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Optimization of EDM Process Parameter for MRR and SR of 17- 4 PH Steel Using Response Surface Methodology

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ABSTRACT

In the present work, an attempt has been made for material removal rate and surface roughness by response surface optimization techniques in Electrical discharge machining. Electrical discharge machining, commonly known as EDM, is a process that is used to remove metal through the action of an electrical discharge of short duration and high current density between the work piece and too. This work presents the results of a mathematical investigation carried out to the effects of machining parameters such as current, pulse on time, pulse off time and lift time on material removal rate and surface roughness in electrical discharge machining of 17-4 PH steel by using copper electrode. Response surface methodology and ANOVA techniques are used for data analysis to solve the multi-response optimization. To validate the optimum levels of the parameter, confirmation run was performed by setting the parameters at optimum levels. Material Removal Rate during the process has been taken as productivity estimate with the objective to maximize it. With an intention of minimizing surface roughness is been considered as most important output parameter. It is found that the good agreement of that current is most significant parameter for material removal rate and less for surface roughness followed by pulse on time and lift time.

***Keywords*:** "EDM"; "MRR"; "SR"; "Response Surface Methodology"; "ANOVA"

1. Introduction

It is a non-traditional electro-thermal machining process, in which electrical energy is used to generate electrical spark and material removal occurs due to thermal energy produced by the spark. EDM is mainly used to machine high strength temperature resistant alloys and materials difficult-to-machine. EDM can be used to machine irregular geometries in small batches or even on job-shop basis. Work material is to be conductive to be machined by EDM.

Due to erosion caused by rapidly recurring spark discharge that taking place between the tool and work piece metal is removed in this process. About a thin gap of 0.025mm is maintained between the work piece and the tool by a servo system shown in **Figure 1**. Both work piece and tool are submerged in a dielectric fluid, EDM oil/kerosene/deionised water.

1.1 Problem identification

In electrical discharge machining, improper option for the process parameter might cause of poor machining rate or performance. This is often as to material removal rate (MRR) characteristic. Less material removal rate (MRR) desires longer time for machining process and become waste and not well for production in manufacturing industries. The second drawback is it will decrease the accuracy of the product due to influence of the surface roughness characteristic. The accuracy of the product happens due to the surface roughness (SR) is low or material removal rate (MRR) is not appropriate. Furthermore, electrode wear imposes high price on makers to substitute the worn difficult electrodes by new ones for die making.

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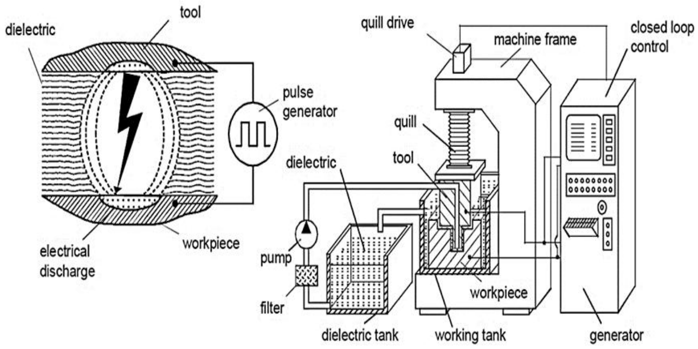

Figure 1; Different parameters of a gear.

2. Methodology

In statistics, response surface methodology (RSM) explores the relationships between several explanatory variables and one or more response variables.

2.1 Material and Model

2.1.1 Material

The work is conducted by literature Chandramouli and Eswaraiah[7] on electric discharge machine are used electrode as a Copper Tungsten (80W:20Cu grade) which had good electrical conductivity, high wear resistance.

