Optimization of Process Parameters for Electric Discharge Machining Of Mild Steel Using Response Surface Methodology

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Abstract: Non-traditional machining method using Electrical Discharge Machine (EDM) die sinking process is proposed to produce intricate shape with tight tolerance on mild steel. Response Surface Methodology (RSM) technique is applied for the machining of mild steel work piece using copper as electrode. Response Surface Methodology is adopted to establish effects of various process parameters such as Peak current (Ip), Pulse on time (Ton) and Gap voltage(Vg) on two important responses like Material Removal Rate(MMR) and Surface Roughness(Ra) of component. Within the scope of present investigation, RSM has been successfully used to determine input process parameters for an optimum or required MRR and Ra.

Keywords- Electric Discharge Machining (EDM), Desirability approach, Response Surface Methodology (RSM) and Material Removal Rate (MRR) and Surface Roughness(Ra).

I.INTRODUCTION

Machining is a term used to describe a variety of material removal processes in which a cutting tool removes unwanted material from a workpiece to produce the desired shape. The non-contact machining technique have been continuously evolving and attracting a significant amount of research interests. EDM which is a noncontact machining technique thermoelectric process in which heat energy of spark is used to remove material from the workpiece. The workpiece and the tool should be made of electrically conductive material. A spark is produced between the two electrodes (tool and workpiece) and its location is determined by the narrowest gap between the twoelectrodes. The volume removed by a single spark is small, in the range of 104-106mm^3, but this basic process is repeated typically 10000 times per second.

Some researchers, Milan Kumar Das[1] worked on EDM difficult to cut materials and studied about the Artificial bee Colony Algorithm for Optimization of MRR and Surface Roughness. For experimentation, machining parameters namely, Pulse on time, Pulse off time, Discharge current and Voltage are varied based on central composite design (CCD).The Second order response equations for MRR and surface roughness are found out using Response Surface Methodology (RSM). ABC analysis, has been made and the optimum combination of input process parameters are obtained and corresponding values of maximum MRR and minimum Ra are found out. Kuppan et al. [2] (2008) worked on an experimental finding of small deep hole drilling of Inconel 718 material by using the EDM process by considering peak current, pulse on time, duty factor and electrode speed as input machining process parameters. Mathematical model was developed for the higher MRR and depth averaged surface roughness response using RSM technique. Lin et al[3] (2012) studied on statistical design of experiments techniques, such as central composite design for developing the model and the performance of the proposed model is then established by ANOVA test. A 3D response graphs has been used to study the effect of input variables (process parameters) on responses.

