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Studying the Effect of Ignition Voltage (U_e) and Amperage (I_e) when Processing Hardened SKD 11 Materials on Wire Cut Electric Discharge Machining (WEDM)

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Abstract:- Machining using spark is one of the widely used advanced machining methods. Surface quality and machining productivity are the two most important parameters[1]. The majority of optimization studies are in single-objective form[10][14]. However, there have also been some studies on the basis of multi-objective optimization problem[10][14].

SKD11 steel is a steel grade according to Japan's JIS standard (AISI standard named D2; DIN standard named 2379), widely used in cold fabrication with high wear resistance characteristics, good tempering permeability. SKD11 large material is used after hardening, so it is usually machined on a spark machine.

This paper studies the influence of two basic parameters: voltage level (U_e); amperage (I_e) on wire cutters when machining SKD 11 material after quenching.

Keywords:- *Processing of hardened SKD 11, machining quality on wire cutting machines, roughness and cutting productivity, influence of technological parameters (U_e; I_e) on wire cutting machines.*

I. INTRODUCTION

- **Studies on optimal parameters to improve quality and productivity when machining on Wire cut electric discharge machining (W-EDM).**

In the process of technology development, requirements for complex shape, size, mechanical properties and precision of the work piece are required. Therefore, processing methods and technologies are always changing and developing to meet social needs as well as improve production efficiency. For each different material, the selection of optimal technological parameters when machining on the same equipment is a very important and necessary issue.

Surface quality and machining productivity are the two most important parameters [1][12]. Therefore, there are quite a few studies focusing on determining the optimal parameters to improve surface quality and machining productivity [1][10][14]

The majority of optimization studies are in single-objective form [10][14]. However, there have also been some studies on the basis of the multi-objective optimization problem [4][6][9][10][11][14]. In addition, the studies also focused on determining the optimal machining method for different materials such as the optimal cutting mode when machining Titanium Ti-6Al-4V alloy[1][10][14], stainless steel AISI-420[14], alloy Ti-44.5Al-2Cr-2Nb[11], ceramics[4], Inconel 718[8], STD11 (or X12M)[13], etc.

A. *Quality of the part after machining*

The quality of the part after machining is evaluated by many factors and different standards such as: size, geometric shape, relative position, roughness. However, this paper only focuses on research on surface roughness and machining productivity to evaluate the machining quality on wire cutting machines.

a) Roughness of the part after machining
Surface quality is one of the criteria to evaluate the quality of the part after processing. To evaluate the surface quality, there are many factors in which the surface shape is of more concern, namely the roughness (R_a)[3]

b) Machining productivity on wire cutters
Machining productivity depends on many factors, the most important of which is the processing time.

Machining capacity is the cut surface area per unit time. In the machining process, if the thickness of the workpiece is the same, and the processing time is the same, the cutting capacity can be considered as the length of the cut on the workpiece. The cutting capacity is calculated according to the formula:

$$P = \frac{s * \delta}{t} \qquad (1)$$

In which:
P is the cutting capacity (mm^2/s); s is the cutting length (mm);
δ is the cutting thickness (mm); t is the machining time(s).

B. *Technological parameters*

Basic technological parameters of wire cutters include[2]:

Spark ignition voltage (U_i);	Ignition delay time (t_d);
Spark discharge voltage (U_e);	Spark discharge current (I_e);
Spark discharge time (t_e);	Pulse duration (t_i).

In addition, the processing quality is also affected by:

Electrode wear;	Large pulse distance;
Debris and air bubbles;	Abnormal discharge.

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In the content of this paper, we focus on studying two basic parameters, namely spark discharge voltage and spark discharge amperage because:

Material removal energy:

$$W_e = U_e * I_e * t_e \quad (2)$$

II. EXPERIMENTALLY EVALUATE THE SIMULTANEOUS EFFECTS OF (UE) AND (IE) ON SURFACE ROUGHNESS AND YIELD

A. Determine the number of experiments

The number of experiments was determined according to the formula:[1]

$$N = 2^k \quad (3)$$

In which: N – Number of experiments

k – Number of input variables

With the input variable k = 2, we have the number of experiments N = 4. In the study considering 3 cases, the number of experiments is N=12. To improve accuracy, increase the number of experiments in 2 cases without changing the value U_e and I_e=> Total number of experiments N=14.

