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Study of Tool Wear Optimization in Micro Holes Machining of SS316 by Die Sinker Electrical Discharge Machining

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Abstract —In modern contribution the tool cost play a vital role in the total manufacturing cost is approximately 50%. In EDM, tool wear is a major problem, because of it the geometrical accuracy and form of the tool are not reproduced on the workpiece exactly while machining. Due to these reasons the tool wear has to be carefully handled while planning electrical discharge machining operations of micro holes. This paper studies the influence of various factors contributing micro hole machining by die sinker EDM with micro electrodes rod of diameters 300µm, 500µm, 900µm with process parameters current, time-on, time-off. The objective of the research is to investigate the wear behaviour of electrodes with Taguchi's L9 Orthogonal array method to optimize the electrical discharge machining process variables for achieving minimum tool wear rate.

Keywords —EDM,Tool wear, Taguchi method, machining conditions

I. Introduction

An ideal tool electrode in electrical discharge machining should not only remove the maximum amount of material from the workpiece surface, but it should resist self-erosion. The machinability of a material is a factor of its electrical and thermal conductivity. Commonly used copper electrode has high thermal and electrical conductivity, resulting in a more effective energy transfer to the workpiece. Duration of each thermal spark mechanism is very short and entire cycle of machining time is done in few micro-seconds with in the area over which a spark is effective is also very small. However, temperature of the area under the spark is around 80000C to 120000C. As a result, the spark energy is capable of removing the melting and vaporizing material from localized area. The material removal mechanism is in the form of craters which spread over the entire surface of the work piece. Finally the dimensional cavity is produced on the work piece is approximately to the replica of the tool [1].

To have machined geometrical cavity as replica of the tool, tool wear should be zero. To minimize tool wear the machining parameters should be selected carefully. While EDM machining particles eroded from the electrodes are known as debris. Usually the amount of material eroded from the tool surface is much smaller than that from the work piece surface [2]. A very small gap between the electrodes and work piece is to be maintained to have the spark to occur. For this purpose, a tool driven by the servo system is continuously moved towards the work piece [10, 11, 12]. Taguchi single objective optimization method was employed to obtain optimal setting of EDM process parameters. Confirmation experiments were carried out to validate the optimal setting of process parameters for achieving minimum value of tool wear rate [7, 8, 9].

II. Experimental methods & Materials

The present work deals with micro hole machining of SS316 stainless steel has been used as work piece material with electrolytic copper were cylindrical grinded to diameter of 300µm, 500µm, 900µm was used as tool electrode are table 1,2. The EDM machining conditions were taken as Current, T-on, T-off.

Table 1. Chemical Composition of SS316

Element	%
C	0.08
Mn	2
Si	0.75
P	0.03
Cr	1.8
Mo	3
Ni	1.4
N	0.10

Table 2. Chemical Composition of Copper

Element	%
Cu	99.90
Zn	0.057
Al	0.15
Bi	0.001
Pb	0.0008

III. EXPERIMENTAL METHODOLOGY & PROCEDURE

Experiments were designed using Taguchi L9 orthogonal array. Table 3.shows the process parameters and their levels. Orthogonal arrays are used in these approaches which reduces the experimental runs [3,4,5,6]. During the experiment we have taken total 9 readings on the copper electrode. Time taken for machining and then weight loss of work piece and electrode are calculated. Taguchi's method has few benefits such as with fewer number of trials run an acceptable solution is achieved. It minimizes the variability around the target value with lesser experimental cost. The optimal setting of parameters obtained from analysis can also be used in real production environment. To determine the effect of each variable on the output, the signal-to-noise ratios, are calculated for each experiment. For the case of minimizing the performance characteristic, the following definition of the SN ratio can be used:

Table 3.Machining conditions for the Experiments

Factors	Level 1	Level 2	Level 3
Current (I)	0.2	0.4	0.8
T-on	6	8	10
T-off	4	6	8

Table 4. Experimental combinations as per L9 Orthogonal array

Experiment No.	Levels of parameters			Actual values of parameters		
	A	B	C	Current (amps)	Ton (µs)	Toff (µs)
1	1	1	1	0.2	6	4
2	1	2	2	0.2	8	6
3	1	3	3	0.2	10	8
4	2	1	2	0.4	6	6
5	2	2	3	0.4	8	8
6	2	3	1	0.4	10	4
7	3	1	3	0.8	6	8
8	3	2	1	0.8	8	4
9	3	3	2	0.8	10	6

