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Optimization of Process Parameters in Electro-Discharge Machining using Taguchi Method

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Abstract

Electric discharge machining is the essential non-traditional machining process. Basically the EDM is mainly used for the hard metals or those materials which are difficult to machine by some other traditional processes. The electric discharge machining process based upon the thermo electric energy between the workpiece and electrode. In this the material removal is occurred electro thermally by a series of successive discharges that are between the electrode and workpiece. With the help of optimization techniques we can attain the best manufacturing environment, which is an essential need for industries to improve the manufacturing qualities of products at the lower cost. This research paper aims to investigate the optimal set of process parameters such as pulse on time, voltage, current in the Electric discharge machining process to achieve results like higher material removal rate, better surface finish and lesser tool wear rate. The experiment is done on the Mild steel AISI18 work piece and the electrode taken is of copper. Taguchi method is used to get the optimized result. Graphs and response table are used to find the optimal levels of the parameters in the Electric discharge machining. The result revealed that the current, voltage & pulse on time have a great influence on the MRR, TWR and surface roughness. At higher value of Voltage, lower value of current & lower value of pulse on time we get the best optimal values of MRR, Ra & TWR.
Keywords: Electric discharge machining, AISI18 steel work-piece, copper electrode, Current, Voltage, Pulse on time, Taguchi L9 orthogonal array, Miinitab-17, S/N ratio, Surface Roughness (Ra), Material Removal Rate(MRR), Tool Wear Rate(TWR)

I. INTRODUCTION

Electro Discharge Machining (EDM) is an electro-thermal non-traditional machining process in which electrical energy is used to generate electrical spark and material removal mainly occurs due to thermal energy of the spark. Electric discharge machining is mainly used to machine those materials which are difficult to machine with other traditional processes. There is no direct contact of the electrode and work piece in the EDM. So the machining problems like the stresses and the vibrations does not arise during the machining processes.

EDM is the thermal erosion process in which metal is removed by a series of recurring electrical discharges between a cutting tool acting as an electrode and a conductive work piece, in the presence of a dielectric fluid. This discharge occurs in a voltage gap between the electrode and work piece. Heat from the discharge vaporizes minute particles of work piece material, which are then washed from the gap by the continuously flushing dielectric fluid.

II. MATERIALS AND METHODS

A. Edm Machine (Press Mach-A25):

A EDM Machine "Press Mach-A25" made by TOOLCRAFT is used to carry out the experimentation.

Table – 1
Specification of the EDM Machine (Press Mach A-25)

Pulse Generator	*A25*
Working Current	*5-9 Amp*
Type of Pulse	*STD/EQUI-ENERGY*
Pulse Time ON/OFF	*2-2000 micro sec.*
Max. MRR Cu-Steel Gr-Steel	*165mm/min.-190mm/min.*
Working Voltage	*40-50 volts*

Surface Finish Cu-Steel	*≤0.5 microns CLA*
Electrode Wear	*≤0.3 %*

1) Selection of Machining Tool:

The cutting tool selected for present work is copper cylindrical electrode of diameter 12.50 mm. Density of copper is 8.96 gm. /cm^3.

2) Selection of Work Piece Material:

The work piece used for current work is AISI 1018 steel. Density of AISI 1018 Steel is 7.87 gm/cm^3.

Table – 2
Composition of AISI 1018 Steel

Carbon, C	*0.14 - 0.20 %*
Iron, Fe	*98.81 - 99.26 % (as remainder)*
Manganese, Mn	*0.60 - 0.90 %*
Phosphorous, P	*≤ 0.040 %*
Sulfur, S	*≤ 0.050 %*

3) Selection of Machining Parameters

The following process parameters, used in this work are shown in table:

Table – 3
Machining Parameters

Polarity	*Positive*
Current	*5-9 amp*
Voltage	*40-50 volt*
Pulse on time	*50-200μs*
Duty factor	*0.7*

4) Process Parameters and Levels Used In the Experiment:

The machining process is done on the EDM by taking Current, Voltage & Pulse on time as process parameters. The parameters and the levels used in the process are shown in table:

Table – 4
Process Parameters and Levels Used In the Experiment

Levels	*Voltage*	*Current*	*Pulse on time*
Level 1	*40*	*5*	*50*
Level 2	*45*	*7*	*150*
Level 3	*50*	*9*	*200*

B. Design Matrix:

According to the present work there are three levels and three factors. So according to Taguchi approach we selected L9 orthogonal array. With the help of minitab-17 following design matrix has been formed.

