Influence Of Technological Parameters On Diameter Deviation And Roundness Error Of Hole Surface In The Process Of EDM

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***Abstract*—This paper presents the study of the influence of technological parameters on the diameter deviation and the roundness error of hole surface in the process of electric discharge machining. The machining material used in this study is WCCo8 hard alloy, the tool used in this study is a copper electrode. Two basic technological parameters of the machining mentioned in this study are ignition voltage and electric discharge time. The experiments were conducted according to four test points of a full two-stage test matrix and three test points at the central level. Analysis of the experimental results has determined the influence of ignition voltage and electric discharge time parameters on the diameter deviation and the roundness error of the machined hole.**

Keywords—Electric discharge machining, WCCo8 hard alloy, copper electrode, diameter deviation, roundness error

I. INTRODUCTION

Currently, in mechanical processing, the method of electric discharge machining using wire electrodes is increasingly popular and promoting its advantages when machining materials that are conductive, highly rigid and durable, or machining surface with the rectilinear generator but the complex profile that are difficult or impossible to implement with traditional cutting methods.

When machined holes by electric discharge method using wire electrodes, machining accuracy is assessed through many criteria, in which the diameter deviation and the roundness error of machined holes are two of the important criteria that determine product quality, thereby determining the efficiency of the machining process.

There are many factors influencing the diameter deviation and the roundness error of machined hole surface when using wire electrodes to machine smooth cylinder surface such as chemical composition of materials, electrode material, ignition voltage, electric discharge time, electrical and thermal conductivity of machined materials, insulation resistance of solvents, etc [1-6]. It is, therefore, difficult to select a set of machining parameters to ensure machining accuracy for all different cases. Therefore, for each specific machining condition, it is necessary to study to determine the degree of influence of technology parameters on machining accuracy, which is the basis for the selection of a reasonable (optimal) set of values for those parameters.

There have been several studies conducted to investigate the influence of some parameters of the machining process on productivity and accuracy when machining some types of mold materials such as SKD61, SKD11, X12M, ect. [2-5]. However, there have not been any studies investigating the influence of technological parameters on the diameter deviation and roundness error of hole surface when machining WCCo8 hard alloy on electric discharge machining machine using copper wire electrodes published.

This study will conduct experiments investigating the influence of two basic parameters of the machining process: ignition voltage and electric discharge time on the difference in the diameter deviation and roundness error of hole surface when using copper wire electrodes to machine WCCo8 hard alloy.

II. EXPERIMENTAL SYSTEM

2.1. Experimental machine

The electric discharge machining machine using wire electrodes used in this study is the Sodick AQ600 (Figure 1).

Fig 1. Sodick AQ600 electric discharge machining machine

2.2. Workpieces

Workpiece material is a 1-carbide hard alloy - WCCo8 (GOST standard - BK8). This type of material is often used to make hot stamping molds and cutting tools.

Before conducting electric discharge machining using wire electrodes, on each components, Ø3 holes are made available by pulse method to put strings through them. To facilitate the measurement of the output parameters (diameter deviation and roundness error of hole surface) and ensure the reasonable cost of the experimental process, we conduct hole machining with a diameter of ∅12. The workpiece is mounted on the machine, as shown in Figure 2.

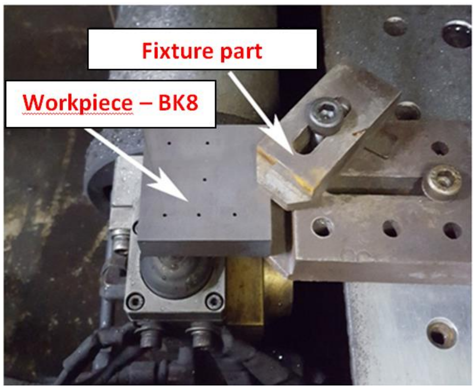

Fig 2. Mounting the workpiece on the machine

2.3. Electrode material

Electrode material used is copper wire with a diameter of 0.2mm of Pungkuk Brand (Korea) with CuZn35 symbol, mechanical tensile strength is 750 - 790 N/mm^2. This is a common material being used popularly in the technology of electric discharge machining.

2.4. Measuring device

The diameter deviation and roundness error of hole surface is measured by a Mitutoyo CRYSTA-Apex S544 3-dimensional measuring machine (Figure 3).

Fig 3. Mitutoyo CRYSTA-Apex S544 3-dimensional measuring machine

The diameter deviation and roundness error of hole surface is measured on a random cross-section within the length of the hole, which is fixed on the samples by the longitudinal stop placed in the heart of the hole.

