties such as high tensile residual stress, high surface roughness, presence of cracks and micro cracks. These properties influence the operation behavior of the work piece surface and known as surface integrity. This study focuses on the microstructure, hardness and surface roughness of AISI H13 hardened steel after undergoing electrical discharge machining process. The machining parameters used are peak current of 1.5 Amp, 2.0 Amp and 3.0 Amp. The pulse time on is set at 8µs, 10µs, and 15µs where as the pulse time off is set at 2µs, 4µs and 6µs. Results showed that the white layers were observed by an optical microscope. In the case of hardened steel, EDM machining process caused the formation of three micro structure layers, i.e. white layer, anneal layer and bulk material layer. From the micro hardness test, there are three types of surface layers existed according to the various reading value of micro hardness. The first layer has an average hardness value that increased from 168 HMV to 194 HMV at a distance of 3µm to 9µm beneath the machined surface. As for the second layer has an average hardness value shows the reading increased from 190 HMV to 195 HMV at the depth below the machined surface of 12µm to 18µm. The third layer has an average hardness value which decreased until reach the bulk of the material hardness of to 192 HMV to 198 HMV beneath the machined surface of 21µm to 30µm. The surface measurement found that obtain a good finishing with a combination of low peak current, the shortest time on and time off.

Keyword: EDM, erosion, AISI H13, peak current, micro structure layers

1. Introduction

Surface intergrity study involves changing which occurred to all surface layers after manufacturing process and its impact to the material characteristics and behaviour when being used. Change that used to happen in work piece after conducting process EDM is mechanical change, chemical change and metallurgy change [1]. Process EDM can be used for all types of material that channel electricity while material melting point determine metal rate of elimination per discharge. It is because of process EDM does not involve mechanical energy, force, strength and firmness, work piece does not affect the rate of elimination. On the other hand, various frequency discharge or energy per discharge is used to control metal rate of elimination. Rate of elimination and surface roughness is increased by current density addition and sprinkle frequency reduction [2].

2. Problem Statement

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Most researchers try to design a combination process of EDM and other different process in order to increase productivity as well as getting an optimum surface integrity. For example Masuzawa et al. (1989) [3] have merged the EDM operation with electric chemical machining (ECM) to improve surface finishing and reduce not required effect after EDM process, in fact there are a few researchers also conducting ultrasonic machinery and followed EDM process. Their objectives are only to remove or strive to prevent white layer that is formed as result of EDM sprinkle on steel and consequently to improve or maintain work piece original characteristics [4].

Work piece surface quality produced by electrical discharge process (EDM) mainly influenced with EDM machinery parameters. Most problems which arose are a suitable parameter combination selection to proffer good quality surface involving surface texture and surface metallurgy. This study is carried out to identify surface layers that exists in tool steel AISI H13 which had undergone EDM process along with cuprum electrode. Nine samples with different machinery parameters are studied to be compared by the surface intergrity. Steel AISI H13 is selected because of its common used in manufacturing industry as mould material for formation process such as die, die holder, dummy block and stem, in plastic moulding application such as thermoplastic injection moulding and others. The effectof the machinery process are studied so that it may be referred in material AISI H13 utilisation machined by EDM machinery.

3. Objective of Study

Electrical discharge machinery perpetrated upon tool steel AISI H13 that have 50±3 HRC hardness by using cuprum electrode with different EDM parameters based on a parameter from ASSAB Steel as main referral. The objectives of the study are as the following:

a) Study peak current, time pulse on and time pulse off on AISI H13 surface finishing that is cut by using EDM.
b) Measure micro hardness on machined surface.
c) Study the AISI H13 microstructure change on machined surface.

4. Scope of Study

AISI H13 tool steel will be machined by using EDM process along with cuprum electrode so that the surface integrity may be studied. Sample will be cut horizontally by using EDM wire. Preparation of metallographic sample will be studied using optical microscope. Sample taken based on different machinery parameter such as peak current and various time pulses on and various time pulses off.

5. Methodology

Nine samples with different machinery parameters are taken and studied to compare the AISI H13 steel surface hardness. AISI H13 steel is selected because of its common used in manufacturing industry as mould material for formation process such as die, die holder, dummy block and stem, in plastic moulding application for example thermoplastic injection moulding and others. Experimental design applied in this experiment is three level cutting parameter to form a table of machinery parameter combination used in the experiment. Parameter selection process for experiment was peak current (Ip), pulse time on (Ti), pulse time off (To) and electrode type (E). Surface roughness factor observed was surface finishing (Ra), micro vickers hardness value and microstructure.