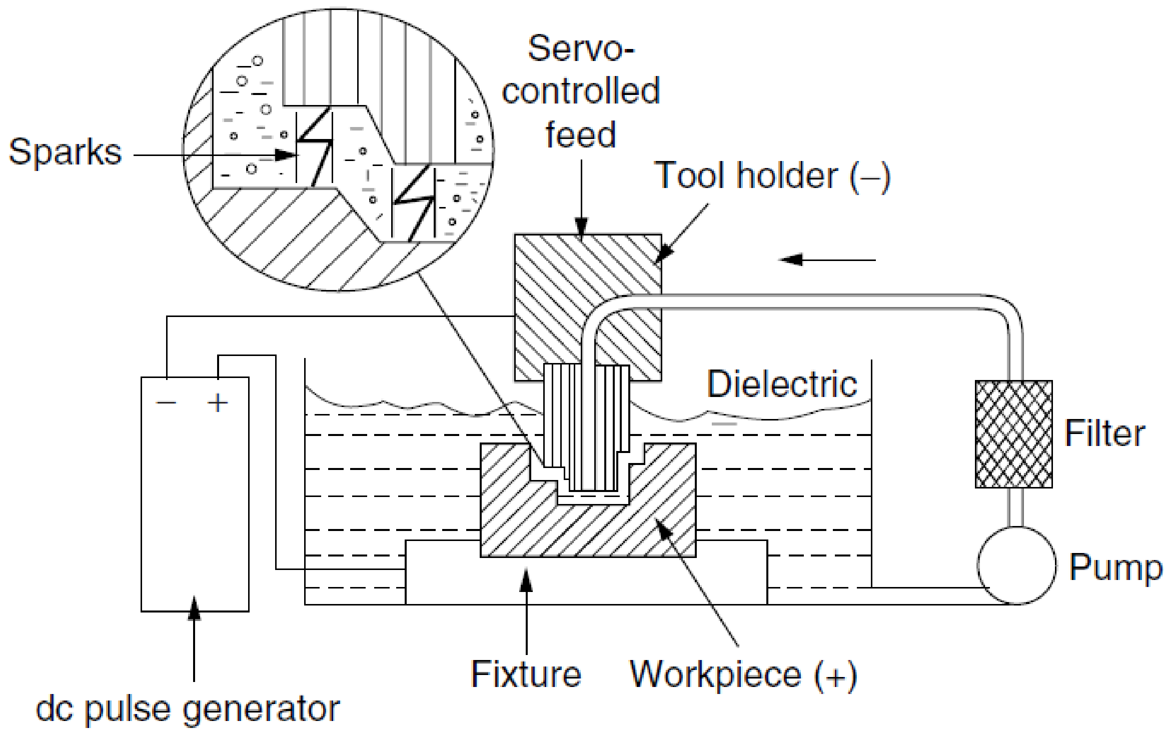


Figure 1 Schematic diagram of principle of working of EDM

- The main components in EDM areElectric power supply, Dielectric medium, Work piece & Tool, Servo control unit. The work piece and tool are electrically connected to a DC power supply.The current density in the discharge of the channel is of the order of 10000 A/cm^2 and power density is nearly 500 MW/cm^2.A gap, known as SPARK GAP in the range, from 0.005 mm to 0.05 mm is maintained between the work piece and the tool.Dielectric slurry is forced through this gap at a pressure of 2 kgf/cm^{2}or lesser.
- The schematic diagram showing the principle of working of EDM and its different sub systems are show in Figure 1 and 2 respectively.

