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Optimization of Electrode Tool Wear in micro holes machining by Die Sinker EDM using Taguchi Approach*

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Abstract

In industries many problems encountered in machining of micro holes. To overcome this, non-traditional machining processes are often used. The study is to optimization the significant machining parameter that influences the EWR in machining of micro holes using a die sinker EDM with Copper electrode of diameter 300 µm. The experiment studies were conducted by varying the current, pulse-on time and pulse-off time, as the process parameters for Taguchi experiment design and to ensure the required dimensional accuracy and geometry.

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Keywords:Die sinker EDM, Electrode wear ratio(ETWR), taguchi design of experiment, microholes, microstructures

1. Introduction

Electrical Discharge Machining (EDM) is a popular non-conventional machining process that is capable of machining precise and complex geometries in electrically conductive hard materials. One of the critical limitations,

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for EDM process will only works with materials having electrically conductive. The process Produces spark plasma in the form heat that melts and vaporises the workpieces by ionisation within the discharge column and impulsive pressure by dielectric fluid to remove the melted material [1, 2]. Although, EDM can produce finishing operations of precise parts, rough machining gives poor surface integrity since the melted material is flushed away incompletely and the remaining material resolidifies to form discharge craters, micro cracks, and white layer [3]. Thus, by choosing the suitable machining parameters, the amount of material remove can be controlled effectively to produce complicated and accurate components.

Machining of micro holes are frequently required in industries, such as medical, automobile, aerospace, electronics. Traditional machining may produce the holes, however much problems were encountered in this practice. The accuracy of small hole-drillings is highly influenced by drill bending rigidity and thinning of the chisel point [4, 5]. To overcome mechanical problems faced in traditional drillings, non-traditional machining processes is applied.

Electrical Discharge Machining (EDM) is another technique to produce micro hole. It can machine a micro hole with diameter down to 170 -500μm[6].The help of NC and CAD minimized the machining time of small hole drilling [7]Application of vibration on the tool or the workpiece enabled this method to produce smaller hole size [8].Tool wear and workpiece material removal per discharge are important variables [9]. Hole-machining by using EDM can be difficult when tiny electrode diameter is employed. Small-diameter-electrode could be sensitive on mechanical force due to rotation of the electrode. Vibration of the electrode might lead to an uncontrolled-movement. Therefore, drilling by using die sinker EDM might be more suitable since only penetration and retract movement of the electrode is required. The work was considered as the new process with less cost. With proper parameters selection, micro holes with diameter of less than 1 mm were successfully machined. However, slag and recast layer were formed at the surface of the hole.[10] With this consideration, the present work aims to study micro-hole drilling using die sinker EDM in SS316 material with copper electrode of diameter 300μm

2. Taguchi approach

Optimization of process parameters is the major step in the Taguchi orthogonal array method for achieving high quality without increasing cost. The optimal process parameters obtained from the Taguchi method are insensitive to the variation of environmental conditions and other noise factors. To select an appropriate orthogonal array for the experiments, the total degrees of freedom need to be computed. 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 Basically, classical technique of manufacture the process parameter design is complex and not easy to use. An advantage of the Taguchi method is that it emphasizes a mean performance characteristic value close to the target value rather than a value within certain specification limits, for improving the product quality. Additionally, Taguchi's method for experimental design is straightforward and easy to apply to many engineering situations, making it a powerful yet simple tool and can be used to identify problems in a manufacturing process from data already in existence.

3. Experimental Work

3.1. Workpiece, Tool Material and Specimen Preparation

SS316 are particularly well suited for parts and structures requiring high strength-to-weight ratio and are the probably the best known materials used extensively in aircraft, steam turbine, automobile .SS316 stainless steel has been used as work piece material with electrolytic copper were cylindrical grinded to diameter of 300μm was used as tool electrode. Table (1) shows the composition of SS316.

Table 1. Material Chemical Composition of SS316

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

3.2. Machining conditions for micro holes:

The machining process was carried on Acro EDM Machine. Only three parameters namely Current, T-on, T-off were investigated in this study. The selected machining process parameters along with their levels are given in Table (2).

Table 2. Experiment Process parameters and their levels

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

3.3. Selection of Taguchi orthogonal array:

The selection of an appropriate orthogonal array (OA) depends on the total degrees of freedom of process parameter and it is defined as the number of comparisons between process parameters that need to be made to determine which level is best and specifically how much best it is. The design of experiment generated by using the Taguchi orthogonal array of L9 (3x3) has been employed with the aid of Minitab 17 software. Table (3) shows the array with input parameters ie Current, T-on, T-off, were used in combination of their levels for each experiment. The output characteristics is electrode tool wear rate with the lower-the-better are analysed using the software.