Table – 5
Design Matrix

Experiment	*Voltage*	*Current*	*Pulse on time*
1	*40*	*5*	*50*
2	*40*	*7*	*150*
3	*40*	*9*	*200*
4	*45*	*5*	*150*
5	*45*	*7*	*200*
6	*45*	*9*	*50*
7	*50*	*5*	*200*
8	*50*	*7*	*50*
9	*50*	*9*	*150*

III. RESULTS AND DISCUSSIONS

The design matrix is formed by using minitab 17 software. According to design matrix, experiments are performed. By using the readings of experiments we calculate MRR, Ra & TWR as follows:

A. Material Removal Rate (MRR):

The material removal rate is generally described as the volume of metal removed per unit time. To calculate MRR following equation is used to calculate the Material Removal Rate (MRR):

$$\mathrm{MRR(mm^3/min.)} = \frac{[\text{Initial Weight of workpiece (gm.)} - \text{Final Weight of workpiece (gm.)}]}{\text{Density (gm./mm}^3\text{)} \times \text{Machining Time (min.)}}$$

B. Surface Roughness (R_a):

Roughness measurement has been done using a portable stylus-type profilometer, Mitutoyo- Surftest SJ- 201P/M. The evaluation length of 2.5 mm is used to measure response R_a value in µm.

C. Tool Wear Rate (TWR):

The Tool Wear Rate is generally described as the volume of metal removed per unit time. To calculate TWR, following equation is used:

$$\text{TWR}(\text{mm}^3/\text{min.}) = \frac{[\text{Initial Weight of Tool (gm.)} - \text{Final Weight of Tool (gm.)}]}{\text{Density (gm./mm}^3) \times \text{Machining Time (min.)}}$$

D. Response Table:

Response table for the experimental design matrix is shown in table.

Table – 6
Response Table of MRR, R_a & TWR

S.N.	*VOLTAGE*	*PULSE ON TIME*	*CURRENT*	*Change in Wt.*	*M/C time*	*MRR*	*Surface Roughness*	*Change in wt.*	*Tool Wear Rate*
1	40	50	5	1.058	12	11.23142	3.4897	0.0031	0.032909
2	40	150	7	1.527	12	16.21019	6.1015	0.0045	0.047771
3	40	200	9	1.614	12	17.13376	7.3028	0.0057	0.06051
4	45	50	7	1.3	12	13.80042	3.7105	0.0041	0.043524
5	45	150	9	1.89	12	20.06369	7.4959	0.0054	0.057325
6	45	200	5	1.331	12	14.12951	6.2275	0.0039	0.041401
7	50	50	9	2.3	12	24.41614	5.9096	0.0048	0.050955
8	50	150	5	1.642	12	17.431	7.1047	0.0041	0.043524
9	50	200	7	2.135	12	22.66454	8.8339	0.0046	0.048832

E. Analysis of Single Response Table:

The optimal settings and the optimal values for MRR, Ra & TWR are determined individually by Taguchi's approach. Table shows these individual optimal values and its corresponding settings of the process parameters for the specified performance characteristics.

Table – 7
Means of MRR, TWR & Surface Roughness at Different Levels

SINGLE RESPONSE								
MRR			*Ra*			*TWR*		
VOLTAGE	*PULSE ON TIME*	*CURRENT*	*VOLTAGE*	*PULSE ON TIME*	*CURRENT*	*VOLTAGE*	*PULSE ON TIME*	*CURRENT*
14.85846	16.48266	14.26398	5.63133	4.36993	5.6073	0.047063	0.042463	0.039278
15.99788	17.90163	17.55839	5.8113	6.9007	6.2153	0.047417	0.04954	0.046709
21.50389	17.97594	20.53786	7.28273	7.45473	6.90276	0.047771	0.050248	0.056263