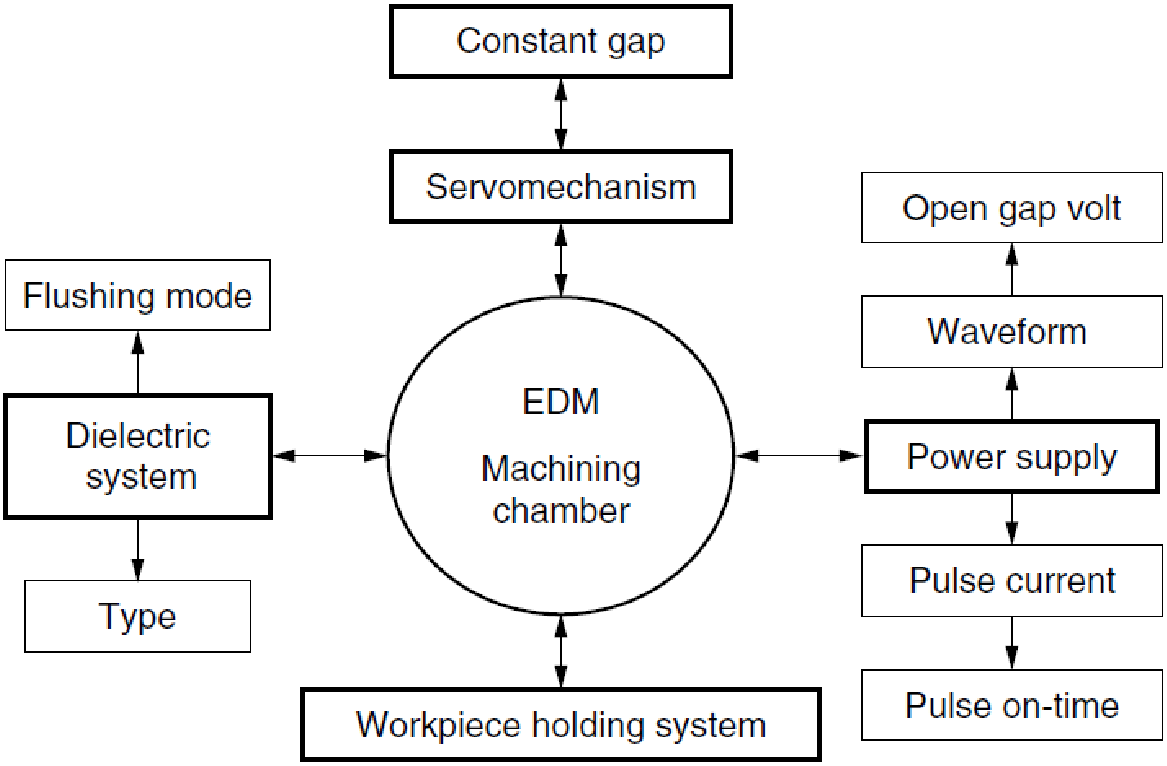


Figure 2 Components of EDM

II. METHODOLOGY

The experiments were carried out to measure the MRR and Raof the components provided using EDM machine (ELECTRONICA). The specification of EDM machine tool used is shown in Table I

Table 1 Specification of EDM machine

Mounting surface (Length x Width)	550 mm x 350 mm
Maximum workspace height	250 mm
Maximum job weight	300 kg
X Axis travel	300 mm
Y Axis travel	200 mm
Width of the work tank	800 mm
Depth of work tank	500 mm
Height of work tank	350 mm
Peak Current, IP	0 – 200 A
Bi – Pulse Current, IB	0 – 5 A
Pulse ON Time, TON	0.25 to 4000 µ sec
Gap Voltage, Vg	40 to 150 V
Work Time, TW	0 to 30 sec
Retraction Distance, Rd	0 to 20 mm

2.1 Surface Roughness Testing

Surface roughness ofcomponent is surface texture. It is quantified by the deviations in the direction of the normal vector of a real surface from its ideal form. If these deviations are large, the surface is rough; if they are small, the surface is smooth. Roughness plays an important role in determining how a real object will interact with its environment. A surface profile measurement can be made with a profilometer that can be contact non contact type.

2.2 Overview of Response Surface Methodology

Response Surface Methodology (RSM) investigates the interaction between several illustrative input variables and one or more response variables. Box and Draper [9] introduced RSM in 1951.The most important purpose of RSM is to use a series of designed experiments to attain an optimal response. A second-degree polynomial model is used in RSM. These models are only an approximation, is easy to estimate and apply, even when little is known about the process. The process of RSM includes designing of a series of experiments for sufficient and reliable measurement of the response and developing a mathematical model of the second order response surface with the best fittings. Obtaining the optimal set of experimental parameters, thus produce a maximum or minimum value of the response. The Minitab Software can be used to analyze the data.

Response surface methodology (RSM) is a collection of mathematical and statistical techniques for empirical model building. By careful design of experiments, the objective is to optimize a response (output variable) which is influenced by several independent variables (input variables).

The application of RSM to design optimization is aimed at reducing the cost of expensive analysis and their associated numerical noise. The problem can be approximated as described in smooth functions that improve the convergence of the optimization process because they reduce the effects of noise and they allow for the use of derivative-based algorithms.. Each contour corresponds to a particular height of the response surface.

In this method if the response is well modeled by a linear function of the independent variables, then the approximating function is the First-order model

$$YU = b0 + b1X1 + b2X2 + \ldots.+biXi + e \qquad (1)$$

If there is curvature in the system, then a polynomial of higher degree must be used, such as the second order model

$$Y_{u=b_0+\sum_{i=1}^{k} b_i x_i+\sum_{i=1}^{k} b_{i=1} x_i^2+\sum_{j>i}^{k} b_{ij} x_i x_j+\cdots \ldots\ldots e} \qquad (2)$$

Wherei is the linear coefficient, j is the quadratic coefficient, and β is the regression coefficient, k is the number of studied and optimized factors in the experiment, and e is the random error. Analysis of variance (ANOVA) has taken into account in order to estimate the suitability of the regression model.