Table 1 : Cutting Parameters

Parameter	unit	0	1	2
Arus puncak (I_p)	Amp	1.5	2.0	3.0
Selang masa *on* (T_i)	µs	8	10	15
Selang masa *off* (T_o)	µs	2	4	6

6. Implementation of Study

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Study procedure explicable as all measures taken in do the study reach final decision was grabbed. Figure 1 show steps involved in conducting overall experiment. All these measure was explained, explanation especially are going to focus on experiment preparation

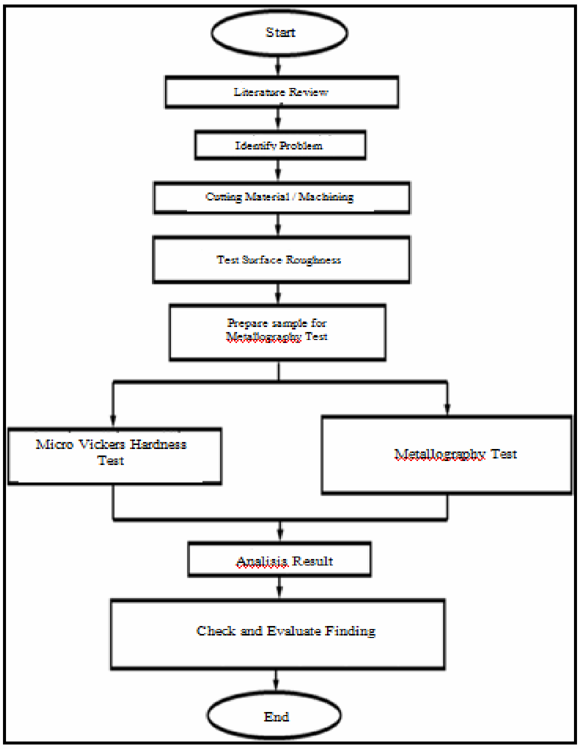

Figure 1 : Implementation Flow Chart

7. Result And Discussion

In implementing study which focuses to microstructure and hardness which occurred after EDM process, three tests carried out that are surface roughness test, hardness test Micro Vickers and microstructure analysis.

7.1 Microstructure

According to Ghanem et al. (2003) [5], annealed layer influenced by type, steel hardening level and machinery parameters. Generally, annealed layer thickness is increasing when more and more heat levied at particle under work object surface. Finally, white layer presence and anneal influence mechanical nature. For example, fracture in surface can cause material fail before the yield point. White layer shows hardness twofold far bigger than bulk material, while glaze layer quench have force that lower than bulk [6].

Table 2 : Method Taguchi In Deciding machinery Parameter Combination

Experiment No.:	EDM Parameters Level		
	A (I_p)	B (T_i)	C (T_o)
1	1.5	8	2
2	1.5	10	4
3	1.5	15	6
4	2.0	8	4
5	2.0	10	6
6	2.0	15	2
7	3.0	8	6
8	3.0	10	2
9	3.0	15	4

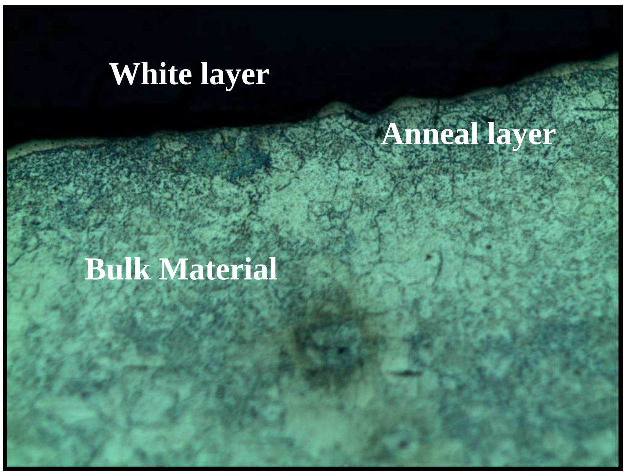

Figure 3 : Steel surface microstructure with parameter, I_P = 2.0A, T_i = 10µs, T_o = 6µs.

There is fragmentation and micro fracture that exists in white layer such as which indicated in figure 4. This in line with study carried out by Lee & Tai (2003) [6]. Fracture that exists in white layer seldom across the annealed layer except because peak energy (pulse energy) that sufficiently high. High carbon content in work piece also affects micro fracture formation [7].

