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OPTIMIZATION OF EDM SMALL HOLE DRILLING PROCESS USING TAGUCHI APPROACH

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ABSTRACT

Electrical Discharge Machining (EDM) is a process used to remove or cut a material into desired shape through the action of spark discharge between the tool and work piece. The objective of this paper is to optimize the independent variables to achieve better accuracy in EDM small hole drilling by using Taguchi method. The L_9 orthogonal array is employed to study the performance characteristics in drilling operations of mild steel (AS3679) as workpiece by using 1 mm copper (Cu) pipe electrode. Three drilling parameters namely, pulse off time, peak current and servo standard voltage are considered to optimize drilling hole diameter. The result concluded that use of greater pulse off time, greater peak current and medium servo standard voltage give the better hole diameter for the specific test range. Further study in this topic could consider different factor such as pulse on time, material removal rate (MRR) and coolants to investigate how these factors would affect hole diameter.

Keywords: EDM small hole drilling, taguchi approach, AS3679.

INTRODUCTION

Electrical Discharge Machining (EDM) is a process that is used to remove metal through the action of an electrical discharge of short duration and high current density between the tool or electrode and the workpiece (Khanna & Garg, 2013). It has proved valuable and effective in machining of super tough, hard, high strength and temperature resistance of conductive material. These metals would have been difficult to machine by conventional methods (Singh, Chalotra, & Rajpal, 2015).
EDM small hole drilling is one of the EDM stand-alone machine used to drill small hole with an x–y axis that can machine blind or through holes (Hussain & Yusoff, 2014). This machine is one of the best ways in drilling super tough material especially in term of getting micro-hole. Material is removed by means of rapid and repetitive spark discharge across gap between electrode and work piece (Liew, Yan, & Kuriyagawa, 2014).

The basic physical characteristics of the EDM small hole drilling process is essentially similar to that of the conventional EDM process with the main difference being in the size of the tool used, the power supply of discharge energy, and the resolution of the X-, Y- and Z-axes movement. The schematic diagram of the machine is shown in Figure-1.

In previous works, a number of researchers have conduct studies to identify the optimum input parameter setting in gaining the best output in EDM small hole drilling. (Yusoff, Ghazalli, & Che Hussain, 2009) for instance implement Taguchi approach to identify best parameter setting to drill aluminum using EDM small hole drilling. (Dev, Patel, Pandey, & Aravindan, 2009) used similar technique to identify best parameter setting for SiCp-Al composite. Besides that, researcher also studies the machining quality when machining different materials such as titanium alloy (Hussain & Yusoff, 2014) and mould material (Kim & Lee, 2014).

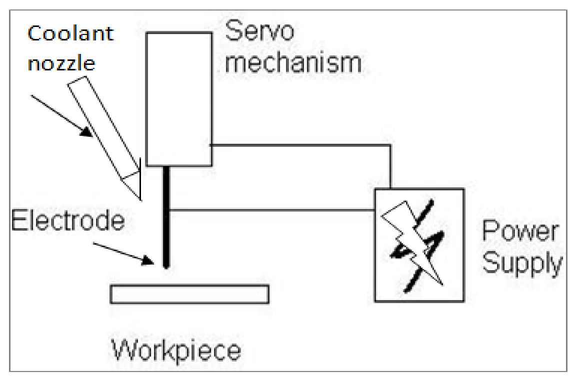

Figure-1. Schematic diagram of EDM drilling.

Even though there are a large number of works on EDM small hole drilling optimization, the needs for optimization is still there because of variance in machine, man and materials. The objective of this paper is to optimize the EDM small hole drilling parameter to machine mild steel grade AS3679 using Taguchi approach. Machining accuracy of the workpiece is one of the main problems to achieve since this characteristic determine hole accuracy. In order to achieve the objectives, optimum parameter of pulse off time, peak current, and servo standard voltage parameter have to be determined.

EXPERIMENTAL DETAILS

In this study, mild steel AS3679 with dimension 50mm x 75mm x 5mm is used as specimen as shows in Figure-2.

Figure-2. Sample of specimen.

Meanwhile, the electrode material is copper with 1 mm diameter. In EDM small hole drilling, the electrode is equipped with internal cooling channel. The machine used for experimental purpose is Sodick K1C EDM small hole drilling as shown in Figure-3.

Figure-3. Sodick K1C EDM.