IV. RESULTS AND DISCUSSION

The experimental results of Tool wear were obtained after conducting the micro holes machining on Die sinker EDM by copper electrode with diameter 300µm, 500µm, 900µm for all nine specimens and the application of three parameters are summarized in Table (4, 5). In the latter, the results were analysed by employing main effects, and the signal-to-noise ratio (S/N) analyses. Finally, a confirmation test was carried out to compare the experimental results with the estimated results.

Table 5. Experimental observations of tool wear by EDM

Experiment No.	Current (amps)	Ton (µs)	Toff (µs)	Tool wear With dia (300µm)	Tool wear With dia (500 µm)	Tool wear With dia (900 µm)
				mg/min	mg/min	mg/min
1	0.2	6	4	0.05820722	0.041459	0.017326518
2	0.2	8	6	0.06651885	0.028211	0.013747594
3	0.2	10	8	0.04718836	0.022161	0.010343936
4	0.4	6	6	0.03595398	0.021211	0.009839292
5	0.4	8	8	0.05293006	0.034594	0.016091954
6	0.4	10	4	0.03907638	0.027241	0.012434999
7	0.8	6	8	0.02452698	0.025840	0.013584320
8	0.8	8	4	0.05330053	0.057701	0.030113505
9	0.8	10	6	0.02938034	0.038952	0.019524317

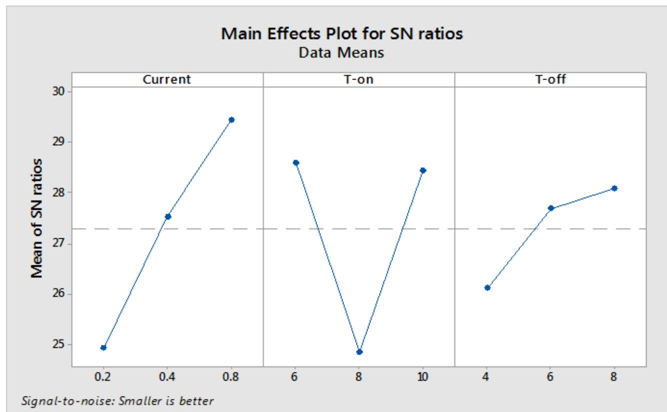

Figure 1: S/N ratio of tool wear with 300µm electrode for micro hole machining

Table 6.Response Table for Signal to Noise Ratios of 300µm with smaller the better

Level	Current	T-on	T-off
1	24.92	24.60	26.11
2	27.52	24.84	27.69
3	29.44	28.44	28.09
Delta	4.52	3.75	1.98
Rank	1	2	3

From figure 1, the graph obtained shows the combination **A3B1C3** (i.e., Current 0.8, T-on 6, T-off 8) for 300µm electrode for micro hole machining with minimum tool wear and the combination is coincide with the experimental observations .Signal to noise ratio response tabulated with all the average of the experiment data with factors dominating the input parameters while machining in table 6.

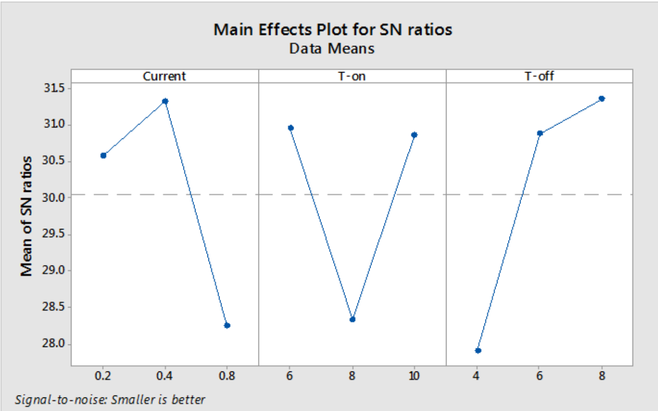

Figure 2: S/N ratio of tool wear with 500µm electrode for micro hole machining

Table7.Response Table for Signal to Noise Ratios of 500µm with smaller the better

