Optimization of EDM Process Parameters For MRR, TWR and SR Using Response Surface Methodology

Kamal Kishore Rathore[1], Ganpat Lal Rakesh[2]

[12]Department of Mechanical Engineering, Christian College of Engineering and Technology, Bhilai.

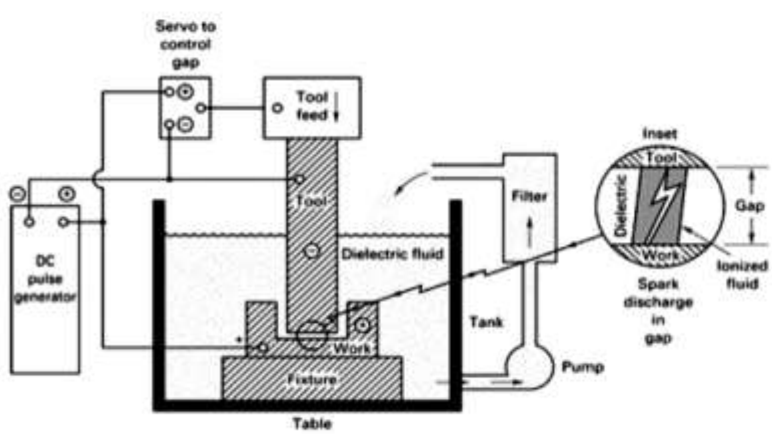
ABSTRACT

This work proposes an optimization methodology for the selection of optimum process parameters in electric discharge machining. In today's competitive environment, the industries around the world are trying to increase their profits without increasing the sales price of their products. This can only be done through minimizing the losses that are occurring during production. In this work the Titanium super alloy and copper are used as work piece and tool electrode. Regular cutting experiments are carried out on die-sinking machine under different conditions of process parameters. The process model is formed by using central composite design using reputed literature data. This model is occupied to simultaneously maximize the material removal rate as well as minimize the tool wear rate and surface roughness using response surface methodology from Minitab 17.0 software. Finally, flexibility of method is compared with literature results. All results are shown in the form of tables and figures.

Keywords- *Electrical Discharge Machining, Process Optimization, MRR, TWR, SR, Response Surface Methodology.*

I. Introduction

Electrical discharge machining (EDM), is one of the non-conventional machining processes, where the tool and workpiece do not come into contact with each other during the machining process. If an appropriate voltage is developed across the tool electrode (normally cathode) and the workpiece (normally anode), the breakdown of dielectric medium between them happens due to the growth of a strong electrostatic field. Owing to the electric field, electrons are emitted from the cathode to the anode on the electrode surfaces having the shortest distance between them. These electrons impinge on the dielectric molecules of the insulating medium, breaking these dielectric fluid molecules into positive ions and electrons.



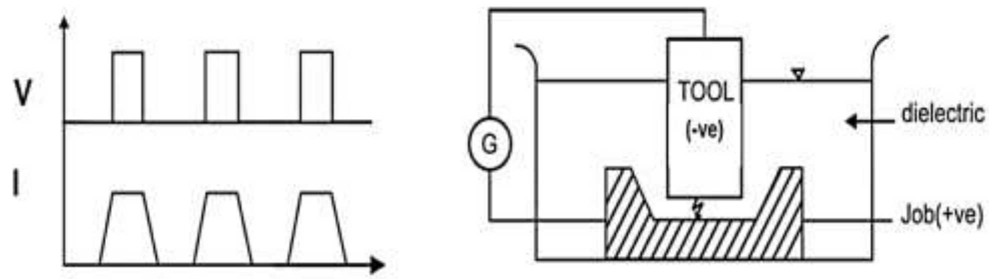


Fig 1. Electric discharge machining (EDM)

II. Problem Identification

Whereas the efficiency of traditional cutting processes is limited by the mechanical properties of the processed material and the complexity of the workpiece geometry, electrical discharge machining (EDM) being a thermal erosion process, is subject to no such constraints. The lack of correlations between the cutting rate, the surface finish and the physical material parameters of this process made it difficult to use. This work highlights the development of a comprehensive mathematical model for correlating the interactive and higher order influences of various electrical discharge machining parameters through response surface methodology (RSM), utilizing relevant experimental data as obtained through a good literature.

