International Journal of Advanced Research in Engineering and Applied Sciences

ISSN: 2278-6252
Impact Factor: 7.358

MATHEMATICAL MODELLING AND OPTIMISATION OF WEDM PARAMETERS USING RESPONSE SURFACE METHODOLOGY IN MACHINING OF AISI D2 STEEL

Rakesh Bhandari, Research Scholar, Sangam University

Harish Nagar, Associate Professor, Sangam University

Abstract: *The objective of the present work is to investigate the effects of various WEDM process parameters such as pulse on time, pulse off time, servo voltage and wire feed rate on the Material Removal Rate (MRR) and Surface Roughness (SR). Secondly, to obtain the optimal settings of machining parameters at which the Material Removal Rate (MRR) is maximum and the Surface Roughness (SR) is minimum in a specified range of input parameters. The experiments were carried out as per design of experiment approach using L27 (3^4) orthogonal array. In the present investigation, AISI D2 steel specimen is machined by using brass wire(0.25 mm) as electrode and the response surface methodology (RSM) is used for modelling a second-order response surface to estimate the optimum machining condition to produce the best possible responses within the experimental constraints. The results from this study will be useful for manufacturing engineers to select appropriate set of process parameters to machine AISI D2 steel to optimise cutting conditions.*

Keywords: *Taguchi's L27 orthogonal array, Response Surface mythology, ANOVA, material removal rate, Surface roughness, DOE*

1. INTRODUCTION

The electrical discharge machining (EDM), is a thermo-electric non-traditional manufacturing process, which is gaining popularity, since it does not require cutting tools and allows machining involving hard, brittle, thin and complex geometry. As there is no direct contact between electrode and the work piece in EDM methodology, the common problems like mechanical stress and vibration problems in machining are eliminated. In electric discharge machining (EDM), material is removed from the workpiece through localized melting and vaporization of material. Electric sparks are generated between two electrodes when the electrodes are held at a small distance from each other in a dielectric medium and a high potential difference is applied across them. Localized regions of high

temperatures are formed due to the sparks occurring between the two electrode surfaces. Workpiece material in this localized zone melts and vaporizes. Most of the molten and vaporized material is carried away from the inter-electrode gap by the dielectric flow in the form of debris particles.

Nomenclature

WEDM	wire cut electrical discharge machining
MRR	material removal rate
SR	surface roughness
T_{on}	pulse on time
T_{off}	pulse off time
SV	servo voltage
WF	wire feed
ANOVA	analysis of variance
S/N ratio	Signal-to-noise ratio

2. EXPERIMENTAL DETAILS

2.1. Electrode and Workpiece material

Experiment was performed with AISI D2 steel as workpiece and brass wire of 0.25 mm diameters as electrode. The experiment work was conducted on the wire EDM of ELECTRONICA ULTRACUT S2 machine. De-ionized water was used as the dielectric fluid.MRR is expressed as the ratio of the difference in weight of the work piece before and after machining to the machining time and density of the material. Surface roughness of the workpiece was measured using Taylor-Hobman surface tester and Cutting rate was displayed digitally on the machine.

2.2. Design of experiment

In the present study according to the Taguchi method, a robust design and an L27 (3^4) orthogonal array are employed for the experimentation. Based on the machine tool, cutting tool (electrode) and workpiece capability, four machining parameters are considered as controlling factors – namely, Pulse on time, Pulse off time, Servo voltage, Wire Feed and each parameter has three levels – namely low, medium and high, denoted by L1, L2 and L3,

respectively. The factors and their respective levels have been selected on the basis of pilot experiments.

Table 1: Important process parameters and their levels

Factor	Parameters	unit	Levels		
			L1	L2	L3
A	Pulse on time	µ sec	110	115	120
B	Pulse off time	µ sec	45	50	55
C	Servo voltage	volts	20	35	50
D	Wire feed	mm/min	2	4	6

Apart from the parameters considered, there are other factors that can have an effect on the performance parameters. In order to minimize their effects, these parameters are held constant. These are- workpiece material (AISI D2 steel), electrode material (brass wire), wire tension (110 units), water pressure (115 units) workpiece thickness (14mm) and vertical angle of cut.