III. EXPERIMENTATION

3.1 Selection of process parameters and their levels

Among all process parameters three parameters namely Peak current (Ip), Pulse on time (Ton), Gap voltage (Vg) are varied during experimentation on three levels. The range of which are found by trial and error method.Apart from these parameters others are considered to be constant to minimize their effect.

Table 2 Control Parameters and their levels

Sl. No.	Control Parameters	Level 1	Level 2	Level 3
1	A, Peak Current (IP), A	2	4	6
2	B, Pulse ON Time (TON), µs	10	15	20
3	C, Gap Voltage (Vg), V	40	50	60

3.2 Experimental Design Using RSM L20 Array

In RSM L20 orthogonal array was chosen. It consists of 20 rows corresponding to the number of experiments with threecolumns of process parameters. Face centered central composite design was adopted to design the experiments as shown in Table 3. Importantly RSM was used to develop second order regression equation which gives relation between process parameters (Ip, Ton and Vg) and performance parameters(MRR and Ra).

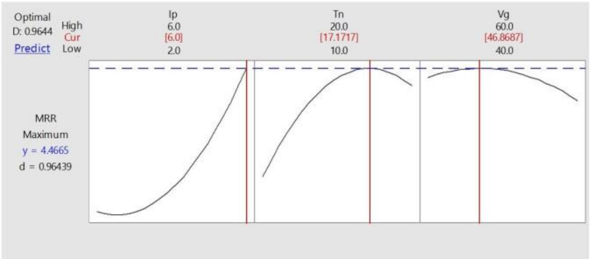
Table 3 L20 Orthogonal array and Experimental results

Sl no	Ip (A)	Ton(µs)	Vg (V)	MRR ($\frac{mm^3}{min}$)	Ra (µm)
1	2	10	40	0.403	2.148
2	6	20	40	3.796	3.051
3	6	10	60	1.8137	2.386
4	2	20	60	0.467	1.707
5	4	15	50	2.21	2.602
6	4	15	50	2.21	2.602
7	6	10	40	2.195	2.411
8	2	20	40	1.27	2.567
9	2	10	60	0.31	1.507
10	6	20	60	3.68	2.877
11	4	15	50	2.21	2.602
12	4	15	50	2.21	2.602
13	2	15	50	2.1654	2.275
14	6	15	50	4.62	2.33
15	4	10	50	1.46	2.312
16	4	20	50	1.73	2.748
17	4	15	40	2.659	2.714
18	4	15	60	1.75	2.295
19	4	15	50	2.21	2.602
20	4	15	50	2.21	2.602

IV. RESULTS AND DISCUSSION

4.1 Optimization using desirability approach

The ultimate objective of work was to maximize the MRR and minimize the Surface Roughness. Desirability approach has been used for finding out the optimum values of the input variables in order to get the maximum value of MRR and minimum value of Ra. FromFigure 3 and Figure 4 it is clear that highest value of MRR 4.4665($\frac{mm^3}{min}$)and lowest value of Ra is 1.5473µm respectively obtained for the following combination of the variables:



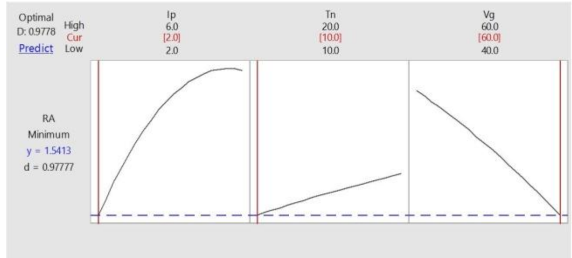


Figure 3 Optimization plot for MRR**Figure 4**Optimization plot for Ra

4.1.1 Surface plots for MRR

1. MRR increases with increased Ip and decreased Vg. This is due to the reason that with the increase of Ip and decrease of Vg, the interval of electric discharge increases and hence number of sparks which produce higher spark energy and high temperature. The variation in Figure 5 indicates that MRR increases rapidly till certain value and it became constant.