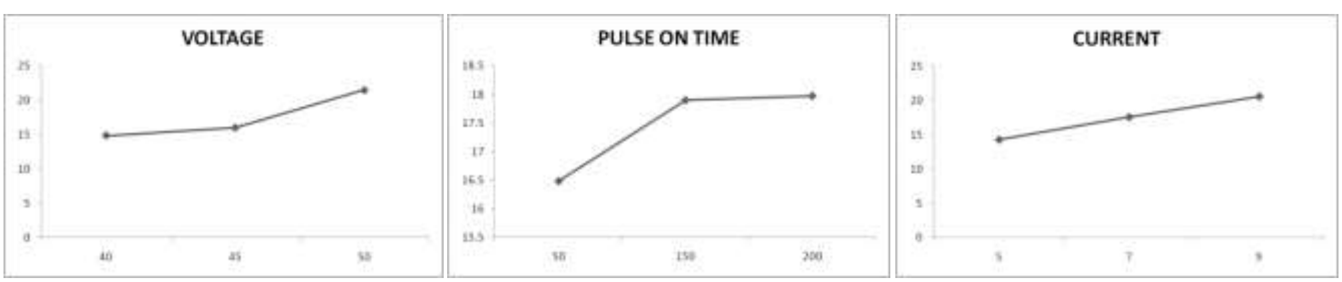

Fig. 1: RESPONSE GRAPH FOR MRR

F. Interpretation of Plots FOR MRR:

The data gathered from the experimental work is ploted. The above graphs shows the optimum level for MRR. These optimal values for MRR are plotted in three graphs: one based on voltage, and another two are based on current & pulse on time.

- BASED ON VOLTAGE: From the graph it is clear that with the increase in voltage, MRR also increases.
- BASED ON PULSE ON TIME: With the increase in pulse on time, the value of MRR also increases.
- BASED ON CURRENT: Initially at 5amp the MRR is low but as the value of current increases, MRR also increases.

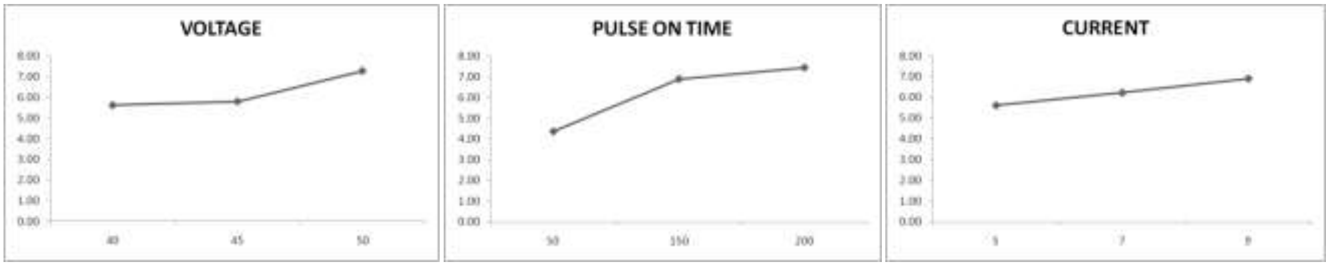

Fig. 2: RESPONSE GRAPH FOR Surface Roughness

G. Interpretation of Plots For Surface Roughness:

- BASED ON VOLTAGE: Surface roughness increases with the increase in voltage.
- BASED ON PULSE ON TIME: With the increase in pulse on time, the value of Surface roughness increases.
- BASED ON CURRENT: As the value of current increases, surface roughness also increases.

