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Optimization of EDM Parameters during Machining of EN19

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Abstract

This paper presents work of an investigation of EDM process parameters on EN 19 material, for optimization of surface roughness only. The experiment is carried out by considering three controllable input variables namely Pulse on Time, Pulse off Time and voltage Gap. The design of experiments is carried out by Response Surface Methodology (Central Composite Rotatable Method) and optimization of surface roughness as well as influence of EDM parameters is carried out by ANOVA.

Keywords: ANOVA, Response Surface Methodology (RSM), CCR, Electric Discharge Machining (EDM).

1. Introduction

Electrical discharge machining (EDM) is material removal process by a series of rapid recurring electrical discharges between the cutting tool (electrode) and the work piece in the presence of dielectric fluid. Electrical Discharge Machining (EDM) process involved removal of material by erosion. Basic EDM process consists of electrode, work piece materials, dielectric and the range of pulse rate, current and voltage. The functions of the dielectric are: transportation of removal particles, to increase the energy density in plasma channel, recondition of the dielectric strength and cooling of the electrode. Electric discharge machining is non conventional machining process. EDM is generally used for machining for those materials which are cannot processed by conventional machining process. In EDM electric spark is used to cut the workpiece, which is generally taken the shape of the cutting tool which is opposite to the work piece. The cutting tool or the electrode and the workpiece both are submerged in dielectric fluid. There is very less space (about the thickness of human hair) is in between the cutting tool (electrode) or the workpiece. Electric discharge machining process is a metal removing process which is based on the principle of erosion of metal. The metal get eroded by the help of an intermitted electric spark discharge which take place in between the tool (cathode) and the workpiece (anode). Electric discharge machining is also known as the spark erosion machining, electro-erosion machining and spark erosion machining process. EDM is also known as the Non-Traditional method as well as non physical metal removal process. Spark erosion in Electric Discharge Machining is like having an electric short that burns a small hole to the workpiece. In EDM process both the electrode and the workpiece should be electricity conductivity. The electrode tool is generally made of graphite and copper which is given a shape required to produce. The electrode formed is fed to the workpiece vertically down and the shape of the electrode (tool) is formed on the workpiece.

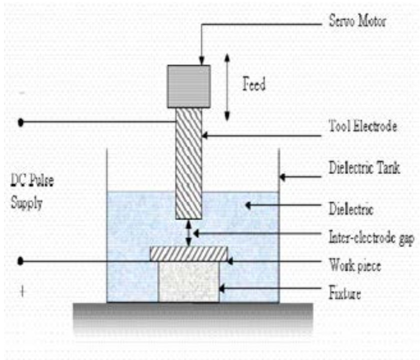

Figure 1: Working Principle of EDM.

2. Methodology

Response surface methodology is essentially collection of mathematical and statistical technique and a type of skills used to solve the problem in which the response parameters are biased by some convenient factor to optimize the response. Response surface methodology is generally used while focusing an optimization of experiments allied to machining operations. RSM reduces the number of experiments to reduce the machining cost as well as machining time. Response surface methodology is used to develop the prediction model which is based on face centered design. The experiments should be conducted according to design matrix. The design matrix has different combinations of input parameters. Then measure the dependent (response) parameters. In the present work spindle speed, feed and depth of hole are taken as input parameters on the other hand surface roughness is consider as response. Design Expert software was used to work on Response Surface Methodology.

3. Experimental Work

The experimental work includes the input parameters, output parameters and details of electrode tool, work piece and surface roughness. A design matrix based on orthogonal array has been developed. Taguchi Analysis is applied to determine the optimal EDM parameters to achieve minimum surface roughness value for EN19 under varying machining conditions. The machine used for machining EN19 was "**EMS 5535 – R50 ZNC" EDM** of 2000 series. This is an EDM machine which is in the MSME workshop, Jaipur, where all the machining experiment was performed. The main purpose of this machine is to form the complex and small objects, having high accuracy.

Figure 2: EMS 5535 - R50 ZNC

Three factors were selected with two levels i.e., the maximum and the minimum level to organise total number of experimental runs for the experiment and create design matrix.