Input Parameters/Factors	**Low**	**Intermediate**	**High**
Discharge current (I) (A)	9	12	15
Pulse on time (T_{on}) (μs)	50	100	200
Pulse off time (T_{off}) (μs)	20	50	100
Lift Time (T) (μs)	10	20	50

Table 1. Process parameters [7]

S. No.	**I**	**Ton**	**Toff**	**Lift time**	**MRR**	**Surface Roughness**
1	9	50	20	10	68.73	6.88
2	9	50	50	20	66.96	7.63
3	9	50	100	50	70.72	7.20
4	9	100	20	20	24.37	7.45
5	9	100	50	50	25.3	8.07
6	9	100	100	10	23.7	5.61
7	9	200	20	50	2.53	3.46
8	9	200	50	10	6.51	3.97
9	9	200	100	20	5.04	3.71
10	12	50	20	20	47.66	7.31

11	12	50	50	50	26.70	7.93
12	12	50	100	10	94.07	8.01
13	12	100	20	50	33.93	8.08
14	12	100	50	10	29.81	6.68
15	12	100	100	20	31.32	6.92
16	12	200	20	10	9.54	4.35
17	12	200	50	20	11.12	4.17
18	12	200	100	50	10.13	3.53
19	15	50	20	50	122.6	9.78
20	15	50	50	10	189.27	9.19
21	15	50	100	20	162.8	10.54
22	15	100	20	10	54.96	7.23
23	15	100	50	20	45.27	8.24
24	15	100	100	50	39.77	10.12
25	15	200	20	20	15.42	3.58
26	15	200	50	50	14.03	4.89
27	15	200	100	10	16.03	4.86

Table 2. Corresponding response values of MRR and SR[7]

Response	**Experimental Values[25]**	**Chandramouli and Eswaraiah[25]**	**DOE RSM (Present Work)**	**% Improvement**
MRR (mg/min)	142.4	134.19	**163.98**	**17.13%**
SR (µm)	3.21	2.89	**2.59**	**10.38%**

Table 3. Comparison of results with present work and previous work[7]

2.2 Response Surface Methodology (RSM)

Response Surface Methodology (RSM) was introduced by Box and Wilson in 1951 and later popularized by Montgomery. As per the introducer of the idea response-surface methodology can be defined as an empirical statistical technique employed for multiple regression analysis by using quantitative data obtained from properly designed experiments to solve multivariate equations simultaneously. The graphical representations of these equations are called response surfaces, which can be used to describe the individual and cumulative effect of the test variables on the response and to determine the mutual interactions between the test variables and their subsequent effect on the response.

$$Y_u = \beta_0 + \sum_{i=1}^{S} \beta_i X_i + \sum_{i=1}^{S} \beta_{ii} X_i^2 + \sum_{i>i}^{S} \beta_{ij} X_i X_j \ldots,$$

3. Result and discussion

The Response surface optimization method is to identify the parameter settings which improve the quality of the product or process robust to unavoidable.

In **Figure 2** and **Figure 3**, shows the normal probability model is adequate as represented by the points falling on a straight-line plot. It mentioned that the errors are normally distributed. Also, the plot of the residuals vs predicted response is structure less i.e. containing no obvious pattern.

