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Research Article

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Parametric Optimization of Surface Roughness in EDM Using Low-Frequency Vibration

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Abstract Improve quality of molds surface after electrical discharge machining (EDM) still being considered by many researchers. Integrated vibration in electrical discharge machining showed that it is one of processing methods can get high efficiency. This paper report on the results of surface quality of mold steels after EDM **using low-frequency vibration of workpiece assigned** in fine machining. The process parameters includes pulse on-time (Ton), pulse off-time (Tof), current (I) and frequency of vibration (F) were parameters considered in the research. These material are most commonly used with die sinking EDM in the manufacture of molds has been selected as the subject of research: workpiece material was SKD61 mold steel, and electrode material was copper. Taguchi method is used to design experiments. The influence of the parameters to surface roughness (SR) was evaluated through the average value and ratio (S / N) of it. The results indicate that the optimum parameters required to achieve the multi-objective were Ton = 12 µs, I = 6 A, Tof = 12.5 µs, and F = 512 Hz, at the resultant quality criteria of SR = 2.19 µm.

Keywords SR; Frequency, Vibrational, EDM

1. Introduction

Electrical discharge machining (EDM) is a method most commonly used for the fabrication of surface molds. This method has no binding of hardness between workpiece and tools, problems such as vibration, mechanical stress, noise does not appear during the processing. However, Machining by EDM with low machining productivity and machining surface quality is not high and this leads to increased manufacturing costs of its. The large number of parameters of technology, machining mechanism is unclear and process optimization always require exact values of the process parameters. And this has caused many difficulties in research on EDM.

The EDM process has been frequently used to form dies, tool. It is highly effective in the machining of complex geometries in difficult-to-work materials. Integrated vibrations in EDM have been achieved by integrating electrodes or workpieces. The low-frequency vibrations are assigned to electrical arc machining for W9Mo2Cr4V. The results indicate that integrated vibration in the machining process increases MRR by reducing the tool wear and surface roughness. Similar results have been reported for EDM ofInconel-718 via the application of low-frequency vibrations (F = 0–80Hz). The results indicated that the increased vibration frequency causes an increase in the MRR by 27.6%, electrical wear rate (EWR) by 6.16%, in addition to a reduction of overcut and taper angle by 31.84% and 18.58%, respectively. The increasing performance measure is associated with the improvement in the flow of chips at various vibrations of electrodes or workpieces in EDM drilling [1-10]. The assignment of vibrations to µ-EDM results in higher efficiency.

2. Experiment Design Method

The overall objective was to create a product with the highest quality and lowest price. These methods were based on traditional experimental design, following the Taguchi method, which can examine the influence of process parameters, specific to the quality of the production process and cost. There are many orthogonal array's available in the Taguchi's method, therefore selection depended upon the number of factors and degrees of freedom of each factor. The analysis of variance (ANOVA) was based on data obtained from Taguchi's experimental design and was used to select new parameter values to optimize the quality characteristics. Data from the table was analyzed by using charts, pictures, ANOVA and the Fisher ratio test (F). To analyze the results of experiments Taguchi used a ratio, S/N, to evaluate the impact of interference. The S/N ratio was calculated to determine the effects of these parameters and their interactions to the quality characteristics in processing.

The Lower- the- better:

$$(S/N)_{LB} = -10\log(MSD_{LB}) \quad (1)$$

where $MSD_{LB} = \frac{1}{r}\sum_{i=1}^{r} y_i^2$

In this equation, MSD_{LB} represents the mean square deviation, and $\sum_{i=1}^{r} y_i^2$ is the overall typical value of each experiment.