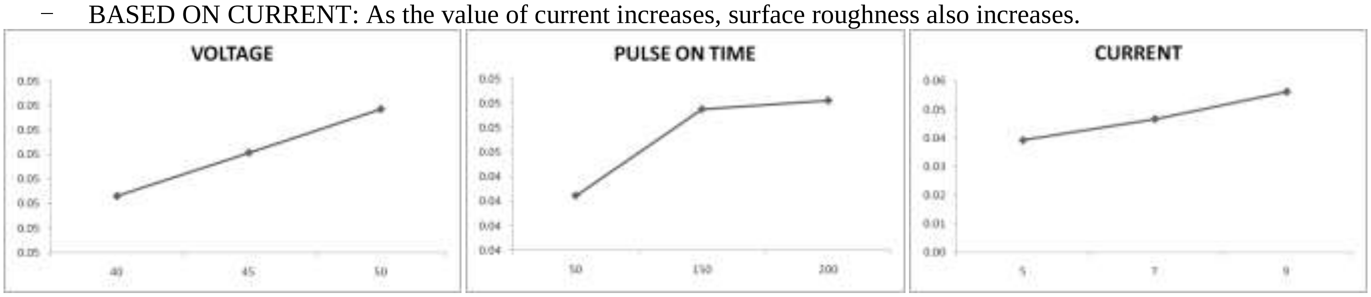

Fig. 3: RESPONSE GRAPH FOR TOOL WEAR RATE

H. Interpretation of Plots for Tool Wear Rate:

- BASED ON VOLTAGE: As the value of voltage increases, Tool wear rate also increases.
- BASED ON PULSE ON TIME: Tool wear rate increases with the increase in pulse on time.
- BASED ON CURRENT: As the value of current increases, Tool wear rate also increases.

I. Analysis Of Multi-Response Stage:

The S/N ratio considers both the mean and the variability. In the present work, a multi- response methodology based on Taguchi technique and Utility concept is used for optimizing MRR, Ra & TWR. Taguchi proposed many different possible S/N ratios to obtain the optimal process efficiency. Two of them are selected for the present work. Those are,

- Larger the better S/N ratio for MRR

$$\eta_1 = -10\log_{10}[\frac{1}{MRR^2}]$$

- Smaller the better type S/N ratio for R_a

$$\eta_2 = -10\log_{10} Ra^2$$

- Smaller the better type S/N ratio for TWR

$$\eta_3 = -10\log_{10} TWR^2$$

From the utility concept, the multi-response S/N ratio of the overall utility value is given by

$$\eta_{obs} = W_1\eta_1 + W_2\eta_2 + W_3\eta_3$$

Where W_1, W_2 & W_3 are the weights assigned to the MRR, R_a & TWR. Weights are defined according to the importance and choice of the operator, customer's requirements. Weights values taken for W_1, W_2 & W_3 are as follows:
W_1 for MRR = 0.35, W_2 for Ra = 0.35
W_3 for TWR = 0.30

The best combination for process parameters for simultaneous optimization of Material removal rate (MRR), Surface roughness (R_a), &Tool Wear Rate (TWR) is obtained by the mean values of the multi-response S/N ratio shown in Table.

Table – 8
Design Matrix with Multi-Response S/N Ratio

S. N.	VOLTAGE	PULSE ON TIME	CURRENT	MRR	η_1 for MRR	Surface Roughness	η_2 for R_a	Tool Wear Rate	η_3 for TWR	η_{obs}
1	40	50	5	11.23142	21.0087	3.4897	-10.8558	0.032909	29.65378	12.44966
2	40	150	7	16.21019	24.19576	6.1015	-15.7087	0.047771	26.41677	10.89549
3	40	200	9	17.13376	24.67705	7.3028	-	0.06051	24.36352	9.901599

							17.2698			
4	*45*	*50*	*7*	*13.80042*	*22.79785*	*3.7105*	*-11.3886*	*0.043524*	*27.22534*	*12.16082*
5	*45*	*150*	*9*	*20.06369*	*26.04822*	*7.4959*	*-17.4965*	*0.057325*	*24.83314*	*10.44305*
6	*45*	*200*	*5*	*14.12951*	*23.00254*	*6.2275*	*-15.8863*	*0.041401*	*27.65973*	*10.78861*
7	*50*	*50*	*9*	*24.41614*	*27.75354*	*5.9096*	*-15.4312*	*0.050955*	*25.85619*	*12.06969*
8	*50*	*150*	*5*	*17.431*	*24.82644*	*7.1047*	*-17.0309*	*0.043524*	*27.22534*	*10.89604*
9	*50*	*200*	*7*	*22.66454*	*27.10694*	*8.8339*	*-18.923*	*0.048832*	*26.22586*	*10.73212*