S. No.	Parameters	Level (-1)	Level (+1)
1.	$Pulse_{on}$ Time	35	50
2.	$Pulse_{off}$ Time	30	70
3.	Voltage Gap	35	47

4. Design of Experiment

Table: Design of experiment using RSM

Exp. No.	Pulse on time	Pulse off time	Voltage gap
1.	42.50	50.00	41.00
2.	35.00	30.00	35.00
3.	42.50	50.00	41.00
4.	42.50	16.36	41.00
5.	50.00	70.00	47.00
6.	50.00	30.00	35.00
7.	42.50	83.64	41.00
8.	42.50	50.00	41.00
9.	50.00	70.00	35.00
10.	42.50	50.00	41.00
11.	42.50	50.00	41.00
12.	42.50	50.00	41.00
13.	35.00	70.00	47.00
14.	35.00	30.00	47.00
15.	42.50	50.00	51.09
16.	29.89	50.00	41.00
17.	55.11	50.00	41.00
18.	35.00	70.00	35.00
19.	42.50	50.00	30.91
20.	50.00	30.00	47.00

Results of Surface Roughness

In this experiment, the surface roughness after each experiment was measured and noted as response. The result of the surface roughness (SR) is represented along with parameters in the table given below.

Table: Experimental result for SR

Exp. No.	(T_{on})	(T_{off})	(V)	(SR)
1.	42.50	50.00	41.00	3.336
2.	35.00	30.00	35.00	3.209
3.	42.50	50.00	41.00	2.998
4.	42.50	16.36	41.00	3.551
5.	50.00	70.00	47.00	1.383
6.	50.00	30.00	35.00	2.322
7.	42.50	83.64	41.00	2.954
8.	42.50	50.00	41.00	2.954
9.	50.00	70.00	35.00	3.101
10.	42.50	50.00	41.00	2.983
11.	42.50	50.00	41.00	2.919
12.	42.50	50.00	41.00	3.002
13.	35.00	70.00	47.00	3.627
14.	35.00	30.00	47.00	2.924
15.	42.50	50.00	51.09	1.827
16.	29.89	50.00	41.00	3.758
17.	55.11	50.00	41.00	1.338
18.	35.00	70.00	35.00	4.275

19.	42.50	50.00	30.91	3.555
20.	50.00	30.00	47.00	1.664

5. ANOVA

ANOVA or analysis of variance means the breakdown of complete variability into its constituents. Using ANOVA, we can find the most effective parameters in the study and name the significant ones very easily and performance parameter can be optimized successfully. It helps in understanding the means of groups and the chances of them being equal. It is a very helpful method in finding the significance when we have two or more means to analyse.

Response 1 SR						
ANOVA for RS Qadratic Model						
ANOVA Table [Partial sum of square - Type-III]						
Source	**Sum of Square**	**DF**	**Mean Square**	**F-Value**	**P-Value Prob.>F**	
Model	13.40	9	1.49	64.782	< 0.0001	Significant
A	7.18	1	7.18	312.17	< 0.0001	Significant
B	0.68	1	0.68	29.565	0.0020	Significant
C	2.92	1	2.92	126.95	< 0.0001	Significant
AB	0.17	1	0.17	7.391	0.0635	Not Significant
AC	0.30	1	0.30	13.043	0.0205	Significant
BC	0.22	1	0.22	9.565	0.0402	Significant
A^2	0.74	1	0.74	32.173	0.0015	Significant
B^2	0.68	1	0.68	29.565	0.0020	Significant
C^2	0.36	1	0.36	15.652	0.0129	Significant

Residual	0.39	10	0.039			
Lack of Fit	0.28	5	0.056	2.40	0.1790	Not Significant
PureError	0.12	5	0.023			
Core Total	13.18	19				
Std. Dev.			0.20	**R-Squared**	0.9715	
Mean			2.92	**Adj. R-Squared**	0.9456	
C.V.%			6.79	**Pred. R-Squared**	0.8301	
PRESS			2.34	**Adeq. Precision**	22.961	

6. Results and Discussion

The surface roughness was recorded and analysed using Response Surface Methodology with the help of Design Expert software which helped us in creating graphs for the final results which makes it easier to understand the effect of the parameters on the response.

One factor plot for SR

In one factor plot for SR, the linear graph is plotted between SR and the factor selected that we want to study. The selected factor range is in between level -1 to level +1 and SR is in between (1.337 μm to 4.279 μm).
There are overall three one factor plots to signify the result of each parameter on SR even though their effect is concerned with an interface of rest three parameters but we take their constant values for superior one factor.

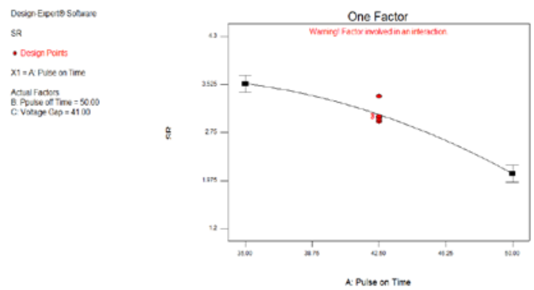

Figure 3: One factor plot of $Pulse_{ON}$ Time and SR.