The tabulated results below (table 2) depict the process parameter, performance parameter and the SN ratio. SN ratio signifies the higher value representing better machining performance such as MRR and CR, 'higher-the-better' and inversely the characteristics with lower value represents better machining performance, such as SR, 'lower-the-better'.

Table2. L_{27} Experimental result and Signal-to-noise ratio

RUN NO.	PROCESS PARAMETERS				PERFORMANCE PARAMETERS		S/N RATIO	
	Ton	Toff	SV	WF	SR	MRR	SR	MRR
1	120	55	50	6	2.853	5.3935	-9.5922	14.5499
2	110	45	35	6	2.500	6.3649	-8.1353	16.3259
3	115	45	50	4	3.126	7.8610	-9.5483	17.7416
4	110	50	50	2	1.773	3.3416	-4.9158	11.4752
5	115	55	35	2	3.080	5.3416	-9.6218	14.5454
6	115	55	35	2	3.093	5.2389	-9.6218	14.5454
7	115	50	20	6	3.333	8.4649	-10.7573	18.6007
8	120	55	50	6	3.173	5.2870	-10.7573	14.5454
9	120	45	20	2	3.653	12.6792	-11.5106	21.9682
10	115	50	20	6	3.593	8.6974	-11.5106	14.5454
11	115	55	35	2	2.906	5.4350	-11.5106	14.5454
12	120	45	50	6	2.820	5.2896	-9.0050	14.4685

13	120	45	20	2	3.773	12.2545	-9.0050	14.5454
14	115	45	50	4	3.046	7.7948	-9.0050	14.5454
15	110	45	35	6	2.553	6.5610	-9.0050	14.5454
16	115	45	50	4	2.826	7.4909	-9.0050	14.5454
17	110	50	50	2	1.840	3.9922	-9.0050	14.5454
18	115	50	20	6	3.420	8.3831	-9.0050	14.5454
19	120	50	35	4	3.733	8.5234	-11.3246	18.3586
20	110	55	20	4	2.833	3.8078	-8.9363	11.9396
21	120	45	20	2	3.860	12.7117	-9.0050	14.5454
22	110	55	20	4	2.780	3.7454	-9.0050	14.5454
23	120	50	35	4	3.846	8.4259	-9.0050	14.5454
24	110	50	50	2	1.666	4.0390	-9.0050	14.5454
25	110	55	20	4	2.780	4.3987	-9.0050	14.5454
26	110	45	35	6	2.600	6.7429	-9.0050	14.5454
27	120	50	35	4	3.460	7.9234	-9.0050	14.5454

3. EFFECT ON SURFACE ROUGHNESS

The SN ratio given in the table 2 and the average value of surface roughness for each parameter and the respective levels are plotted in the graphs (fig. 1a).The 'main effect plot' shows the influence of each parameter on machining performance. Figs.1b, 1c, 1d (Response Surface plot) show the influence of the three different parameters pulse on time, servo voltage and wire feed on the performance parameter surface roughness. The figures below demonstrate that with the increase in pulse on time the surface roughness decreases and with the increase in servo voltage the surface roughness decreases. With the increase of wire feed the surface roughness first increases and then decreases having a very little effect on pulse off time.

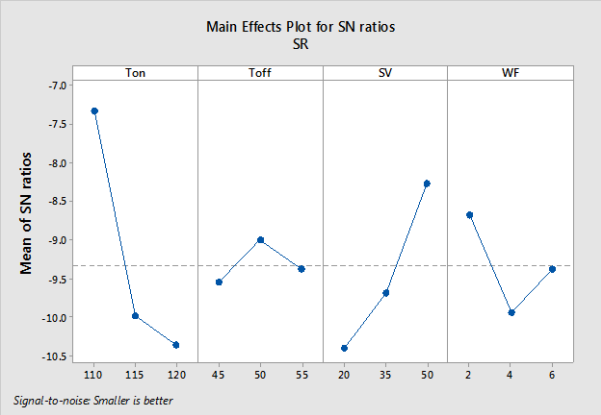


Fig.1(a)