Table – 9
Mean Values of H_{obs} At Different Levels

Levels	*Mean Value of η_{obs} for Process Parameters*		
	VOLTAGE	*PULSE ON TIME*	*CURRENT*
Level 1	*11.08225*	*12.22672*	*11.3781*
Level 2	*11.13083*	*10.74486*	*11.26281*
Level 3	*11.23262*	*10.47411*	*10.80478*

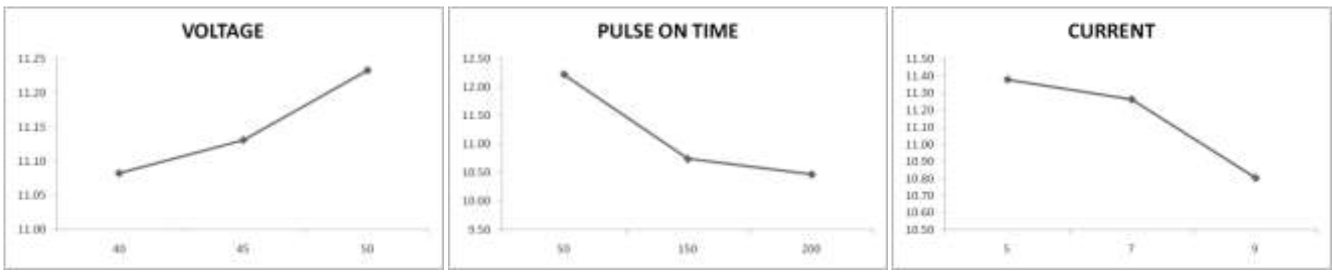

Fig. 4: MULTI-RESPONSE S/N RATIO GRAPH

J. Interpretation of Plots:

The multi response S/N ratio graphs show the optimal level of MRR, Ra & TWR with the variation in parameters i.e. Voltage, Curret & Pulse on time. As there are three process parameters, so there are three graphs: one based on Voltage and another two based on current & pulse on time.

K. Based on Voltage:

This graph is a plot between the process parameter i.e. Voltage on x-axis and the optimum values obtained from Multi-response table on the y-axis. This graph gives the combined result for MRR, Surface Roughness and TWR. As the voltage is increased from its initial value 40 volts the multi response value for MRR, Ra & TWR also increases. We get the best optimum value for MRR, Ra & TWR at voltage 50 volt.

L. Based on The Current:

This graph is a plot between the process parameter i.e. Current on x-axis and the optimum values obtained from Multi-response table on the y-axis. This graph also gives the combined result for MRR, Surface Roughness and TWR. From the graph the max. Value of multi response is at current value of 5 Amp. So we get the optimum values of MRR, Ra & TWR, at lower value of current.

M. Based on Pulse on Time:

This graph is a plot between the process parameter i.e. Pulse on time on x-axis and the optimum values obtained from Multi-response table on the y-axis. This graph also gives the combined result for MRR, Surface Roughness and TWR. With the increase in pulse on time the value obtained from multi response reduces. So we get the best optimum values for MRR, Ra & TWR at lower value of pulse on time i.e. 50µm.

IV. CONCLUSION

A set of experiments are performed on AISI 1018 mild steel work pieces with the use of copper electrode in Electric discharge machining. The experimental studies are conducted by varying the parameters like Current, Voltage and Pulse on time. The result shows that current, pulse on time and Voltage have significant effect on MRR,TWR and SR. The results of the present work reveal that proper selection of input parameters will play a significant role in Electric Discharge Machining:

1) Individually MRR increases with increasing voltage, increasing current & increasing pulse on time.
2) With the increase in Voltage or current or pulse on time, Surface roughness increases.
3) The min. Tool Wear Rate is obtained at lower values of Voltage, Current & Pulse on time. So with the increase in Voltage or current or pulse on time, Tool Wear Rate increases.
4) At higher value of Voltage, lower value of current & lower value of pulse on time we get the best optimal values of MRR, Ra & TWR. So the machining parameters should be set as higher voltage, lower current and lower pulse on time.

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