3. Experimental Setup

Through conducting the EDM, experiments involve current (I), voltage (U), pulse on-time (Ton), pulse off-time (Tof). SKD61 die steel has been used as workpiece material having dimensions of 25x25x30 mm (Figure 1). Copper (Cu) electrode material was used in the EDM process. The dielectric fluid of the experiment is D323 oil (Vietnam). The CNC- CM323C die-Sinking machining (CHMER, Taiwan) has been used to experiment. Mass of a workpiece is measured before and after machining with AJ 203 electronic balance (Shinko Denshi Co. LTD - Japan) with a maximum weight of 200g, an accuracy of 0.001g.The vibration unit (Modal: Exciter 4824, Brüel & Kjær, Denmark) was used to investigate the vibrations. The Taguchi method is frequently adopted to optimize the EDM parameters. Taguchi method has numerous advantages such as its ability to accommodate many parameters, the arbitrary choice of its levels, and the smaller number of experiments. In addition, Taguchi is suitable for studying undefined machining methods or machining methods at an early stage. In this study, Taguchi's appropriate orthogonal matrix (L9) was chosen according to **Table 2**.

Table 1: The input of the process parameters

Levels	I (A)	Ton (µs)	Tof (µs)	F (Hz)
1	3	12	5.5	128
2	6	25	12.5	256
3	8	50	25	512

Table 2: Experimental matrix

No EX.	I	Ton	Tof	F	SR (mm^3/min)	S/N
1.	1	1	1	1	2.333	-6.927
2.	1	2	2	2	2.827	-6.808
3.	1	3	3	3	3.564	-9.455
4.	2	1	2	3	4.460	-10.317
5.	2	2	3	1	3.154	-8.691
6.	2	3	1	2	5.470	-11.843
7.	3	1	3	2	5.855	-10.021
8.	3	2	1	3	9.564	-12.547
9.	3	3	2	1	5.205	-12.191

4. Results and Discussion

4.1. Results of experimental

Result of machining surface roughness is evaluated by value of SR. Each experiment was repeated 3 times. Minitab software is currently being used very common to analyze experimental results. The results are processed using Minitab 18 to determine the average value of SR and ratio S / N of them. The results are shown in Table 2.

4.2. Effect of parameters and interaction between process parameters on SR

Main effect plots had shown in the Figure 1 shows that the surface roughness increases with increase in the current and pulse on time. The surface roughness decreases with graphite powder mixing in the dielectric. The workpiece material also affects the surface roughness. Table 3 shows ranks to various input parameters in terms their relative significance.

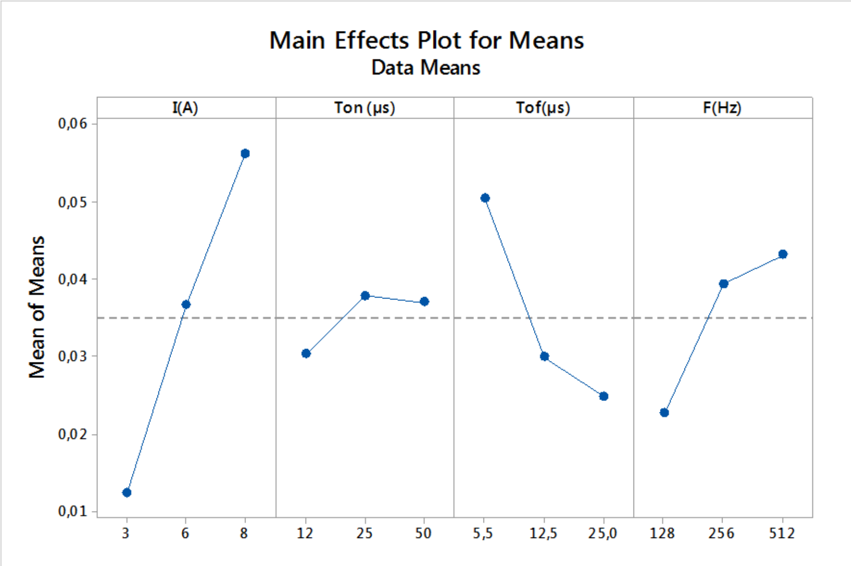

Figure 1: Main effects plot for mean surface roughness

Table 3: Response table for means of surface roughness

Level	I(A)	T_{ON}(μs)	T_{OF}(μs)	F(Hz)
1	2.560	2.890	3.457	3.003
2	2.973	3.050	3.180	3.290
3	3.327	3.650	2.953	3.497
Rank	1	2	3	4

4.3. Optimization parameters of SR

The S/N ratio several repetitions into one value which reflects the amount of variation present. The values of all the results according to Taguchi array parameter design layout are presented in this section. The S/N ratios have been calculated to identify the major contributing factors for variation in the roughness. In this design situation, roughness is the type of 'lower is better', which is a logarithmic function based on the mean square deviation (MSD), given by (1).

