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Optimization of Performing Parameters of SS-316 in Diesinker EDM

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Abstract

Electrical Discharge Machining (EDM) is a non-traditional process that uses electrical thermal energy to machine metals. It is extremely useful in machining hard materials. With the advantages, EDM has to offer and its presence as a common and useable technique, along with the other machining processes available to the industrial world, there is an added strain on the environment. The scope of this paper includes the optimization and analysis of dependent variables in EDM and the resulting outputs by experimentation on SS-316.

Keywords:

Material Removal Rate;
Overcut;
Tool wear;
Taguchi Method;
Fifth keyword.

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1. Introduction

Electro Discharge Machining (EDM) is an electro-thermal nontraditional machining Process, where electrical energy is used to generate electrical spark and material removal mainly occurs due to thermal energy of the spark.

For this spark creation a particular range of voltage, current and type of current are required. Which can be denoted as V, I(DC),Ton,Toff. This Ton and Toff will form when the current is DC pulse type. This pulse current is required because of generating the pulse in particular time interval. The Ton is mentioned for the time required for charging and Toff is mentioned for the time for discharging.In this period of discharge the spark will occur. This spark creats a high thermal engy which is sufficient to vaporize the material layer from the workpiece.

So the factors like Ton,Toff,V,I will affect in the variation of TWR,TOC and MRR.

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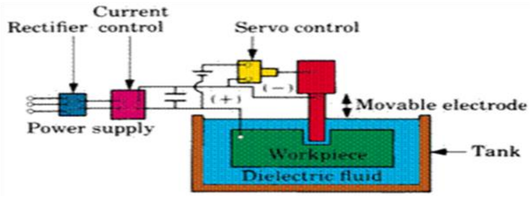

Fig -1: Schematic dig. Of EDM

2. Experimentation

An experimental study was undertaken to investigate the performance of copper and brass electrodes in die-sinking EDM machining of SS-316 material Stainless steel. The experimental set-up and experimental procedures used for machining of SS- 316 stainless steel in this study are presented. The methodology followed for the present study is highlighted in the final section. The experimental investigation was carried out in three stages. The first stage involved the selection of work material, selection of tool material and performance analysis of different electrodes in terms of various influencing parameters such as MRR, TWR, overcut. The experiments were conducted based on Taguchi' s L9 orthogonal array for each electrode. The second stage involved the optimization of multiple performance characteristics using Taguchi-based DOE method using Mini tab 17.0 software The third stage involves developing a regression model relationship the responses and factors using Minitab 17.0 and checking the correlation between them.

2.1 Selection Of Work Piece.

In this experiment SS-316L grade stainless steel of size 80×25×2 mm3 plate is chosen for conducting the experiment. Grade SS 316L is an austenitic Chromium-Nickel stainless steel with superior corrosion resistance. The low carbon content reduces susceptibility to carbide precipitation during welding. This permits usage in severe corrosive environments such as isolator diaphragms. It has excellent oxidization prevention in a numerous range of full of atmosphere environments as well as lots of corrosive medium. It has good corrosion resistance in intermittent service and brilliant weld ability property in entirely available standard fusion methods. The mechanical properties are listed in the table.

Table -1 showing Mechanical Properties of the material

Grade	Tensile strength (Mpa) min	Yield strength 0.2% proof (Mpa)min	Elong (% in 50mm)min	Hardness	
				Rockwell (HRB)	Brinell (HB) max
316l	485	170	40	95	217

2.2 ParametersConsidered In The Experimental Set Up

In this session experimental work is discussed which is based on design L9 orthogonal array. MRR, overcut diameter and tool wear rate of the electro discharge machining measured and effected values of the factors were found out using Taguchi DOE method .This analysis is adopted to find the best parameters setting. In the die-sinking micro-EDM, the influencing machining parameters are listed below:

2.2.1 Input Parameters/Process Parameters

a. Pulse on time -Ton
b. Discharge current-I
c. Feed rate-F

2.2.2. Output Parameters/Performace Characteristics

a. Material removal rate (MRR)
b. Tool wear ratio (TWR)
c. Overcut

Pulse on time, Discharge current, feed rate at three levels was considered as the machining parameters to optimize the process.