B. Experimental equipment and conditions

- Equipment to perform the experiment is a wire cutter CHMER CW- 420HS of CHMEREDM - Taiwan, used at the Center for Machanical Engineering, Hanoi University of Industry.

Fig. 1: Device CW - 420HS

- Use TESA's Rugosurf - 10G roughness meter to measure roughness.

Fig. 2: Rugosurf - 10G . Roughness Gauge

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- Machining time is determined by a stopwatch with units of seconds.

Experiments are carried out on the same conditions, specifically:

Solvent quality and dielectric flow conditions in all experiments were the same (solvent insulation);

The wire cross section remains constant throughout the experiment (diameter of copper cutting wire Ø 0.2mm);

The machining environment temperature is always stable and equal to the temperature in the machining room ($25 \pm 5^0 C$);

The sum of the disturbances affecting dimensional accuracy is stable and unchanged throughout the experiment;

Other conditions as standard;

Carry out experiment:

Controllable input variables:

X_1 : ignition voltage U_e (V);

X_2 : spark discharge current I_e (A);

In the process of learning about wire cutters CW 420HS, we chose to survey two variables: U_e (V) (survey from 70 V to 90 V) and I_e (A) (survey from 2 A to 7 A).

With the input experiment being 2 variables: U_e and I_e, according to the experimental plan, we performed 14 experiments. For each experiment, we change 2 parameters U_e and I_e, the other parameters get the optimal value according to actual experience. So there are experimental planning parameters on the CW420 HS spark wire cutting machine as shown in Table 3.6:

Name	1	2	3	4	5	6	7	8	9	10	11	12	13	14
U_e (V)	70	75	80	85	90	85	85	85	85	85	70	90	70	90
I_e (A)	2	2	2	2	2	2	3	4	5	6	2	2	6	6

Table 1: Parameter table with variable values for each test on wire cutters

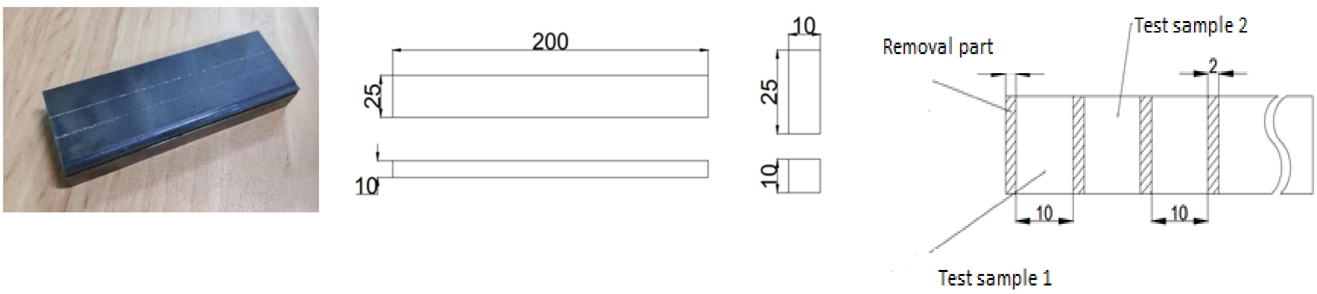
Other technological parameters have values that do not change during the experiment according to the following table.

Name	OFF (μs)	AN (μs)	AFF (μs)	SV (V)	FR (mm/ph)	WF (mm/s)	WT (g)	WL (Kg/cm^2)
Value	13	3	13	43	3	4	5	4

Table 2: Technological parameters have unchanged values

In which:

- U_e is the discharge voltage (V);
- I_e is the spark discharge intensity (A);
- OFF is discharge stop time (μs);
- AN is short circuit discharge time (μs);
- AFF is the rest time (μs);
- SV is the Servo reference voltage (V);
- FR is the adjustment of the machining speed (mm/min);
- WF is wire speed (mm/s);
- WT is the tension in the string (g);
- WL is the cooling pump water pressure (Kg/cm2).



a) b) c)

Fig. 3: SKD11 steel for processing

Perform machining to cut the work piece with a cutting length of 25 mm to produce a sample with dimensions of 10 x 10 x 25 mm.