2.5. Experimental conditions

In addition to the parameters (variables) that will change during the test including ignition voltage and electric discharge time will be detailed in the next part, some basic parameters of the testing process are selected according to specific production conditions as well as suitable for testing machine including feed rate of 3 (mm/min); Wire velocity of 82 (mm/s); Wire tension force of 1500 (g); Working voltage between two electrodes of 60 (V); Water pressure of 6 (kg/cm^2); Electric discharge stop time of 26 (μs).

III. EXPERIMENT AND ANALYSIS OF RESULTS

3.1. Experiment design

With two input parameters that will change during the test process including the ignition voltage (U) and electric discharge time (t), there will be $2^k = 2^2 = 4$ the original test points (at encryption level -1 and +1); and should select at least 3 central points (at encryption level 0) [8]. Thus, the test plan will consist of 7 points, after being arranged in the standard order, the test matrix is shown in Table 1.

Table 1. Matrix of experiment

No.	U	t
1	-1	-1
2	+1	-1
3	-1	+1
4	+1	+1
5	0	0
6	0	0
7	0	0

Table 2. Value of parameters at levels

Parameter	Symbol	Unit	Value at levels		
			-1	0	+1
Ignition voltage	U	V	65	80	95
Electric discharge time	t	s	4	6	8

Table 3. Experimental results

No.	Code value		Actual value		Out-put parameters	
	U	t	U	t	δ (mm)	Δ (mm)
1	-1	-1	65	4	0.009	0.003
2	+1	-1	95	4	0.015	0.006
3	-1	+1	65	8	0.014	0.005
4	+1	+1	95	8	0.023	0.008
5	0	0	80	6	0.017	0.005
6	0	0	80	6	0.017	0.006
7	0	0	80	6	0.018	0.005

The value of ignition voltage parameters and electric discharge time during the test is selected based on practical experience in production and in accordance with the type of machine used for the test. Their values in encrypted form are shown in Table 2.

3.2. Experimental results

Conducting the test in the order designed in Table 1, with the values of the variables at the levels shown in Table 2; at each test point, at least 3 holes will be machined, the value of diameter deviation (δ) and roundness error (Δ) of the machined hole shall be measured at each hole at least 3 times and then take the average of the consecutive measurements. The results are shown in Table 3.

3.3. Analysis of results

Using Minitab 16 statistical software to analyze the results in Table 3 for two parameters, which are the diameter deviation and roundness error, the results are presented in Tables 4 and 5.

Table 4. ANOVA analysis for diameter deviation

	df	*SS*	*MS*	*Significance F*			
Regression	5.0000	0.0001	0.0000	0.0841			
Residual	2.0000	0.0000	0.0000				
Total	7.0000	0.0001					
	Coefficients	*Standard Error*	*t Stat*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.0173	0.0003	52.0000	0.0159	0.0188	0.0159	0.0188
U	0.0038	0.0003	12.9904	0.0025	0.0050	0.0025	0.0050
t	0.0033	0.0003	11.2583	0.0020	0.0045	0.0020	0.0045
U*U	-0.0021	0.0004	-4.7246	-0.0040	-0.0002	-0.0040	-0.0002
t*t	0.0001	0.0000	65535	0.0000	0.0000	0.0000	0.0000
U*t	0.0001	0.0003	2.5981	-0.0005	0.0020	-0.0005	0.0020

Table 5. ANOVA analysis for roundness error

	df	*SS*	*MS*	*Significance F*			
Regression	5.0000	0.0000	0.0000	0.2379			
Residual	2.0000	0.0000	0.0000				
Total	7.0000	0.0000					
	Coefficients	*Standard Error*	*t Stat*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.0053	0.0003	16.0000	0.0039	0.0068	0.0039	0.0068
U	0.0015	0.0003	5.1962	0.0003	0.0027	0.0003	0.0027
t	0.0010	0.0003	3.4641	-0.0002	0.0022	-0.0002	0.0022
U*U	0.0002	0.0004	0.3780	-0.0017	0.0021	-0.0017	0.0021
t*t	0.0001	0.0000	65535	0.0000	0.0000	0.0000	0.0000
U*t	0.0001	0.0003	0.0000	-0.0012	0.0012	-0.0012	0.0012

The observation of Table 4 shows:

- Both ignition voltage and electric discharge time have a significant influence on the diameter deviation of machined hole. In particular, the influence of ignition voltage on the diameter deviation of machined hole is greater than the influence of electric discharge time.
- When increasing the values of ignition voltage and electric discharge time, the value of diameter deviation of the hole also increases. This problem is clearer when observing Figure 4.
- The interaction between ignition voltage and electric discharge time has a negligible influence on the difference in the diameter deviation . This problem will also be shown more clearly in Figure 5.