3. Experimental Set-Up

The experimentations be there performed by operating on Electric Discharge Machine classified as die-sinking type ELEKTRA EMS 5535 MODEL -whose polarization on the electrode be located as negative whereas that of work piece be located as positive. The dielectric liquid recycled was EDM oil having specific gravity - 0.763.

The experimentation has been done by using commercial grade of EDM oil whose specific gravity= 0.763, freezing point= 94ºC used as a catalyst liquid. It is recycled for each experiment by pump. It is works as a coolant and intermediate carrier of molecules between work piece and tool during spark erosion process important function of the dielectric fluid.

Fig. 2 Die Sinker EDM machine setup with tool and work piece (Model: ELEKTRA EMS 5535 MODEL)

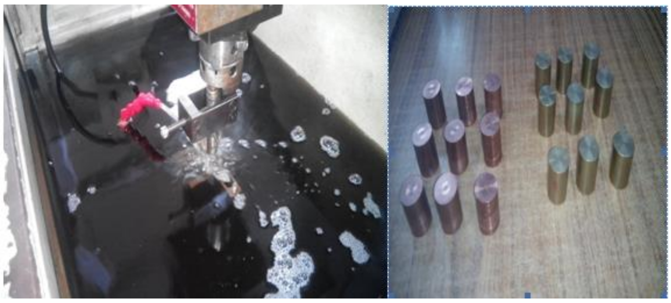

Fig. 3 Die Sinker EDM machining with tool and work piece (Model: ELEKTRA EMS 5535 MODEL)

3.1 Machined Workpiece

Fig.4 machining using brass as electrode

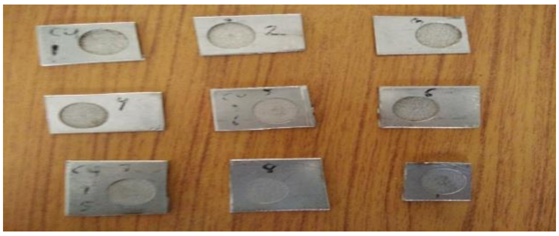

Fig. 5 machining using copper as electrode

4. Determination Of Machining Performance Characteristics

The overview of various measurement methods involved to measure output parameters such as MRR, TWR, overcut are described in this section.

4.1. Formula Of MRR Calculation

MRR is calculated as the proportion of the change of weight of the work piece before and after machining to the product of machining period and density of the material.

$MRR = (W_{bm} - W_{am}) / t \times \rho$

Whereas:
Wbm = Weight of workpiece before machining.
Wam = Weight of workpiece after machining.
t = Machining period
ρ = Density of SS 316 stainless steel work piece = 7800 kg/m3

4.2 Tool Wear Ratio

Tool wear ratio is defined as the ratio of amount of electrode to the amount of work piece removed. One of the most difficult output parameters is to calculate tool wear ratio in micro-EDM process. Four methods are used to measure the TWR by means of measuring weight, length, shape and total volume, respectively. In this study, the tool wear ratio was calculated based on the total volume.

TWR = (Volume of electrode wear)/ (Volume of material removal arte from the work piece)

4.3 Overcut

Overcut is the difference between the radius of the micro-hole and the radius of the electrode. This can be measured by using VMS. In this study, the overcut was represented in terms of percentage and was calculated as the ratio of the radial difference between the hole on the work piece and the radius of the electrode divided by the radius of the electrode.

Overcut = (Rh- Re)/ Re

Where, Rh-radius of the hole on the work piece
Re-radius of the electrode

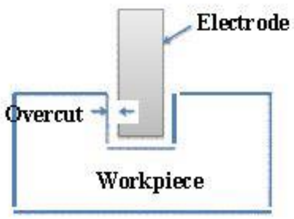

Fig.6 Measurement of Overcut

5. Design Of Experiments Using Taguchi Method (Doe)

Dr. Genichi Taguchi' s approach or DOE is highly effective wherever and whenever it is suspected that the performance of a part or process is controlled by more than one factor.

DOE technique is an experimental strategy used to reduce the number of experiments without affecting the quality of the performance.

Orthogonal arrays are important means of DOE and the experiments were conducted based on the following calculations highlighted in the section. The inputs parameters are used in the experiment are pulse on time, Discharge current and feed rate.