III. Methodology

The work is conducted by literature Laxman and Raj [7] on die-sinking electric discharge machine with a copper (99.9% of copper) prismatic electrode and a titanium super alloys rectangular work piece. The chemical composition of the work material is shown in Table 4.1. Commercial 30 Grade EDM Oil is used as dielectric.

3.1 Techniques of the Response Surface Methodology

Basically, RSM is a combination of statistical experimental design fundamentals, regression modelling techniques, and optimization methods. Response Surface Methodology (RSM) uses the following Design of experiments (DOE) techniques:

$$Y_u = \beta_0 + \sum_{i=1}^{s} \beta_i X_i + \sum_{i=1}^{s} \beta_{ii} X_i^2 + \sum_{i>i}^{s} \beta_{ij} X_i X_j \dots, \qquad (1)$$

Table 1. Chemical composition of work piece material [7]

Titanium	**Al**	**C**	**Mo**	**Zr**	**Si**	**Fe**	**P**	**V**
Base	5.5-6.8%	< 0.13%	0.5-2%	1.5-2.5%	< 0.15%	< 0.3%	0.8-2.5%	0.3%

Table 2. Levels of process parameters in EDM process [7]

Input Parameters/Factors	**Levels**		
	-1	**0**	**+1**
Peak Current (Ip) (A)	9	12	15
Pulse On time (Ton) (μs)	5	20	50
Pulse Off time (Toff) (μs)	20	50	100
Tool Lift time (Tlift) (μs)	5	10	20

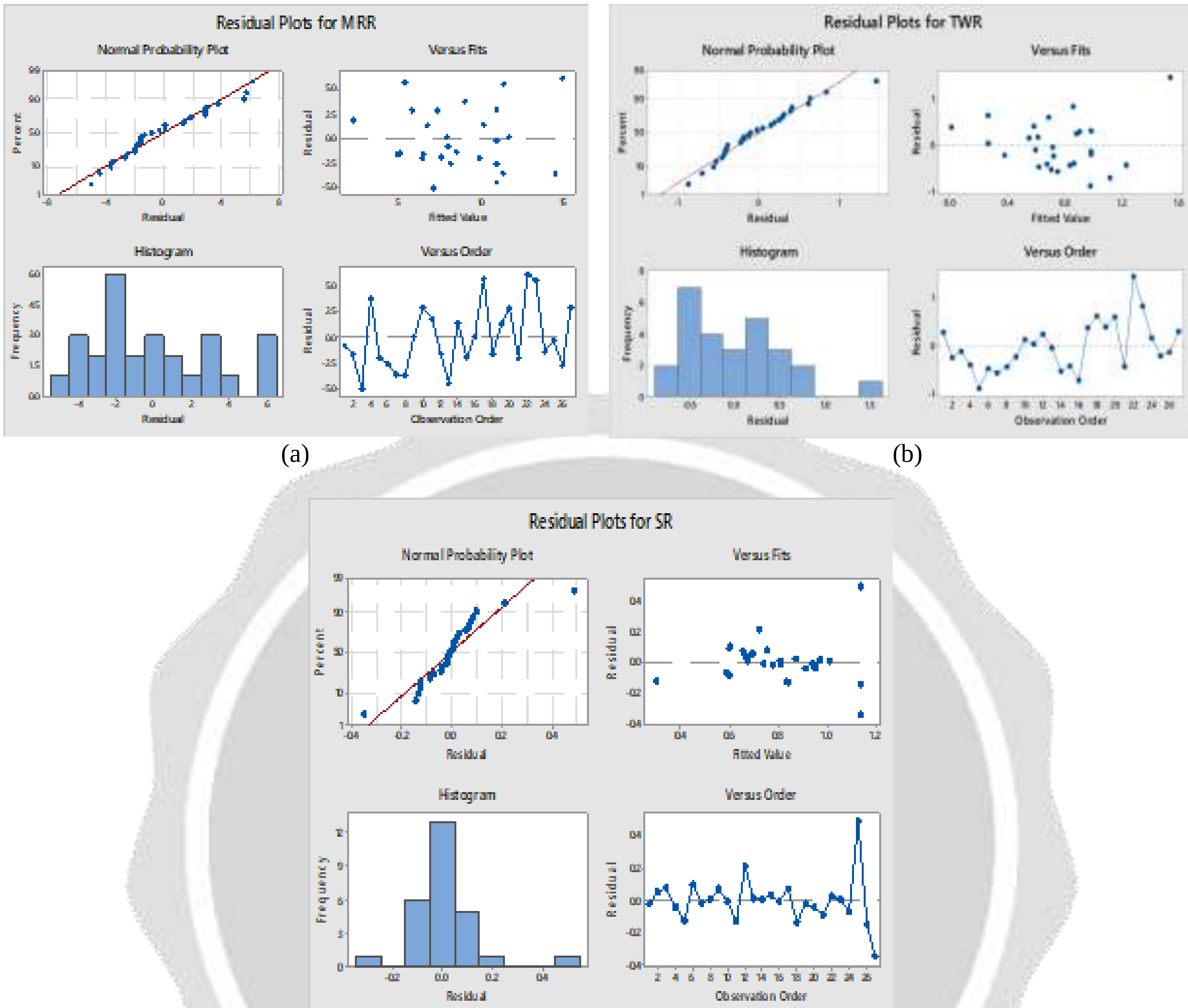
Table 3. Level code plan for factors with corresponds to MRR, TWR and SR [7]