- To determine the effect of ignition voltage (U_e) on surface roughness and cutting productivity, we cut 5 test samples No.1; 2; 3; 4; 5 during the test with only electric current. Ignition pressure (U_e) changes, other parameters are kept unchanged, figure 4.a.
- To determine the effect of spark discharge intensity (I_e) on surface roughness and cutting productivity, we cut 5 test samples No. 6; 7; 8; 9; 10 (Figure 4.b).
- To determine the simultaneous influence of ignition voltage (U_e) and spark discharge intensity (I_e) on surface roughness and cutting yield, we cut 4 experimental samples No.11; 12; 13; 14 (Figure 4.c) with input parameters U_e and I_e adjusted to change at the maximum and minimum values, respectively.

a) b) c)

Fig. 4: Experimental sample after processing on CW- 420HS

III. RESULTS

Experiment was performed, with the cutting time determined by a stopwatch and the roughness measured on a Rugosurf - 10G machine. We have the following table of results:

Experiment	$I_e t_e$(A)	U_e(V)	Value		Note
			R_a (µm)	t(s)	
1	2	70	1.252	1020	
2	2	75	1.283	831	
3	2	80	1.335	657	
4	2	85	1.393	586	
5	2	90	1.424	544	
6	2	85	1.347	592	
7	3	85	1.527	519	
8	4	85	1.691	420	
9	5	85	1775	372	
10	6	85	1.812	336	
11	2	70	1.298	1015	
12	2	90	1.447	540	
13	6	70	1.612	487	
14	6	90	1.921	298	

Table 3: Experimental results

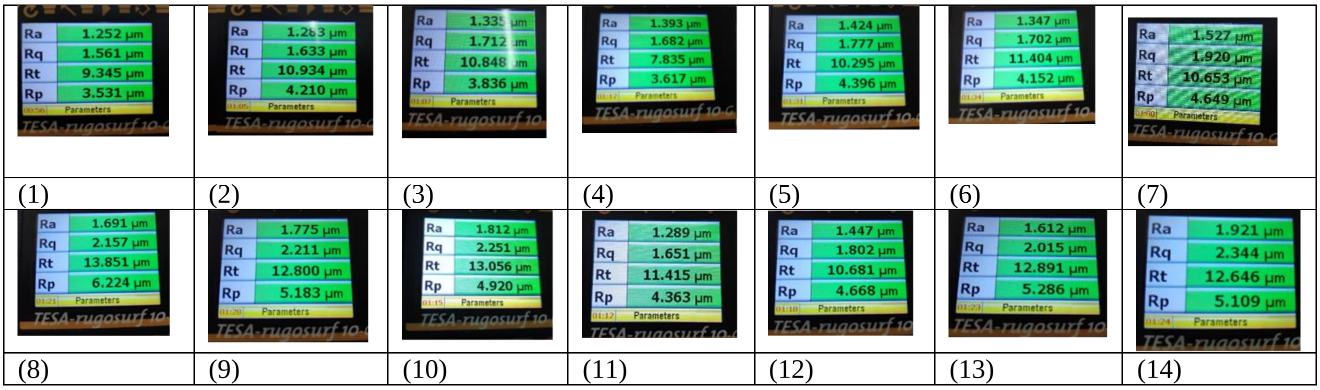


Fig. 5: Results of measuring surface roughness after machining of the respective experiments

- **Analyze and evaluate the simultaneous influence of U_e and I_e on quality and processing productivity**

Studies have shown the relationship between the surface roughness of the part (R_a); cutting capacity (V) with ignition voltage (U_e) and spark discharge intensity (I_e) and obeys the exponential rule[1]:

$$R_a = a * U_e^b * I_e^c \qquad (4)$$

In which:

- a is the coefficient to be determined;
- b; c is the exponent to be determined;
- R_a is the surface roughness (µm);
- U_e is the ignition voltage (V).
- I_e is the spark discharge current (A);

Cutting capacity:

$$P = x * U_e^y * I_e^z \qquad (5)$$

In which:

- x is the coefficient to be determined
- y; z is the exponent to be determined.
- P is the cutting capacity (mm^2/s)

Using the orthogonal experimental planning method, according to experimental results can be determined:

$$R_a = 0.09 * U_e^{1.78} * I_e^{1.25} \qquad (6)$$

$$P = 8.37 * 10^{-6} * U_e^{10.27} * I_e^{1.82} \qquad (7)$$

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Programming with Matlab R2018b software to draw the graph influence of R_a byU_e and I_e.