Table -2 Machining parameters and their level

Sl.No	Parameters	Unit	Level-1	Level-2	Level-3
1	Pulse on time	µs	50	200	750
2	Discharge current	Amps	10	25	40
3	Feed rate	µm/s	3	5	7

5.1 Orthogonal Array (Oa)

Orthogonal arrays are special standard experimental design that requires only a small number of experimental trials to find the main factors effects on output. Before selecting an orthogonal array, the minimum number of experiments to be conducted is to be fixed based on the formula below.

N Taguchi = 1+ NV (L – 1)
N Taguchi = Number of experiments to be conducted
NV = Number of parameters
L = Number of levels
In this work

NV = 3 and L = 3, Hence
N Taguchi = 1+ 3 (3-1) = 7.
The standardization of 3 levelsorthogonal array is L9, L18, L27 to design a experiment.
In this work L9 is sufficient. It would require a total of 27experiments to optimize the parameters. Taguchi experimental design of experiments suggests L9 orthogonal array, where 9 experiments are sufficient to optimize the parameters. Based on main factor, the variables are assigned at columns, as stipulated by orthogonal array. It is important that all experiments are conducted. The performance parameter (output) is noted for each experimental run for analysis.

5.2 Orthogonal Array Formation

Table-3 L9 orthogonal array with input parameters Ton,I and F

SL.NO	T-on time	Discharge current	Servo feed
1	50	10	3
2	50	25	5
3	50	40	7
4	200	10	5
5	200	25	7
6	200	40	3
7	750	10	7
8	750	25	3
9	750	40	5

5.2.1 Response Table

The response table shows the calculated values of MRR, TOC and TWR are along with the input factors.

Table-4 Calculated values of response with input factors Ton,I and F

SL.NO	T-on time	Discharge current	Servo feed	MRR	TOOL OVER CUT	TOOL WEAR RATE
1	50	10	3	0.117	0.1925	0.08205
2	50	25	5	0.195	0.775	0.63282
3	50	40	7	0.117	0.1175	0.10726
4	200	10	5	0.507	0.0825	0.01321
5	200	25	7	0.234	0.0825	0.03483
6	200	40	3	0.669	0.0775	0.00995
7	750	10	7	0.468	0.005	0.01731
8	750	25	3	0.312	0.005	0.03558
9	750	40	5	0.702	0.0175	0.00321

6. Result and Discussion

Table-5 Experimental results for performance characteristics using Copper Electrode.

Exp. Number	Observed values for Copper					
	MRR		TOC		TWR	
	MEAN	SN ratio	MEAN	SN ratio	MEAN	SN ratio
1	0.039	-28.17870786	0.035	29.118639	0.09208	20.716694
2	0.039	-28.17870786	0.13	17.721133	0.09208	20.716694
3	0.078	-22.15810795	0.0275	31.213346	1.3813	-2.80576
4	0.273	-11.27674706	0.0175	35.139239	0.7893	2.0551579
5	0.078	-22.15810795	0.0375	28.519375	0.9209	0.7157505
6	0.429	-7.350854156	0.0825	21.670921	0.1675	15.519704
7	0.234	-12.61568285	0.035	29.118639	0.04605	26.735407
8	0.312	-10.11690812	0.1625	15.782933	1.036	-0.307195
9	0.351	-9.093857671	0.04606	26.733521	0.2046	13.781887

Table-6 Experimental results for performance characteristics using Brass Electrode.

Experiment. Number	Observed values for Brass					
	MRR		TOC		TWR	
	MEAN	SN ratio	MEAN	SN ratio	MEAN	SN ratio
1	0.117	-18.6363	0.1925	14.31139	0.08205	21.71843
2	0.195	-14.1993	0.775	2.213966	0.63282	3.974396
3	0.117	-18.6363	0.1175	18.59924	0.10726	19.39124
4	0.507	-5.89984	0.0825	21.67092	0.01321	37.58194
5	0.234	-12.6157	0.0825	21.67092	0.03483	29.16093
6	0.66857143	-3.49704	0.0775	22.21397	0.00995	40.04354
7	0.468	-6.59508	0.005	46.0206	0.01731	35.23406
8	0.312	-10.1169	0.005	46.0206	0.03558	28.97588
9	0.702	-3.07326	0.0175	35.13924	0.00321	49.8699

6.1. Analysis Of Experiment And Discussions

6.1.1. Influences On MRR

The S/N ratios for MRR are calculated as given in Equation 4.1. Taguchi method is used to analysis the result of response of machining parameter for “**larger is better””** criteria.

$$\text{LB: } \eta = -10 \log \left[\frac{1}{n} \sum_{i=1}^{n} yi^{-2} \right]$$

Where η denotes the S/N ratios calculated from observed values, yi represents the experimentally observed value of the i^{th} experiment and n=1 is the repeated number of each experiment in L-9 Orthogonal Array is conducted.