Table 3. Experimental matrix adopted as per L9 Orthogonal array

Experiment No.	FACTORS		
	Current (amps)	Ton (μs)	Toff (μs)
1	0.2	6	4
2	0.2	8	6
3	0.2	10	8
4	0.4	6	6
5	0.4	8	8
6	0.4	10	4
7	0.8	6	8
8	0.8	8	4
9	0.8	10	6

4. Results & Discussion

The experimental results, in terms of Electrode Tool wear were obtained after conducting the micro holes machining on Die sinker EDM by copper electrode with diameter 300µm for all nine specimens and the application of three parameters are summarized in Table 4. 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 4. Factors with Experiments results of machined surface of SS316

Experiment No.	FACTORS Current (amps)	Ton (µs)	Toff (µs)	Results ETWR (mg)
1	0.2	6	4	0.0582072
2	0.2	8	6	0.0665188
3	0.2	10	8	0.0471884
4	0.4	6	6	0.0359540
5	0.4	8	8	0.0851064
6	0.4	10	4	0.0390764
7	0.8	6	8	0.0245270
8	0.8	8	4	0.0903405
9	0.8	10	6	0.0293803

4.1. Main effects

Design of experiments is to examine differences among level means for one or more factors. A main effect is present when different levels of a factor affect the response differently. The values of Electrode tool wear rate for each factor i.e. A, B and C at each level i.e. level 1, level 2 and level 3 were obtained from Minitab 17 and the results are summarized in Tables

Table 5. levels average for Electrode tool wear

Symbol	Parameters	Electrode Tool Wear Level - 1	Level - 2	Level - 3
A	Current	0.0573048	0.053378933	0.0480826
B	T-on	0.039562733	0.080655233	0.038548367
C	T-off	0.062541367	0.043951033	0.052273933

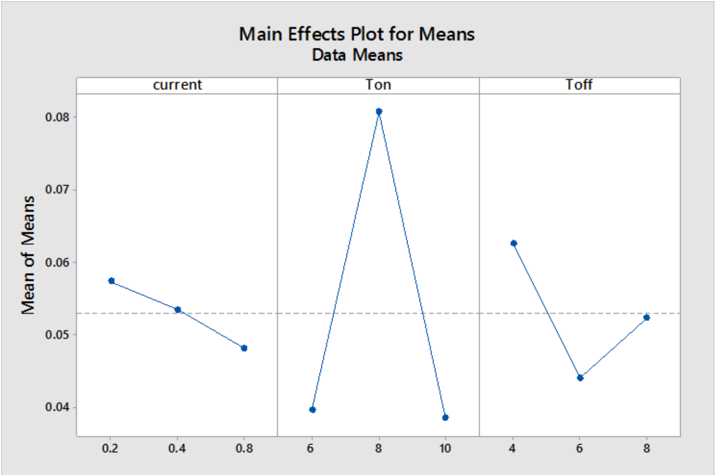

Fig .1.Main effects graph of Electrode tool wear

Figure1. shows the main effect graph for electrode tool wear characteristics formed by Minitab 17 software. The quality characteristics investigated in this study was "the-smaller-the-better" owing to the fact that smaller electrode tool wear value finish. It can be seen from Figure 1 that the combination of parameters and their levels A3B3C2 yield the optimum quality characteristic for

4.2. Signal to Noise Ratio (S/N)

Taguchi experiments design use a 2-step optimization process. In step 1 use the S/N ratio to identify those control factors that reduce variability and in step 2, identify control factors that bring the mean to target and have little or no effect on the S/N ratio. The signal-to-noise (S/N) ratio measures how the response varies relative to the nominal or target value under different noise conditions. As mentioned earlier the quality characteristic used in this study was "the-smaller-the-better" and "the-larger-the-better", i.e. the smaller electrode tool wear and the higher hardness of the test specimen results in better finish and consequently better performance. In order to perform S/N ratio analysis, mean square deviation (MSD) for quality characteristics and S/N ratio were calculated from the following equations.

Characteristic smaller the better:

$$MSD = 1/n \sum ki^2$$

$$S / N = -Log\,(MSD)$$

Where, Ki=is the electrode tool wear of i^{th} experiment

Using the above two formulae the S/N ratios for the nine experiments were calculated and the results are presented i

Table 6. S/N ratio responses for Electrode tool wear

Level	Current	Ton	Toff
1	24.91654	28.59246	24.57642
2	26.14917	21.94141	27.68835
3	27.90945	28.441	26.71039
Delta	2.99	6.66	3.11
Rank	3	1	2

4.3. Confirmation Test

The confirmation test is the final stage in the first iteration of the design of the experiment process and it is to validate the conclusions drawn during the analysis phase with a specific combination of the factors and levels previously evaluated. the optimal combination of process parameters with their levels was obtained, the final step was to verify the estimated result against experimental value. It may be noted that if the optimal combination of parameters and their levels coincidently match with one of the experiments in the OA, then no confirmation test is required. Estimated value of the bending deflection at optimum condition was calculated by adding the average performance to the contribution of each parameter at the optimum level Confirmation test was required in the present case study because the optimum combination of parameters and their levels i.e. A3B1C3 and A3B3C2.