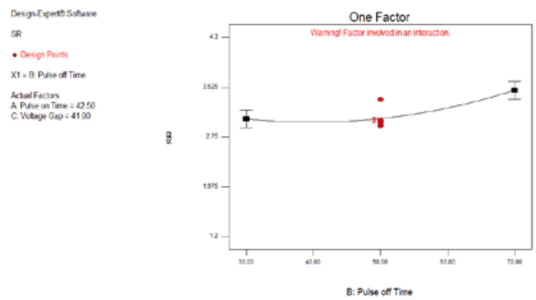

Figure 4: One factor plot for SR and Pulse off time

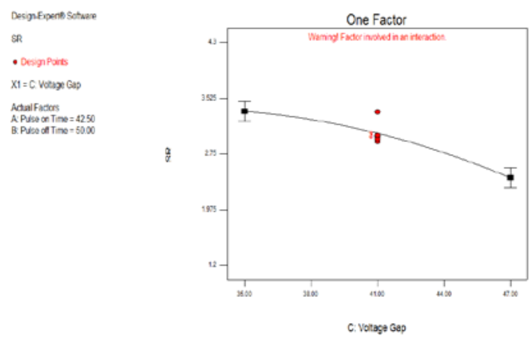

Figure 5: One factor plot for SR and Voltage gap

Interaction plot for SR

This segment deals with the effect of interaction of parameters on surface roughness (SR). To study the interaction result of parameters selected for achieving minimum surface roughness (SR).

There are over all three interaction plots for response SR with grouping of any two factors, these all plots are shown below.

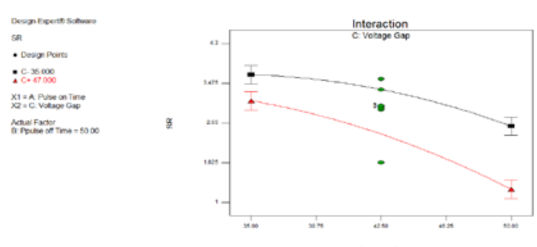

Figure 6: Interaction Plot for pulse on time and voltage gap

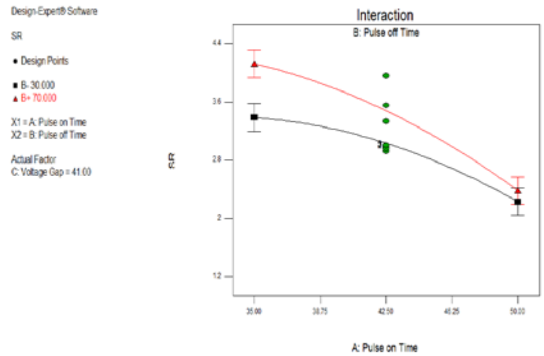

Figure 7: Interaction plot for pulse on time and pulse off time

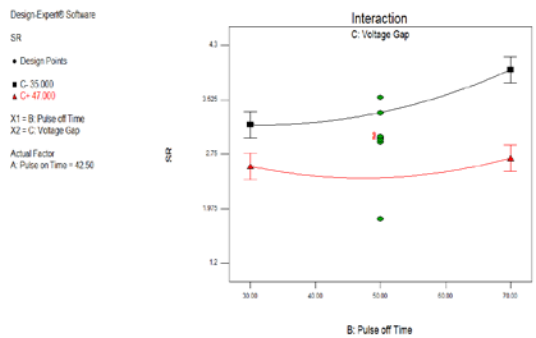

Figure 8: Interaction plot of pulse off time and voltage gap

7. Conclusion

The present experiments were conducted on an EDM machine using copper tool working as electrode on metal EN19 as work piece material. 20 runs were conducted for the experiment using different combinations of input parameters. The surface roughness was selected as responses under different EDM conditions for combinations of EDM input parameters. Response surface methodology has been used with ANOVA for the analysis work. The application of RSM optimization of process parameters in electric discharge machining (EDM) of EN19 is effectively verified in this work. The significant conclusions haggard from the present work are given briefly as follows:

- Pulse on-time is the most effective factor among the other factors and for every increase in the value of Pulse on-time SR decreases.
- Voltage gap is also an effective factor for achieving minimum surface roughness.
- Pulse off time is the most affective factor as the minor increment in its value increase the SR.
- The mathematical prediction model for SR has been developed successfully. The predicted results are in good concurrence in comparison with measured ones. These relationships are suitable within the ranges of tested parameters.
- The value of R- squared if it is found too close to one which indicates the good prediction ability of developed model.
- The minimum surface roughness 3.037 (µm) is obtained as the minimum predicted SR at pulse on time at 41.40 µsec, pulse off time at 46.40 µsec, and voltage gap at 37.13V.

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