In this experimental analysis, the main effect plot and interaction plot in Figure 2 used to estimate the mean surface roughness. The greater S/N ratio showed that research results were less affected by noise. The S/N ratio value for SR was affected by the parameters shown in Figure 2. The results showed that the steel materials, Current of 3 A, pulse on time of 12μs, pulse off-time of 25μs, and frequency of 128 Hz influenced the S/N ratio for SR. These process parameters decreased the degree to which the SR was affected by the noise, and consequently resulted in most optimal value for SR with the least amount of alteration.

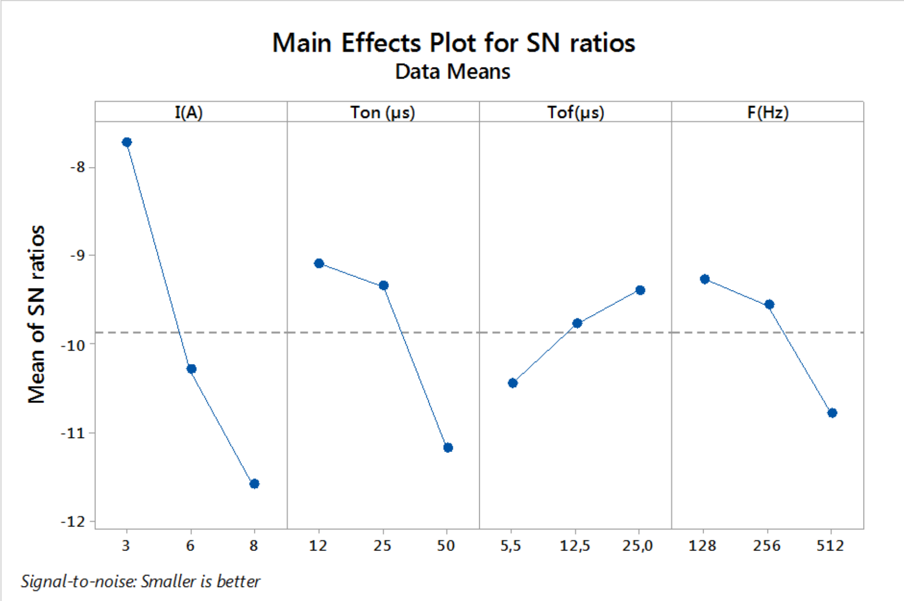

Figure 2: Main effects plot for S/N of SR

Estimated value of $\overline{R}_a$ *under optimal conditions:* Process parameters for Ra included the following: A1, B1, C3, D1. Therefore, the SR value was determined by the formula (2):

$$R_{aOPT} = I_1 + T_{ON1} + T_{OF3} + F_1 - 3.T \quad (2)$$

$\overline{R}_{aopt}$ = 2.05 µm, the confirmation experiments were conducted where the process parameters were determined through calculations. The result of SR = 2.19 µm demonstrated high accuracy, with discrepancies between the calculated and experimental results of 6.82%.

5. Conclusions

The application of low-frequency vibration in EDM can be used to significantly increased machining efficiency. This often results in the shortest distance between tools and workpieces. The approach also enhances the flushing effect and creates better dielectric circulation between the electrode and the workpiece. The effect of parameters i.e. pulse on time, pulse off time, current, and frequency of vibration were evaluated using ANOVA and factorial design analysis. The purpose of the ANOVA was to identify the important parameters in prediction of surface roughness. Some results consolidated plots are given below: The optimal process parameters are Ton = 12 µs, I = 3 A, Tof = 25 µs, and F = 128 Hz and the associated quality indicators are SR = 2.19 µm. Some parameters like polarity, voltage, amplie of vibration were kept constant, these can also be varied and their effect studied.

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