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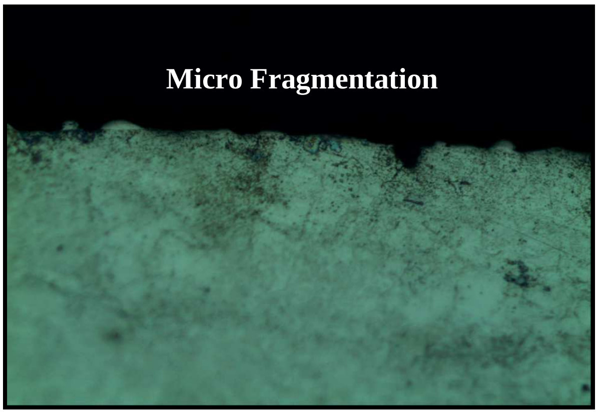

Figure 4: Surface micro fragmentation after deducting in I_P = 3.0A, T_i = 15µs, T_o = 4µs.

7.2 Micro Vickers Hardness

In micro Vickers hardness test, 10 gram burden levied at sample surface 10 seconds starting from distance 3µm above white layer outer surface until bulk part approximately 30µm from surface machined with distance expansion 3µm. For each specimen, there was ten micro hardness testing points.

Table 3 : Micro Vickers hardness test measurement data for AISI H13

Distance (μm)	Percentage of rise/decline of micro hardness compared to bulk hardness average
3	-13%
6	-6%
9	1%
12	-1%
15	0%
18	2%
21	3%
24	3%
27	2%
30	-

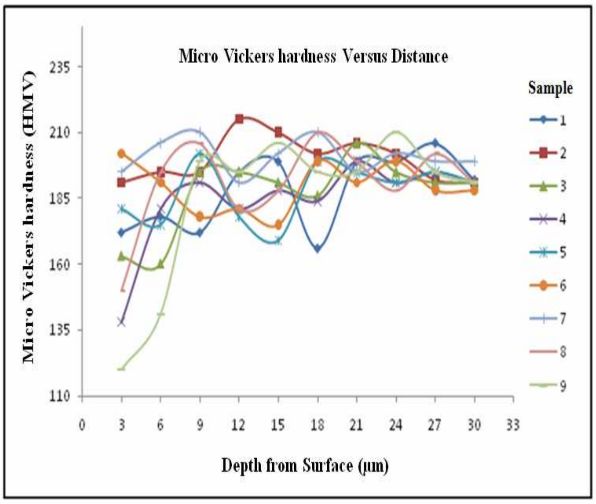

Figure 5: Graph of Micro Vickers hardness versus distance, tool steel AISI H13

Overall, micro hardness experiment may divide hardness value into three surface layer types that exist and stated based on hardness value. First layer is layer that has hardness average value which showed increase reading from 168 HMV until 194 HMV in surface machined depth 3µm to 9µm. The hardness generally caused by white layer existence in work object surface. White layer thickness depends on machinery parameters used. Increasingly higher time pulse on, the thicker the white layer formed. Likewise with peak current raises that increase white layer thickness. Through studies Lee & Tai (2003) [6] it finds out white layer formation is due to resolidification of metal meltdown which is not channel the flow out by dielectric in refrigerating process. Due to carbon pervasion and structure that are unlike bulk material, the layer hardness is far higher than bulk material. Referring to Lee & Tai (2003) [6] that increasingly higher time pulse on, the thicker white layer that formed.

While for second layer is layer that have hardness average value that still showing increase reading from 190 HMV until 195 HMV in depth of 12µm to 18µm from surface machined. It is due to annealed layer formed when work piece microstructure treated with heat below melting point when electric discharge formed. Furthermore this layer chilled slowly by EDM process dielectric. The hardness value in second layer which is better known as not tempered layer roughly shows the hardness

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devaluation state due to quick refrigeration by fluid dielectric.

The same result also obtained by researcher Puertas et al. (2004) [7] where high hardness value in white layer followed by lower hardness value than bulk material in annealed layer and consequently bulk layers of material. Whilst research from Ghanem et al. (2003) [5] found out that outer layer hardness is threefold of tool steel type X155CrMoV12 and high carbon content C90 that has been machined with EDM process. This due to carbon pervasion and metallurgy transformation which involves martensite phase formation; the hardening source in outer layer.

After that, third layer is layer that has hardness average value which showed reduction reading until steel bulk material tool AISI H13 that is from 198 HMV until 192 HMV in depth 21µm to 30µm from surface machined. Whereas in third layer; the over tempered layer where specimen do not experience heating that is sufficient to achieve hardening temperature and what is going on is process that named tempering-back where hardness value produced experience reduction until achieving the specimen original hardness value or tool steel AISI H13.