2. MRR increases with increased Ip and decreased Ton. From Figure 6, it is clear thatMRR increases initially with the increase of Ip and decrease of Ton but after reaching certain value MRR starts to decreasing this is due to the reason that with the increase of Ip discharge will be more. Also with decrease of Ton the advance of wire or table is more, which results into higher debris. These debris deposited on to the workpiece and results unwanted spark. This causestool material erosion which results into lesser MRR, further decrease in Ton causes wire breakage.

3. MRR Increases with decreased Ton and decreased Vg (Figure 7)This is due to the reason that, decrease in Vg causes increase in MRR to a certain value and after that it decreases. This is due to the same reason mentioned above. Decrease in Ton causes increase in discharge and hence MRR.

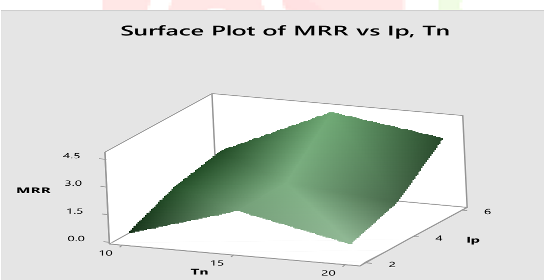


Figure 5 Ip, Ton vs MRR

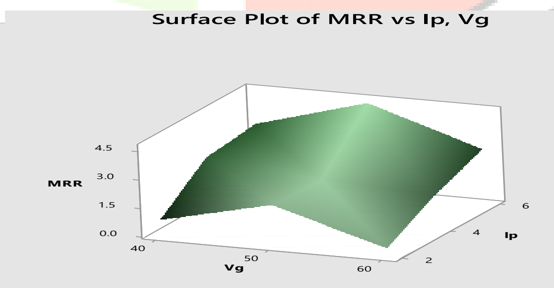


Figure 6 Ip, Vg vs MRR

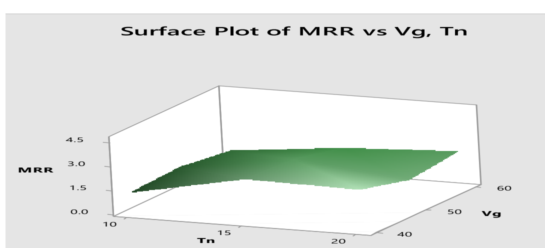


Figure 7 Ton, Vg vs MRR

4.1.2 Surface plot for Ra

The parameter analysis has been carried out to study the influences of the input process parameter such as Ip, Ton and Vg on the process response (Ra). Contour plots and three-dimensional response surface plots are formed based on the quadratic model to evaluate the variation of response. The plots are shown in Figures 8-10. These plots can also provide further assessment of the correlation between the process parameters and response as under:

1. Ra increases with increased Ip and decreased T_{on}. This is due to higher spark energy from high temperature. (Figure 8) .
2. Ra increases with increased T_{ON} and decreased Vg (Figure 9).
3. Ra Increases with decreased applied voltage Vg and decreased Ton(Figure 10).