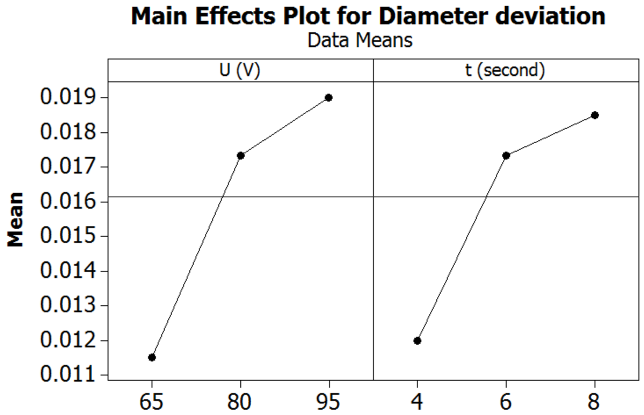

Fig 4. Main effects plot for diameter deviation

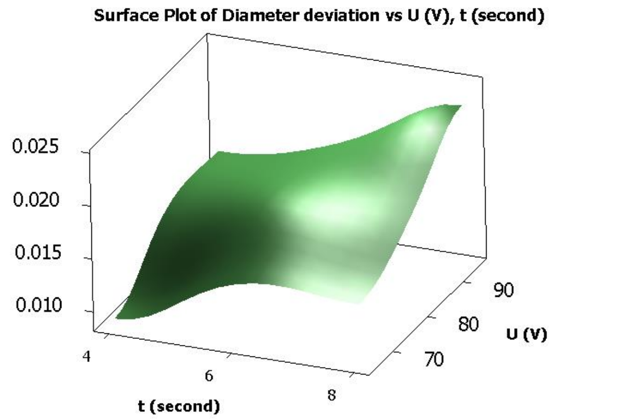

Fig 5. Interaction between ignition voltage and electric discharge time on the diameter deviation

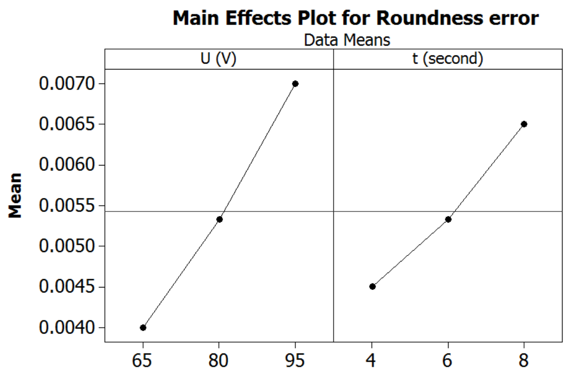

Fig 6. Main effects plot for roundness error

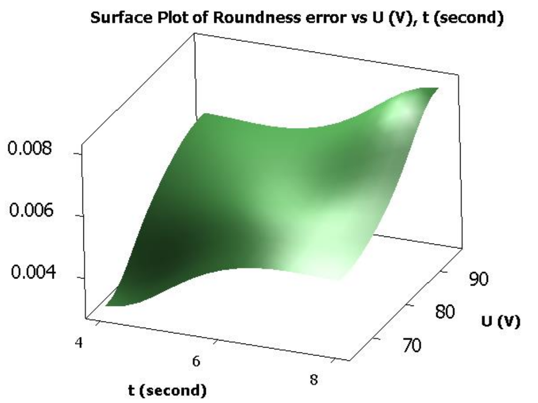

Fig 7. Interaction between ignition voltage and electric discharge time on the roundness error

The observation of Table 5 shows:

- Both ignition voltage and electric discharge time also have a significant influence on the roundness error of the machined hole surface. In particular, the influence of ignition voltage on the roundness error of machined hole surface is greater than the influence of electric discharge time.

- When increasing the values of ignition voltage and electric discharge time, the value of roundness error of the machined hole surface also increases. This problem is clearer when observing Figure 6.

- The interaction between ignition voltage and electric discharge time has a negligible influence on the roundness error of the machined hole surface. This problem will also be shown more clearly in Figure 7.

IV. CONCLUSION

From some results made in this study, some conclusions can be drawn when machining WCCo8 hard alloy by wire cutting method using copper electrodes as follows:

- Both ignition voltage and electric discharge time also have a significant influence on the diameter deviation and the roundness error of the machined hole surface. In particular, the influence of ignition voltage on the two output parameter is greater than the influence of electric discharge time.

- When increasing the value of ignition voltage and electric discharge time, the values of the diameter deviation and the roundness error of the machined hole surface also increase.

- The interaction between ignition voltage and electric discharge time has a negligible influence on the diameter deviation and the roundness error of the machined hole surface.

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