Run	I (amp)	T_{on} (µs)	T_{off} (µs)	T_{lift} (µs)	MRR (mm^3/min)	TWR (mm^3/min)	SR (µm)
1	-1	-1	-1	-1	7.2	1.2	0.7567
2	-1	-1	0	0	3.3	0.5	0.75
3	-1	-1	+1	+1	2.1	0.5	0.68
4	-1	0	-1	0	12.81	0.48	0.91
5	-1	0	0	+1	7.93	0.11	0.71
6	-1	0	+1	-1	5.6	0.16	0.7
7	-1	+1	-1	+1	7.8	0.19	0.79
8	-1	+1	0	-1	10.9	0.42	1.02
9	-1	+1	+1	0	8	0.17	0.833
10	0	-1	-1	0	8.7	0.7	0.73
11	0	-1	0	+1	4	0.31	0.176
12	0	-1	+1	-1	3.5	1.13	0.936
13	0	0	-1	+1	6.5	0.69	0.986
14	0	0	0	-1	11.6	0.18	0.81
15	0	0	+1	0	5.6	0.28	0.7
16	0	+1	-1	-1	11.8	0.41	0.936
17	0	+1	0	0	11.1	0.4	0.726
18	0	+1	+1	+1	4.9	0.9	0.71
19	+1	-1	-1	+1	8	1	0.936
20	+1	-1	0	-1	10.2	1.3	0.866
21	+1	-1	+1	0	4.4	0.8	0.51
22	+1	0	-1	-1	21.2	3	0.896
23	+1	0	0	0	17	1.7	0.683
24	+1	0	+1	+1	7.1	0.8	0.516
25	+1	+1	-1	0	10.7	0.8	1.63
26	+1	+1	0	+1	8.3	0.86	0.99
27	+1	+1	+1	-1	13.9	1.3	0.786

IV. Results and Discussions

From the ANOVA model it has been found that the regression model has a large value of goodness of fit R2=95.69%, 97.28% and 94.65% for MRR, TWR and SR respectively. The P value are smaller than 0.05. It implies that the quadratic model has a high accuracy for predicting optimal injection molding process parameter.

The Figure 2 is indicating the residual plot of work like normal probability or regression plot of the prediction, versus fits value, histogram and observation order of the model. It can be seen that the residuals generally fall on or near a straight line, show that the errors are normally distributed.



(a) (b)

(c)

Fig 2. Residual plot for the (a) material removal rate (MRR), (b) Tool wear rate (TWR) and (c) Surface roughness (SR)

4.1 Optimization

The optimizations plot for material removal rate (MRR), tool wear rate (TWR) and surface roughness (SR) is shown in Figure 3. The main objective of this work was to maximize the material removal rate (MRR) and minimize the tool wear rate (TWR) surface roughness (SR). The desirability approach was used for determining out the optimum values of material removal rate (MRR), tool wear rate (TWR) and surface roughness (SR).