In order to design the experiment, Taguchi orthogonal array is used (Taguchi, Chowdhury, & Wu, 2005). In this study, three parameters that considered are pulse off time, peak current, and servo voltage. Each of parameters is set at three levels as in Table 1. Meanwhile, the output parameter is the actual hole diameter that produces using different input parameter setting.

To select an appropriate orthogonal array for experiments, the total degrees of freedom need to be considered. The degrees of freedom are defined as the number of comparisons between process parameters that need to be made to determine which level is better and specifically how much better it is. For example, a three-level process parameter counts for two degrees of freedom. The degrees of freedom associated with interaction between two process parameters are given by product of the degrees of freedom for the two process parameters. However, in this study, the interaction between the drilling parameters is neglected. Therefore, there are six degrees of freedom owing to the three drilling parameters in drilling operations.

Table-1. Input parameter level setting.

Symbol	Drilling Parameter	Level 1	Level 2	Level 3
A	Pulse of time	8	2	6
B	Peak current	5	7	9
C	Standard voltage	2	4	6

Once the degrees of freedom required are known, the next step is to select an appropriate orthogonal array to fit the specific task. Basically, the degree of freedom for the orthogonal array should be greater than or at least equal to those for the process parameter. In this study, a L_9 orthogonal array was used. This array has twenty six degrees of freedom and it can handle three-level process parameters. Table 2 shows experimental table for this work.

The goal of this research is to produce minimum diameter, in a drilling operation. Smaller diameter values represent better or improved accuracy. Therefore, a smaller-the-better quality characteristic was implemented and introduced in this study. The signal-to-noise ratio (S/N) formula is presented in equation 1.

Smaller-the-better:

$$S/N = -10\log^{\left(\frac{1}{n}\sum_{i=1}^{n} y_i^2\right)} \quad (1)$$

Where y is the observed data and n is the number of observations.

EXPERIMENTAL RESULT AND DISCUSSION

Table-2 presents the experimental results as well as calculated signal-to-noise ratio for respected experiment number. Since the experimental design is orthogonal, it is then possible to separate out the effect of each drilling parameter at different levels.

For example, the mean S/N ratio for the pulse off time at level 1, 2 and 3 can be calculated by averaging the S/N ratios for the experiments 1-3, 4-6, and 7-9, respectively. The mean S/N ratio for each level of the other drilling parameters can be computed in the similar manner. The mean S/N ratio for each level of the drilling parameters is summarized and called the mean S/N response table for hole diameter (Table-2). In addition, the total mean S/N ratio for the nine experiments is presented in Table-3.

Table-2. Experimental results for hole diameter and S/N ratio.

No. of Exp	Drill parameter level			Hole diameter ø (mm)	S/N ratio
	Pulse Off Time	Peak Current	Standard Voltage		
1	1	1	1	1.117	-0.9611
2	1	2	2	1.104	-0.8594
3	1	3	3	1.092	-0.7645
4	2	1	2	1.077	-0.6443
5	2	2	3	1.102	-0.8436
6	2	3	1	1.113	-0.9300
7	3	1	3	1.107	-0.8830
8	3	2	1	1.113	-0.9300
9	3	3	2	1.072	-0.6039

Table-3. Response table mean S/N ratio for hole diameter factor and significant interaction.

Symbol	Drilling parameter	Mean S/N ratio			
		Level 1	Level 2	Level 3	Max - Min
1	Pulse off time	-0.8617	-0.8060	-0.8056	0.0561
2	Peak current	-0.8295	-0.8777	-0.7661	0.0634
3	Standard voltage	-0.9404	-0.7025	-0.8304	0.1100

Figure-4 (a-c) shows the mean S/N ratio graph for hole diameter. The S/N ratio corresponds to the smaller variance of the output characteristics around the desired value. Figure-4(a) shows effect of pulse off time to the hole diameter. Based on the graph, there is a small changes of the output parameter (hole diameter) when the pulse off time level is change from level 1 to level 2. While, the hole diameter is nearly constant when the pulse off time is change from level 2 to level 3. This trend shows that the pulse off time only has small contribution (or no contribution at all) to the hole diameter. This is because the pulse off time is more associated with flushing efficiency compared with material removal.

Meanwhile Figure-4(b) shows effect of peak current to the hole diameter. Based on the observation, the peak current also has good effect on the output parameter. On the other hand the standard voltage level has greater effect on the drilling hole diameter based on Figure-4(c). However, the significant of the effect must be determined with statistical test. Therefore, the Analysis of Variance (ANOVA) test is conducted.