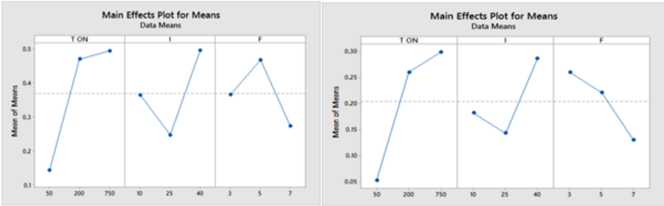

Fig.7 Means of means plot for copper and Brass

Table-7 Response Table for Signal to Noise Ratios for MRR using Copper Electrode

Level	T ON	I	F
1	-17.157	-10.377	-10.75
2	-7.338	-12.311	-7.724
3	-6.595	-8.402	-12.616
Delta	10.562	3.908	4.892
Rank	1	3	2

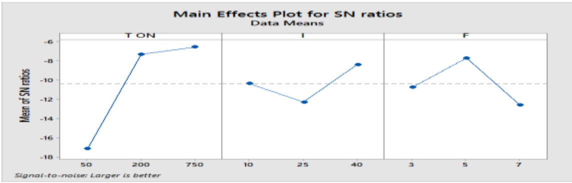

Fig.8. Mean effects plot of S/N for Copper electrode

The analysis of variances for the factors is shown in table , is clearly indicates that the pulse on current plays is important for influencing MRR comparing with current on and feed parameters. The delta values are pulse on, current and feed are 10.562,3.908,4.892 respectively, depicted in table 4.4 . The case of MRR, it is " **Larger is better**" , so from this table it isclearly definite that pulse on is the most important factor then current and feed of the tool.

Table-8 Response Table for Signal to Noise Ratios for MRR using Brass Electrode

Level	T ON	I	F
1	-26.17	-17.36	-15.22
2	-13.6	-20.15	-16.18
3	-10.61	-12.87	-18.98
Delta	15.56	7.28	3.76
Rank	1	2	3

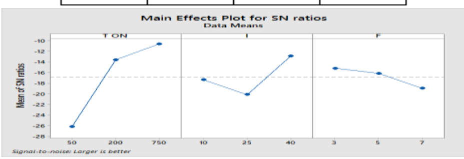

Fig .9 Main effects plot for MRR S/N ratio for Brass electrode

The analysis of variances for the factors is shown in table, is clearly indicates that the pulse on current plays is important for influencing MRR comparing with current on and feed parameters. The delta values are pulse on, current and feed are 15.56, 7.28, 3.76 respectively, depicted in table 4.6. The case of MRR, it is " Larger is better" , so from this table it isclearly definite that pulse on is the most important factor then current and feed of the tool.

From the above tables it is clearly definite that pulse on is the most important factor then current and feed of the tool. Pulse on current has a significant impact on MRR as compared to current and feed rate.

Percentage contribution of Copper is about 56.5% and for brass is 54.5% .This states the impact of Pulse on time Material removal rate of the work-piece in EDM process. The parameters such as discharge current (Ip) and feed rate (F) have very less impact on MRR of the work-piece. Comparing Copper electrode and brass electrode copper is having better percentage contribution than brass. This shows that copper electrode gives better MRR than brass electrode. The analysis states that the effectiveness of the Pulse on time on the EDM process.

6.1.2. Development Of Regression Equation Influencing Variables (Mrr And Ton, If) Of Edm Machining.

The observed values of observed data are programmed in Minitab software and a regression equation is obtained.
Regression equation generated between pulse Ton time, discharge current and feed, Material removal rate.Ton,I, and F are predictors and MRR is response for copper and Brass electrodes.