Level	Current	T-on	T-off
1	30.58	30.96	27.91
2	31.33	28.33	30.88
3	28.24	30.86	31.35
Delta	3.09	2.63	3.45
Rank	2	3	1

From figure 2, the graph obtained shows the combination **A2B1C3** (i.e., Current 0.4, T-on 6, T-off 8) for 500µm electrode for micro hole machining with minimum tool wear and the combination is not coincide with the experimental observations .Signal to noise ratio response tabulated with all the average of the experiment data with factors dominating the input parameters while machining in table 7.

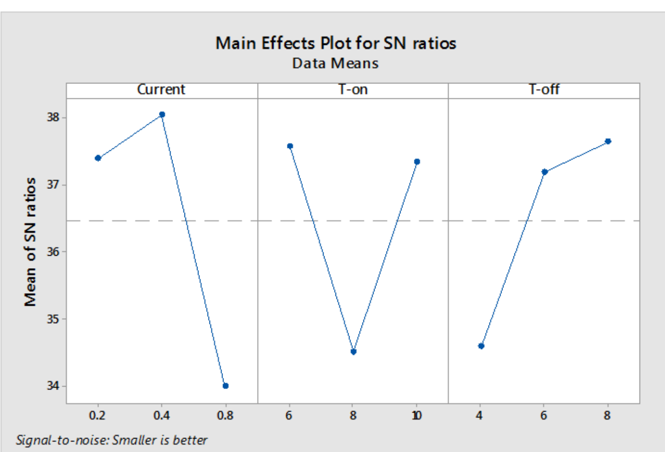

Figure 3.S/N ratio of tool wear with 900µm electrode for micro hole machining

Table 8.Response Table for Signal to Noise Ratios of 900µm with smaller the better

Level	Current	T-on	T-off	Level
1	37.39	37.57	34.59	1
2	38.04	34.51	37.19	2
3	33.98	37.33	37.64	3
Delta	4.05	3.06	3.05	Delta
Rank	1	2	3	Rank

From Figure 3, the graph obtained shows the combination **A2B1C3** (i.e., Current 0.4, T-on 6, T-off 8) for 900µm electrode for micro hole machining with minimum tool wear and the combination is not coincide with the experimental observations .Signal to noise ratio response tabulated with all the average of the experiment data with factors dominating the input parameters while machining in table 8.

V. CONFORMATION TEST

The final step was to verify the estimated result against experimental value with the combination of process parameters and their levels. It may be noted that if the optimal combination of process parameters and their levels were not coincidently match with one of the experiments in the OA, then confirmation test is required

$$y_{opt} = m + (mA_{opt}-m) + (mB_{op}t-m) + (mC_{opt}-m)$$

Where m: average performance
Y optimum condition

- for **500µm** micro hole machining of TWR = 0.01862777mg/min.
- for **900µm** micro hole machining of TWR = 0.00121079mg/min.

Table 9. Conformation test for the Optimum machining conditions for TWR

MRR	Optimum machining conditions for TWR of 300µm ,500µm, 900µm micro holes	
	Prediction	**Experiment**
Level	A2B1C3	A2B1C3
for **500µm**	0.01862777	0.0183123
for **900µm**	0.00121079	0.0011967

VI. CONCLUSIONS

On the basis of the results obtained from the present case study the following can be concluded:

- The combination of parameters and their levels for optimum tool wear for 300 µm electrode is A3B1C3 (i.e. Current 0.8Amps,T-on 6µs, T-off 8 µs) which is coinciding with the experimental analysis.

- The combination of parameters and their levels for optimum tool wear for 500 µm& 900 µm electrode is A2B1C3 (i.e. Current 0.4Amps,T-on 6µs, T-off 8 µs) from the confirmation test obtained.

The tool wear rate is mainly influenced by current, T-on, T-off had less on tool wear and has least effect on it.

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