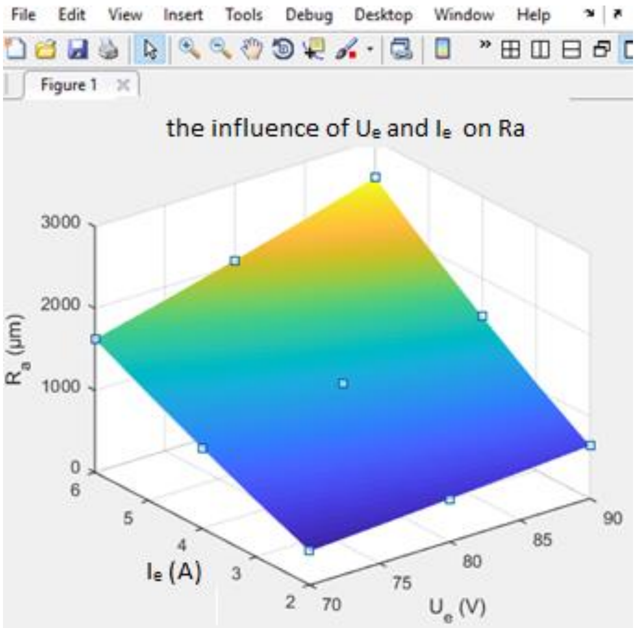

Fig. 6: Graph showing the influence of U_e; I_e to R_a

From the graph, we see that the roughness $R_a$is affected simultaneously by the spark discharge intensity I_e and the ignition voltage difference U_e. The relationship between R_a and U_e; I_e is shown through the graph of Figure 6 and the mathematical formula (6)

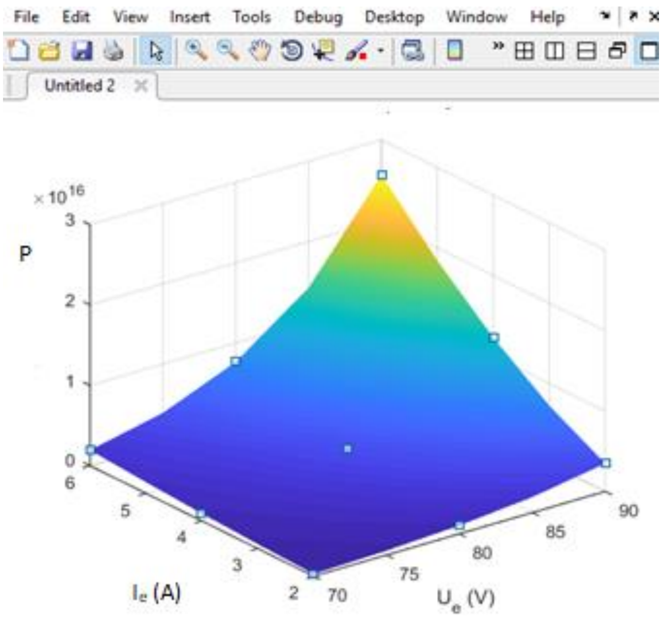

Fig. 7: Graph showing the influence of U_e; I_e to P

Programming with Matlab R2018b software to draw graphs of relation equations between P and U_e; $I_e$shown through the graph of Figure 7 and the mathematical formula (7)

IV. CONCLUSIONS

Research results when processing SKD11 steel material after quenching on CW 420HS machine shows that:

Processing quality:

The relationship between R_a and U_e and I_e according to the graph of Figure 6 and is determined by the formula:

$$R_a = 0.09 * U_e^{1.78} * t_e^{1.25}$$

The relationship between P and U_e and I_e according to the graph of Figure 7 and is determined by the formula:

$$P = 8.37 * 10^{-6} * U_e^{10.27} * t_e^{1.82}$$

On the basis of the simultaneous influence of two quantities U_e; I_e to quality and productivity when machining, depending on the goal to be achieved based on the above formula to choose the value of the technological parameters U_e; I_e suitable.

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