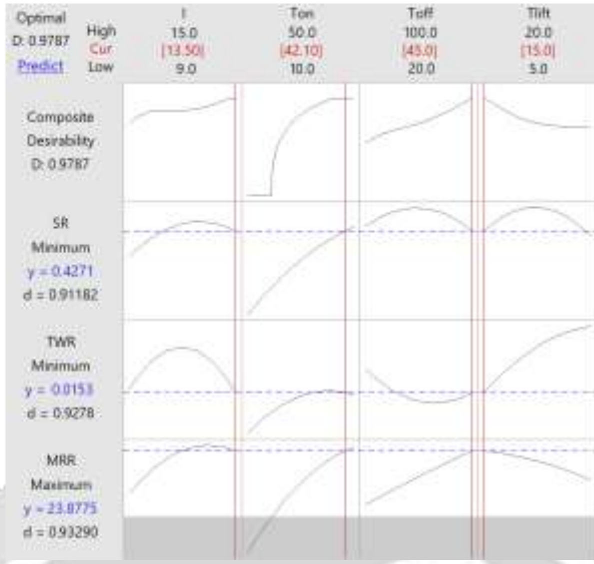


Fig 3. Optimization plot for material removal rate, tool wear rate and surface roughness

Table 4. Comparison of results with present work and previous work [7]

Response	**Experimental Values [7]**	**Laxman and Raj [7]**	**DOE RSM (Present Work)**	**% Improvement**
MRR (mg/min)	21.12	18.768	23.87	**21.37%**
TWR (mg/min)	0.02	0.0178	0.0153	**14.04%**
SR (µm)	0.501	0.5248	0.4271	**18.62%**

V. Conclusion and Further Work

From this work was following conclusions are drawn:

- From this work, it was observed that the RSM method has been quite robust and allowed for this work to find the contribution of each factors and their interaction.
- The aim of the work is to maximize the material removal rate (MRR) and minimize the tool wear rate (TWR) and surface roughness (SR) value.
- From this work, material removal rate increases as the current and pulse on time increases while pulse off time and lift time has been decreasing. The maximum MRR was found 23.87mg/mm.
- The work shows the main effect of process parameters on tool wear rate and the minimum TWR was obtained 0.0153mg/mm.
- The surface roughness is increasing with increase in current and pulse on time but decreasing with an increase in pulse off time and lift time and minimum value of SR was 0.4271 µm.

Further Work

There is some future work to be considered in improving the details of this project work.

- More electrode materials are highly endorsed to be used an electrode for investigation its proficiency.
- This is essential to see clearly the other material machining characteristic. Other than that, the experiments also can be conducted in different parameters.
- This is needed to work other parameters that influence machining performance in electric discharge machine (EDM).

REFERENCES

[1] Amel Chabbi, Mohamed Athmane Yallese, Ikhlas Meddour, Mourad Nouioua, Tarek Mabrouki, François Girardin, "Predictive modeling and multi-response optimization of technological parameters in turning of Polyoxymethylene polymer (POM C) using RSM and desirability function", Measurement (Elsevier), Volume 95, pp 99-115, 2017.

[2] João Eduardo Ribeiro, Manuel Braz Césara, Hernâni Lopes, "Optimization of machining parameters to improve the surface quality", 2nd International Conference on Structural Integrity, Funchal, Madeira, Portugal, Procedia Structural Integrity, Vol. 5, pp 355-362, 2017.

[3] Modi, T and Patel, Jignesh, "A review paper on Optimization of process parameter of EDM for air hardening tool steel", Int. Journal of Engineering Research and Applications, Volume 5, Issue 1 (Part 1), pp 32-37, 2015.

[4] T. Muthuramalingam, B. Mohan, A review on influence of electrical process parameters in EDM process, archives of civil and mechanical engineering, Volume 15, pp 87-94.

[5] B. Venkatesh, Naveen.P, Maurya.B , Shanthi Priya.D, Experimental investigation of EDM using Electrode Materials Copper, Brass and Chromium Copper for alloy steels, International Journal of Advance Engineering and Research Development vol 2,Issue 4, 2015.

[6] Vikas, Shashikant, A.K. Roy and Kaushik Kumar, Effect and Optimization of Machine Process Parameters on MRR for EN19 & EN41 materials using Taguchi, 2nd International Conference on Innovations in Automation and Mechatronics Engineering, 2014.

[7] Jadi Laxman and Kotakonda Guru Raj, "Optimization of Electric Discharge Machining Process Parameters Using Taguchi Technique", International Journal of Advanced Mechanical Engineering, Vol. 4, No. 7, pp. 729-739, 2014.