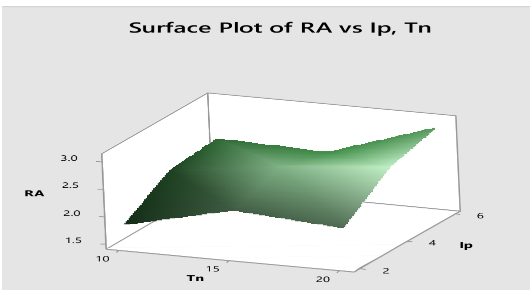


Figure 8 Ip, Ton vs Ra

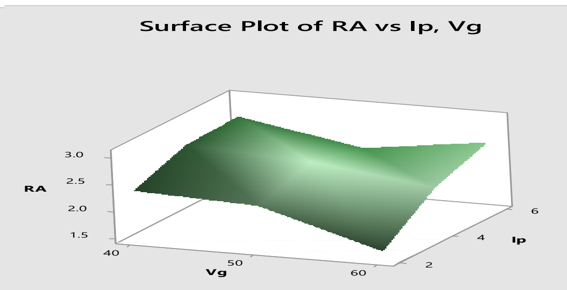


Figure 9 Ip, Vg vs Ra

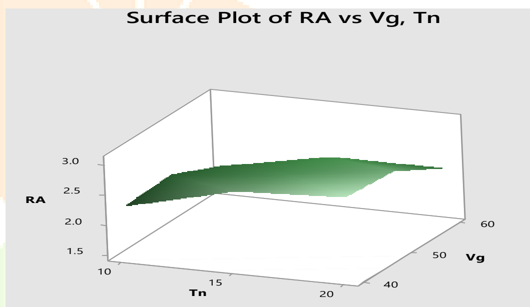


Figure 10 Ton , Vg vs Ra

4.2 Regression Analysis

The experimental results were used to develop a mathematical model, for expressing the relation among process parameters, Ra and MRR respectively. The coefficients of mathematical models are computed using method of multiple regressions. Regression equation can also be used to predict the response parameter value at different levels of input parameter and is also help for confirmation of experiments.

(a) Regression Equation in Uncoded Units as generated in MINITAB Software for MRR is as follows:

MRR = -12.04-1.727*Ip+1.155*Ton+0.312*Vg+.2149*Ip*Ip-0.03753*Ton*Ton-

0.00329*Vg*Vg+0.03054*Ip*Ton +0.00249*Ip*Vg-0.00111*Ton*Vg

For expressing the relation between process parameters and Ra, Regression equation can be shown as

(b) Regression Equation in Uncoded Units as generated in MINITAB Software for Ra is as follows:
RA =1.83+0.114*Ip+0.076*Ton-0.0048*Vg-0.0593*Ip*Ip-0.00039*Ton*Ton-0.000351*Vg*Vg+0.00640*Ip*Ton+0.00814*Ip*Vg-0.00092*Ton*Vg

4.3 Confirmation Experiment

The optimal combinations obtained from the analysis of resultsare verified by conducting the experiments for those combinations. The above mentioned equations were used to predict the performance parameter value for the optimal combinations for both experimental and predicted values and the results are shown in Table 4.

Table 4 Confirmation experiments for MRR and Ra

Response Variables	Process Parameters			Experimental Values	Predicted Values	Prediction Error(%)
	Ip	Ton	Vg			
MRR	6	20	50	3.736	4.0992	8.86
Ra	2	10	50	1.908	1.9088	0.041

V. CONCLUSION

In this study an attempt has been made to determine the values of input parameters to maximize the Material Removal Rate(MRR) and minimize Surface Roughness (Ra) in EDM. The optimization results were obtained are as follows:

- Customized values of MRR and Ra can be obtained by solving equation obtained from desirability approach.
- From the graphs, it is found that MRR increases with increase in Peak Current.
- Peak Current is found to be the most significant factor for both MRR and Ra in EDM ofmild Steel from Figure 5 and Figure 8.
- Optimized parameter for MRR is obtained at IP = 2 A, TON = 10 µs and Vg = 50 V.
- Optimized parameter for Ra is obtained at IP = 2 A, TON = 10 µs and Vg = 60 V.

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REFERENCES

[1]Milan kumar das.2014 Application of artificial Bee Colony Algorithm for optimization of MRR and Surface Roughness in EDM of EN31 Tool steel Procedia Material science, volume 6, pages 741-751.

[2]Kuppan et al 2008 influence of EDM process parameters in deep hole drilling of Inconel, The International Journal Of Advanced Manufacturing Technology, volume 38, pages 74-84.

[3]Ho, K.H., Newman, S T., 2003 State of the art EDM, International Journal of Machine Tools and Manufacturing 43,1287-1300.

[4] V. Muthukumar, N Rajesh 2014 Mathematical Modeling for Radial Overcut on EDM of Incology 800 by RSM, Procedia Material science, volume 6, pages 1671-1682.

[5] Hewidy, M. S., El-Taweel 2005 Modeling the machining parameters of Wire EDM of Inconel 601 using RSM, International Journal of Material Processing Technology 169, pages 328-336.