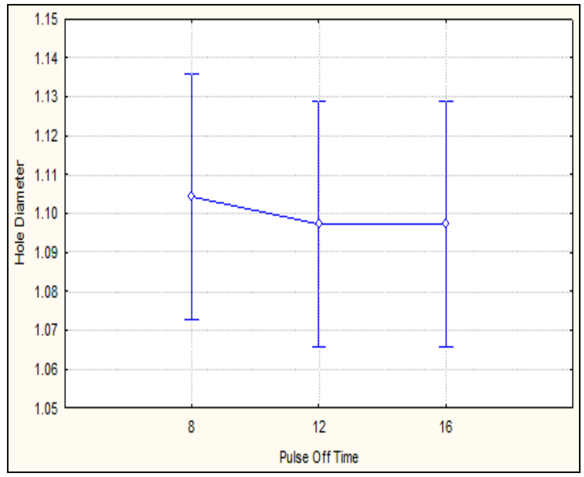

Figure-4(a). Effect of Pulse Off Time to Hole Diameter.

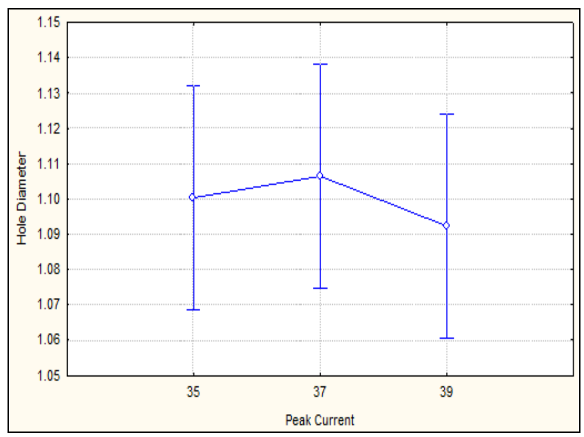

Figure-4(b). Effect of Peak Current to Hole Diameter.

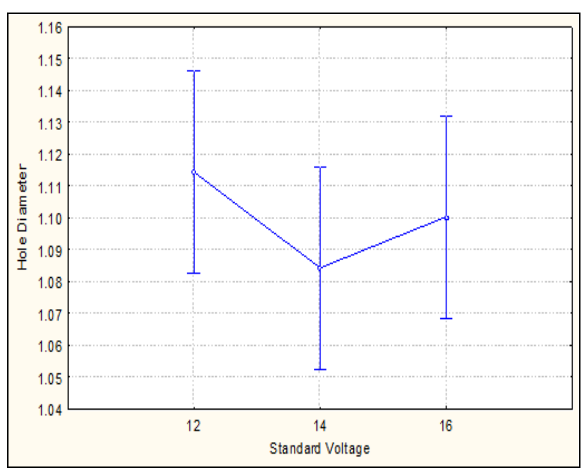

Figure-4(c). Effect of Standard Voltage to Hole Diameter.

ANALYSIS OF VARIANCE (ANOVA)

Table-4 shows the result of ANOVA for hole diameter. From this table the peak current and standard voltage has the highest percent contribution. It means this parameter is the significant drilling parameters for affecting the hole diameter. The change of the pulse off time in the range given by Table-4 has an insignificant effect on hole diameter.

Therefore, based on the S/N ratio and ANOVA analyses, the optimal drilling parameters for hole diameter are the pulse off time at level 3, the peak current at level 3, and the servo standard voltage at level 2.

Table-4. Result of the analysis of variance for hole diameter.

Source of variation	Degree of Freedom, D_p	Sum of Squares, SSp	Mean Square	F Ratio	Contribution, ρ (%)
Pulse off time	2	0.00010	0.00005	0.00078	4.81
Peak current	2	0.00030	0.00015	0.00233	14.42
Standard voltage	2	0.00135	0.00068	0.01047	64.90
Error	2	0.00033	0.00016	0.00256	15.87

CONCLUSIONS

In this study, the effect of pulse off time, peak current and servo standard voltage in EDM small hole drilling for mild steel grade AS3679 is studied using Taguchi approach. The experimental table is setting up using L9 orthogonal array. The experiments were conducted using Sodick K1C machine. The results demonstrated that the peak current and standard voltage are the main parameters from three controllable factors, based on the percentage of contribution (14.42% and 64.9% respectively). The optimum parameter that found from the experiment is higher pulse off time, higher peak current and medium standard voltage. In future, different factor such as pulse on time, material removal rate (MRR) and different coolants type will be considered to have better understanding on micro-EDM drilling.

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