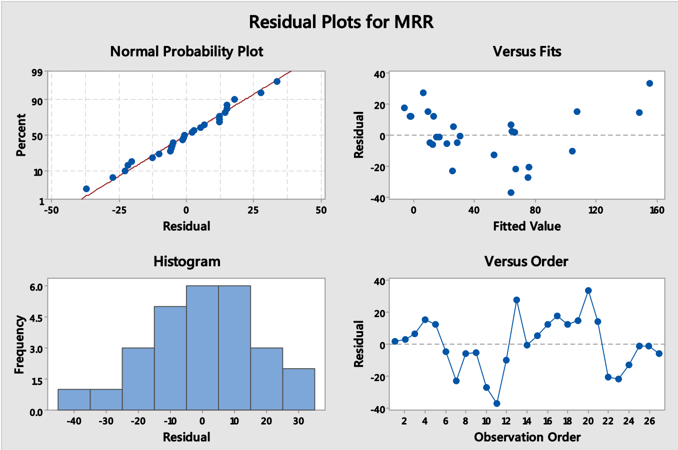

Figure 2; Residual plot for Material removal rate (MRR)**.**

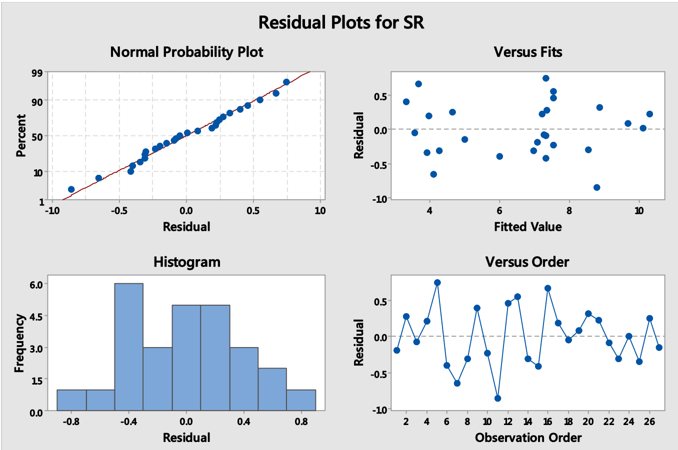

Figure 3; Residual plot for Surface roughness (SR)**.**

3.1 Empirical Models

Regression Equation for MRR and SR is

MRR $= 294 - 35.4\,A - 1.299\,B + 0.43\,C - 0.92\,D + 2.26\,A*A + 0.00640\,B*B - 0.00056\,C*C + 0.0170\,D*D - 0.0775\,A*B - 0.0064\,A*C - 0.094\,A*D - 0.00143\,B*C + 0.00555\,B*D - 0.00053\,C*D$

SR $= 11.72 - 1.131\,A + 0.0407\,B - 0.0402\,C + 0.0381\,D + 0.0522\,A*A - 0.000146\,B*B - 0.000130\,C*C - 0.000444\,D*D - 0.001963\,A*B + 0.00530\,A*C + 0.00283\,A*D - 0.000040\,B*C - 0.000241\,B*D + 0.000002\,C*D$

Where, A = I

B = Ton

C= Toff

D= Lift Time

3.2 Optimization

The optimizations plot for material removal rate (MRR) and surface roughness (SR) is shown in **Figure 4.** The main objective of this work was to maximize the material removal rate (MRR) and minimize the surface roughness (SR). The desirability approach was used for determining out the optimum values of material removal rate (MRR) and surface roughness (SR).

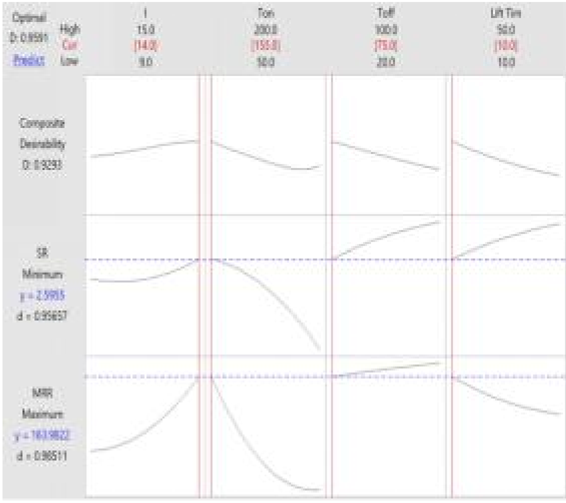

Figure 4; Optimization plot for material removal rate and surface roughness**.**

4. Conclusion

- From above discussion, it was concluded or observed that the response surface methodology has been quite robust and allowed for this work to find the contribution of each machining parameters and their interaction.
- Material removal rate increases as the current and pulse on time increases while pulse off time and lift time has been decreasing.
- Surface roughness are increasing with increase in current and pulse on time but decreasing with an increase in pulse off time and lift time.
- The main objective of the future work is to maximize the Material Removal Rate (MRR) and minimize the Surface Roughness (SR) value.
- The present predicted results were compared with literature[7] and the good agreement and improvement was found approx. 10-17% for MRR and SR value.
- More electrode materials are highly endorsed to be used an electrode for investigation its proficiency.

Author Contributions

Worked on the topic and learnt many things during our research work.

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