7.3 Surface Roughness

Surface roughness was trace or sign produced by cutter tool end or effect from cutter tool erosion in component surface. The sign formed recurring in entire surface that has been machined. Whether uniform or otherwise, surface texture as if forms one pattern in the component surface. Surface roughness be defined as real surface deviation of a component compared generally surface. Following table results showed for surface roughness test.

Table 4 : Surface Roughness Test Data

No.	EDM Parameters Level			Surface Roughness Value (µm)
	A (I_p)	B (T_i)	C (T_o)	
1	1.5	8	2	1.40
2	1.5	10	4	1.31
3	1.5	15	6	1.31
4	2.0	8	4	1.21
5	2.0	10	6	1.21
6	2.0	15	2	1.47
7	3.0	8	6	1.43
8	3.0	10	2	1.43
9	3.0	15	4	1.53

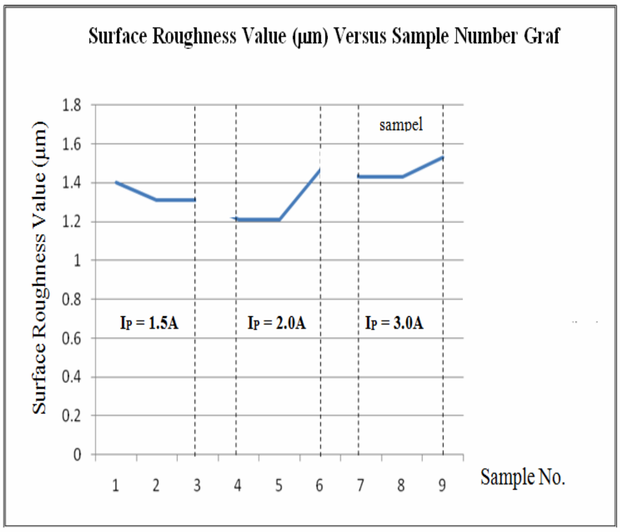

Figure 6: Surface Roughness Value (µm) Versus Sample Number Graph

Referring to table 3 and table 4 which showed micro Vickers hardness test measurement data and surface roughness test data for tool steel AISI H13 after undergoing machinery electrical discharge process. From first sample to ninth sample it shows that peak current, time pulse on and time pulse off are not influenced by apparent surface roughness value but it affects the micro hardness value in first layer of every sample (comparison refer figure 6).

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By referring to table 3 Percentage of rise/decline of micro hardness compared to bulk hardness average for the first two layers are 13% and 6%. Whereas in fifth layer to eighth layer shows 0%, 2%, 3%, 3% and 2%. This decision is supported by study carried out by Amorim & Weingaertner (2004) [8] whom found out that in distance between 10μm and 15μm; under surface machined EDM shows hardness average decline to 56% and 2% before showing constant hardness reading reaching material micro hardness tool steel bulk AISI H13 but compared to study Jaharah et al. (2010) [9]; in first coat to fifth layer show hardness average percentage increase 81% for first layer, 57% for second layer, 29% for third tier, 5% for fourth layer and 2% for fifth layer whereas in sixth layer shows constant hardness reading until material micro hardness tool steel bulk AISI H13.

Thus, it proves that the usage of EDM machine according to manufacturer's manual could not prevent the effect of EDM machinery process on work piece surface especially when machining by using alternate parameter such as time pulse on, time pulse off and high peak current. Usually EDM machinery process would not affect in surface and in work piece inner layer but in some engineering case, reheating layer structure will increase hardness and consequently will increase resilience to ware.

Finally, surface machined with EDM machinery had better from fluid storage aspect in surface, due to pore state or cavity that exist on work piece surface machined with machine EDM compared to work piece surface machined with conventional machine. This will make sure life resilience in a specimen.

8. Conclusion

It may be concluded from the experiment outcome analysis as the following;

1. From surface roughness measurement achieved, the time pulse on, time pulse off and peak current that increasing can cause surface machined become more blatant as well as more corrugated in machined surface. This roughness due to existence of depression, metal cluster, fracture, resolidify metal splinter and of hollow.

2. All samples machined with process EDM have white layer at the surface. There are three layers that formed under surface EDM that are white layer, anneal layer and bulk layers of material. The thickness of white layer depends on machinery parameter. The longer time pulse on and the higher peak current, the thicker white layer formed. However, the influence of peak current on white layer thickness is invisible.

3. Surface hardness achieved have average hardness value of 168 HMV to 194 HMV in outer surface workpiece or white layer, followed with micro hardness average rise in middle layer or anneal layer with value of 190 HMV to 195 HMV and consequently bulk layers of material hardness around 192 HMV.

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