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Optimization of process parameters of Material Removal Rate in Micro hole Machining by Die sinker EDM

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Abstract: The present work deals with optimization of material removal rate in micro holes machining of SS316 sheet materials using copper electrode of diameter 300µm, 500µm, 900µm on Die sinker Electrical discharge machining with input parameters of current (I), Time –on (T-on), Time –off (T-off) Experiment were conducted by taguchi L9 orthogonal Array design has been studied.

Keywords: *Die Sinker EDM, Material removal rate, Micro holes, Taguchi L9 OA*

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I. INTRODUCTION

EDM is a non-traditional machining process where hard materials are machined to get proper machining shape as per design specification in industrial sectors of moulds, dies, automotive, aerospace and surgical instruments. The working mechanism of EDM is based on the thermo spark energy where it is created between the electrode and the work piece, immersed in dielectric fluid with the way of electric current and separated by a small gap called spark gap. Pulsed arc discharges occur in this gap filled with a dielectric liquid like hydrocarbon oil or de-ionized (demineralized) water. The technique of material removal with EDM is still arguable. This is because ignition of electrical discharges in a liquid filled gap, when applying EDM, is mostly interpreted as ion action identical as found by physical research of discharges in air or in vacuum. The reduced spark gap results that the applied voltage is high enough to ionize the dielectric fluid. The electrode and work piece are separated by the short duration pulses which are generated in liquid dielectric gap. The spark is generated at the smallest inter electrode gap. The erosive effect of discharges removes the material from the tool and the work piece It flushes out the removed material during machining and cools the electrode from heating. The erosion of work piece material uses electrical energy and converts them into the thermal energy through a series of electrical discharges. The material is removed by partial vaporization or melting. The removed debris in molten state re-soldified and flushes out with help of dielectric fluid. The thermal energy generates plasma between tool and work material having temperature range 8000˚C to 12000˚C and high as 20000˚C. When the DC supply is switch off then plasma channel breaks down results in reduction in temperatures [6] In EDM operation, the material removal rate is less as compare to conventional machining. The amount of material removal rate is dependent upon the amount of pulsed current in each discharge, frequency of the discharge, dielectric flushing condition, and electrode and work piece material. Surface finish is an important factor for the work-piece. It becomes more vital so as to produce a better surface when hard materials are machined, requiring no subsequent polishing with accurate spark gap

II. EXPERIMENTAL METHODOLOGY

Here, the equipment used to perform EDM experiments and material removal rate analyses are described, and also the properties and dimensions of work piece and tool electrode have been mentioned.

2.1 EDM Equipment Machine:

Die sinker EDM ACRO Machine is used for conducting experiments

2.2 Materials required

Stainless Steel 316 is secondly most common used austenitic steel. The work piece materials were stainless steel 316 and copper electrode of diameters 300µm, 500µm, 900µm and chemical combination of workpiece & electrode are list in Table.1&Table.2

Table 1. Material Chemical Composition of AISI316

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

Table 2. Material Chemical Composition of Copper electrode

Element	Cu	Zn	Al	Bi	Pb
%	99.90	0.057	0.15	0.0011	0.0008

Table 3. Experimental machining condition for micro-hole machining on SS 316

Input Parameters	Description
Work piece	SS316
Electrode	300,500,900 µm
Dielectric fluid	EDM OIL
Polarity Positive	(work piece '+ve' and tool '-ve')
Current	0.2,0.4,0.8 amps
T-on	6, 8, 10
T-off	4, 6, 8

III. DESIGN OF EXPERIMENTS

An efficient experimental design helps to optimize the process and determine factors that influence the variability.Taguchi's orthogonal arrays (OA) provide a set of well-balanced experiments which gives much reduced variance for the experiment with optimum set of control parameters. Minitab 17 software was used to make the design of experiments (DOE). Based on the degree of freedom of control parameters, an L9 Taguchi OA was selected for the present experimental work. Three input parameters, ie, current (amp), pulse-ON time (µs) and pulse-OFF time (µs) each having three levels was used to create the orthogonal array were used in Table4..