Table:7. Results of confirmation test for Electrode tool wear rate

Optimal Condition for Electrode tool wear				
	Estimation	Experiment	Difference	Difference %
Level	A3B3C2	A3B1C3	-	-
EWR	0.0247401	0.0245270	0.00021	0.002
S/N value		32.207		

Table 7 Results of confirmation test for Electrode tool wear rate were obtained from the experiment and there were compared with the estimated value as shown. It clear shows that the difference between experimental result and the estimated result is only 0.00021 milligrams. This indicates that the experimental value of Electrode tool wear rate is very close to the estimated value. This verifies that the experimental result is strongly correlated with the estimated result, as the error is only 0.002%.and machined micro holes with SEM –images are shown in fig.2

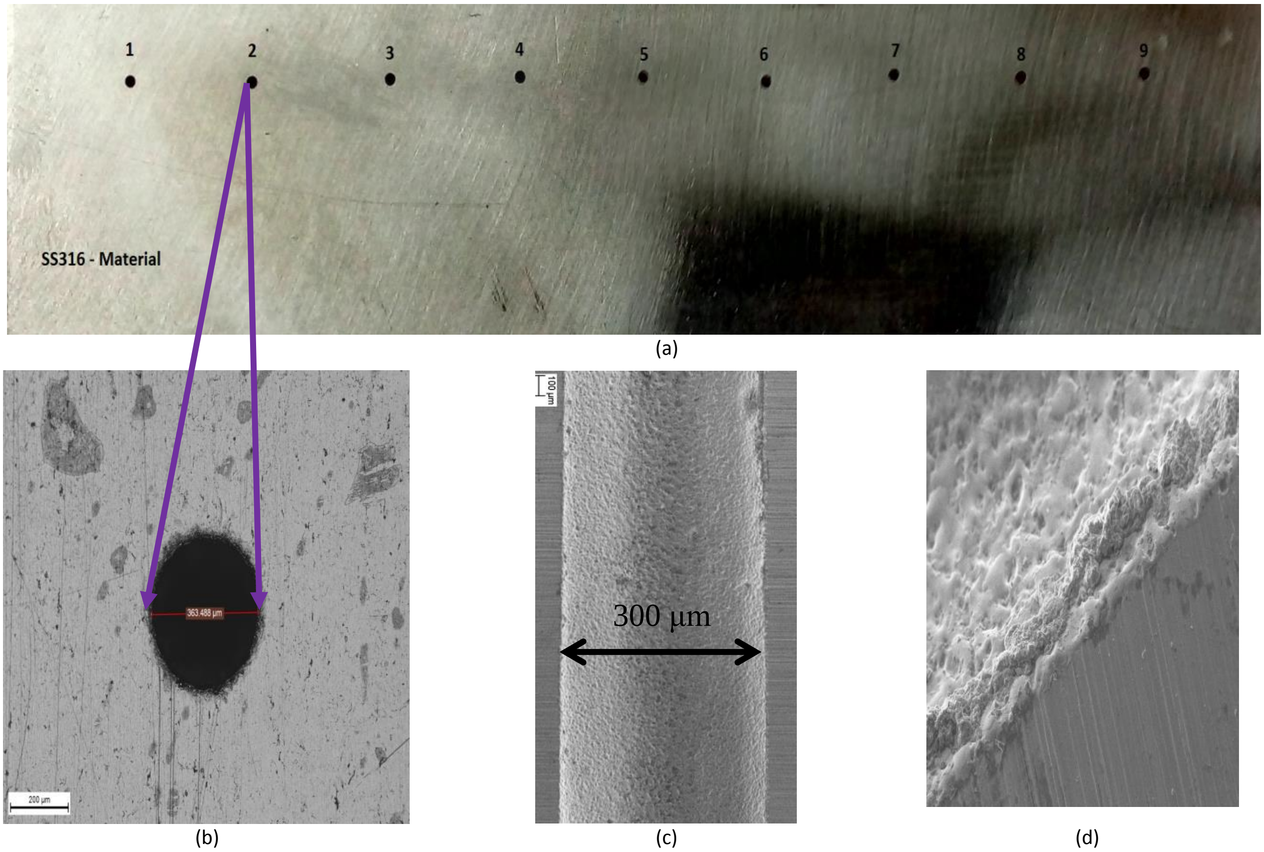

Fig 2: (a) SS316 materials with machined micro holes (b) 1000 X Microstructure of Machined micro hole (c),(d) SEM Microstructure of half section of micro hole

Conclusions

The present paper describes the optimization technique to determine the optimal machining conditions for improving the electrode tool wear rate for micro hole machining performance during the EDM of SS316 stainless steel. Results obtained from the present case study following as follows.

- Electrode Tool wear rate up to 0.00021 mg could be achieved by this process
- According to proposed level of parameters used in the experiment work, Electrode Tool wear rate 0.0245270 milligramscan be achieved by selection combination of A3B1C3 i.e. current of 0.8 Amps, T-on 6µs, T-off 8µs.from Signal to noise ratio the optimum parameters combinations i.e. A3B3C2.(Predicted)

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