For Copper:

MRR = 0.249 + 0.000378 T On + 0.00440 I - 0.0232 F

For Brass:

MRR = 0.187 + 0.000277 T ON + 0.00347 I - 0.0325 F

Table-9 Model Summary for Copper for MRR

Model Summary for Copper			
S	R-Sq	R-Sq(adj)	R-sq(pred)
0.201124	38.07%	0.91%	0.00%
Model Summary for Brass			
S	R-Sq	R-Sq(adj)	R-sq(pred)
0.119804	59.17%	34.67%	0.00%

In these results, the R^2 value indicates that the model fits the data well. For Copper the adjusted R^2 is .91 %, and the predicted R^2 is 0.00 %. For Brass the adjusted R^2 is 34.67 %, and the predicted R^2 is 0.00 %.

The R^2 and predicted R^2 values are not relatively close, which indicates that the model cannot be used for predicting future response values.

Table-10 Coded Coefficients for Brass -MRR

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	0.3941	0.0768	5.13	0.004	
Ton	0.1323	0.0872	1.52	0.19	1
I	0.0659	0.0918	0.72	0.505	1
F	-0.0464	0.0918	-0.51	0.635	1

Table-11 Coded Coefficients for Copper-MRR

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	0.187	0.159	1.18	0.291	
Ton	0.000277	0.000133	2.09	0.091	1
I	0.00347	0.00326	1.06	0.336	1
F	-0.0325	0.245	-1.33	0.241	1

The p-value for each term tests the null hypothesis that the coefficient is equal to zero (no effect). A low p-value (< 0.05) indicates that you can reject the null hypothesis. In other words, a predictor that has a low p-value is likely to be a meaningful addition to your model because changes in the predictor's value are related to changes in the response variable.

6.1.3 Influences On Tool Overcut

The S/N ratios for TOC are calculated as given in Equation 4.2. Taguchi method is used to analysis the result of response of machining parameter for smaller is better (SB) criteriaSmaller is better.

$$SB: \eta = -10\log\left[\frac{1}{n}\sum_{i=1}^{n} yi^2\right]$$

For Copper electrode also the effecting parameters influencing over cut are Ton,Current and tool feed rate.
For brass electrode the experimental results indicate that to minimize TOC the variable pulse on rate (Ton) , current and pulse on rate are the most influencing factors .

6.1.4 DEVELOPMENT OF REGRESSION EQUATION INFLUENCING VARIABLES (TOC AND TON, I, F) OF EDM MACHINING.

Regression equation generated between pulse on time, discharge current and feed, Tool over cut. Ton, I, and F are predictors and Tool over cut is response.

For Copper

TOC = 0.1744 - 0.000160 T on - 0.000750 I - 0.00583 F

For Brass

TOC = -0.1422 + 0.000091 Ton + 0.00305 I + 0.01764 F

6.1.5 Influence Of Tool Wear Rate.

The S/N ratios for TWR are calculated as given in Equation 4.3.Taguchi method is used to analysis the result of response of machining parameter for smaller is better (SB) criteria

$$SB: \eta = -10\log\left[\frac{1}{n}\sum_{i=1}^{n} yi^2\right]$$

6.1.6 Development Of Regression Equation Influencing Variables (Twr And Ton, I, F) Of Edm Machining.

Regression equation generated between pulse on time, discharge current and feed, Tool wear rate .Here Ton, I, and F are considered as predictors and Tool wear rate is response.

For Copper

TWR = 0.177 - 0.000267 TON + 0.00009 I + 0.0027 F

For Brass

TWR = 0.706 - 0.001395 TON + 0.0052 I + 0.177 F

7. Summary

The work evaluates the effect of process parameters via pulse on time, current and feed rate of tool on performance measures via material removal rate, electrode wear and dimensional deviation using copper and brass electrodes as tool and SS-316 grade stainless steel as work piece. This work also includes the micro structure studies of the components produced under EDM machining using copper and brass electrodes.

8. Conclusion

In the present work three factors pulse on time, current and feed rate are considered as input parameters. Using SS-316 stainless steel as work piece and copper, brass electrodes as tool, nine numbers of experiments are conducted to obtain an optimum level in achieving high material removal rate, minimal dimensional deviation and tool wear.

- Among the three input parameters pulse on time highly influences MRR followed by current and feed rate using copper and brass electrodes.
- For tool over cut and tool wear rate the influencing parameter is pulse on time using copper electrode and the influenced parameter is servo feed rate using brass electrode.

Abriviation:

MRR-Material removal rate, Ton-OnTime, Toff-Off Time, F-Feed,I-Current,TWR-Tool Ware rate,TOC-Tool Over Cut.

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