Table 4. Machining Parameters used in the Experiment

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 5 shows for each combination of the factor levels with nine experiments are performed and the machining time is noted in each case

Table 5. Experimental parametric combinations adopted 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

Table 6. Experimental values and S/N ratio of MRR

Experiment No.	Current (amps)	Ton (µs)	Toff (µs)	MRR With Tool dia (300µm)	MRR With Tool dia (500 µm)	MRR With Tool dia (900 µm)
				Mg/mm3	Mg/mm3	Mg/mm3
1	0.2	6	4	3.864013	5.346186	1.77510179
2	0.2	8	6	2.950912	2.358473	1.31885253
3	0.2	10	8	2.734995	1.802401	0.60770623
4	0.4	6	6	3.987745	1.850106	0.93363944
5	0.4	8	8	2.638992	2.204102	0.91494253
6	0.4	10	4	3.603269	1.877167	1.25141307
7	0.8	6	8	8.951643	6.611296	1.75819911
8	0.8	8	4	2.458944	0.630271	2.26777855
9	0.8	10	6	3.116147	7.333569	1.13951012

Signal to noise Ratio wer plotted in table 7.

Table 7. Response Table for Signal to Noise Ratios of 300µm ,500µm, 900µm micro holes

A. Larger is better MRR-**300µm** micro holes machining

Level	Current	T-on	T-off
1	9.960	14.264	10.230
2	10.526	8.548	10.429
3	12.242	9.915	12.069
Delta	2.282	5.717	1.839
Rank	2	1	3

B. Larger is better MRR-**500µm** micro holes machining

Level	Current	T-on	T-off
1	9.044	12.10	5.340
2	5.893	3.436	10.03
3	9.901	9.298	9.462
Delta	4.008	8.668	4.694
Rank	3	1	2

C. Larger is better MRR-**900µm** micro holes machining

Level	Current	T-on	T-off
1	1.02075	3.09647	4.68150
2	0.19316	2.91460	0.98062
3	4.38258	0.41458	0.06563
Delta	4.18942	3.51105	4.74713
Rank	2	3	1

Fig 1. Main Effects Plot for SN ratios for **300µm**

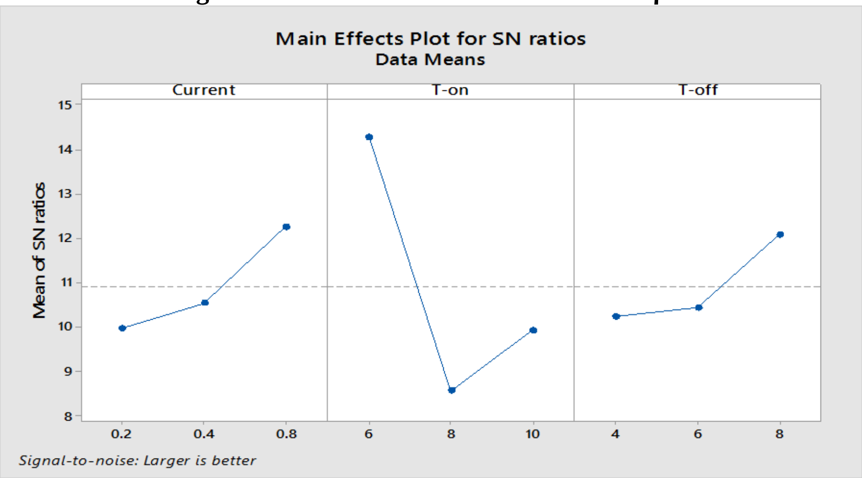


Fig 2. Main Effects Plot for SN ratios **500µm**

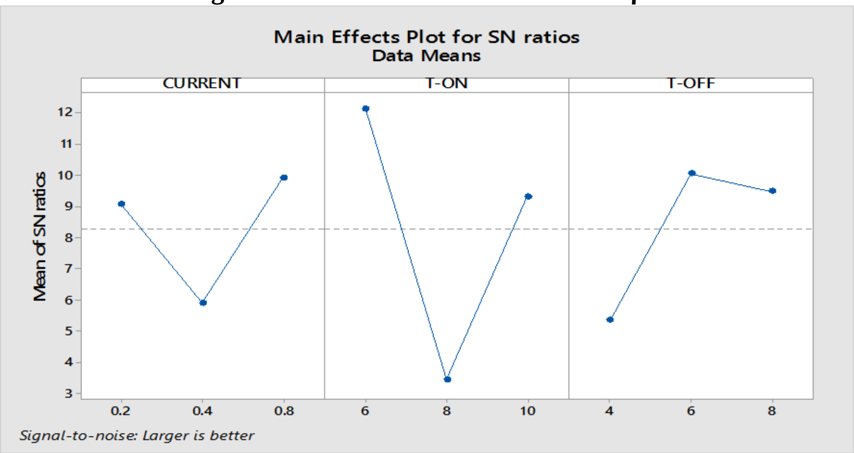
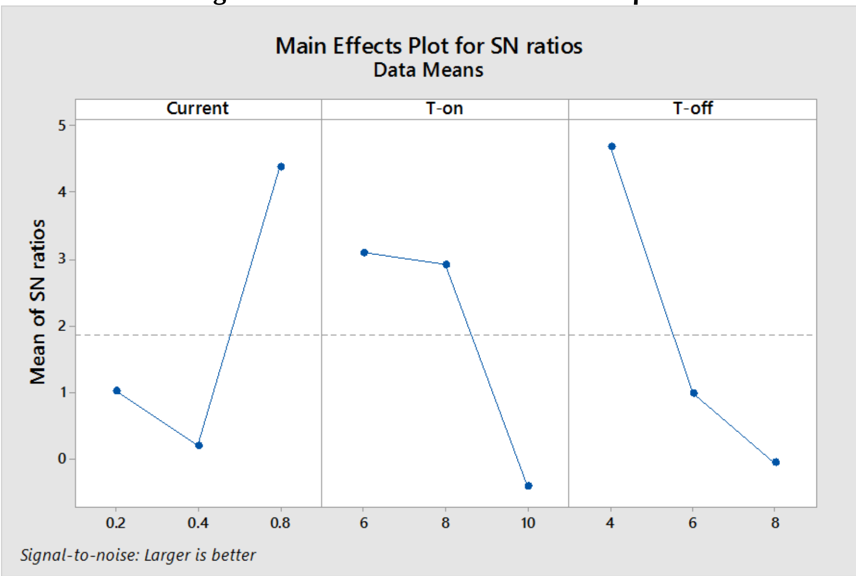


Fig 3. Main Effects Plot for SN ratios **900µm**



From Fig 1. The combination process parameter is A3B1C3 for **300µm**
From Fig 2. The combination process parameter is A3B1C2 for **500µm**
From Fig 3. The combination process parameter is A3B1C1 for **900µm**

Confirmation Test

Once the optimal combination of process parameters and 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 proceee 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 MRR =6.63831 mg/mm^3
- for **900µm** micro hole machining of MRR =2.31624 mg/mm^3

V. CONCLUSION

Results obtained from the Optimum machining conditions MRR for micro holes machining study following can be concluded:

Table 8. From the Confirmation test

MRR	Optimum machining conditions for MRR of 300µm ,500µm, 900µm micro holes			
	Prediction	Experiment	Difference	%
for **500µm**	6.63831	6.59962	0.03869	0.000387
for **900µm**	2.31624	2.23627	0.07997	0.000800

Table 9.The combination for optimum condition for better MRR of micro holes machining is

MRR	Combination	Current	T-on	T-off
for **300µm**	A3B1C3	0.8	6	8
for **500µm**	A3B1C2	0.8	6	6
For **900µm**	A3B1C1	0.8	6	4

Hence the significant improvement in MRR can be obtained by using the Taguchi optimization technique with minimum coast and loss in time in industrials.

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