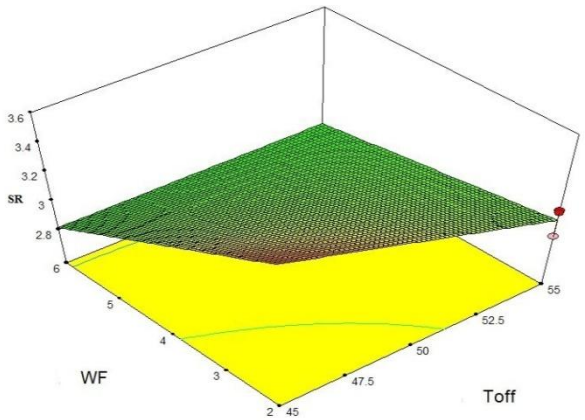
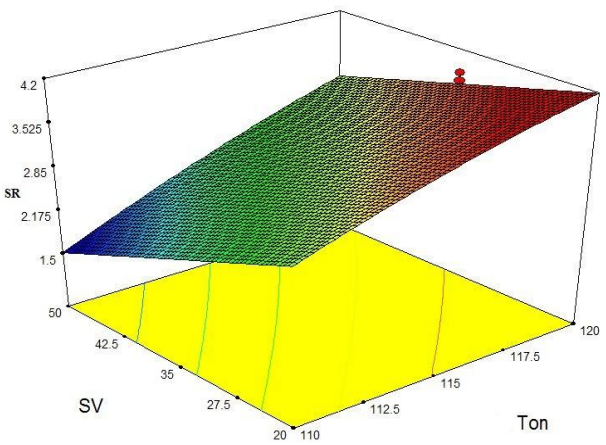


Fig.1(b)



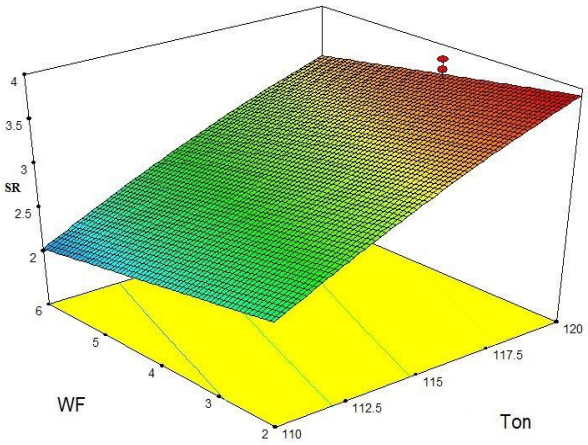


Fig.1(c) **Fig.1(d)**

Fig.1 Main effect plot for SN ratio (a) and the response surface plot between Ton, SV and WF on SR (b, c, d)

3.1 Mathematical Model of Surface Roughness

Regression coefficients of the second order equation are obtained by using experimental data. The regression equation for the gap current as a function of five input process parameters was developed and is given below.

$$Surface\ Roughness = 3.06072 + 0.703806 * Ton - 0.141444 * Toff - 0.637778 * SV - 0.249833 * WF + 0.530111 * Ton * Toff + 0.124444 * Ton * SV - 0.434944 * Toff * SV + 0.142778 * Toff * WF - 0.0848611 * Ton^2 \quad (1)$$

The response table (Table 3) illustrates the average of each response characteristic for each level of each factor. The table includes ranks based on delta statistics, which compares the relative magnitude of efforts. The ranks and delta values show that pulse on time has the greatest effect on surface roughness followed by servo voltage, wire feed and pulse off time in the order.

Table 3. Response Table for Signal-to-noise ratios of SR

Level	Ton	Toff	SV	WF
1	-7.329	-9.550	-10.401	-8.683
2	-9.976	-8.999	-9.694	-9.936
3	-10.358	-9.383	-8.265	-9.372
Delta	3.029	0.551	2.136	1.254
Rank	1	4	2	3

ISSN: 2278-6252
Impact Factor: 7.358

4. EFFECT ON MATERIAL REMOVAL RATE

The SN ratio given in the table 2 and the average value of surface roughness for each parameter and the respective levels are plotted in the graphs (fig. 2a).The main effect plot show the influence of each parameter on machining performance. Fig.2b, 2c, 2d (Response Surface plot) show the influence of the three different parameters pulse on time, pulse off time and servo voltage.The figures below demonstrate that increase in pulse on time results in increase of MRR and the increase of servo voltage and pulse off time results in decrease of MRR, having a very little effect of wire feed on MRR.

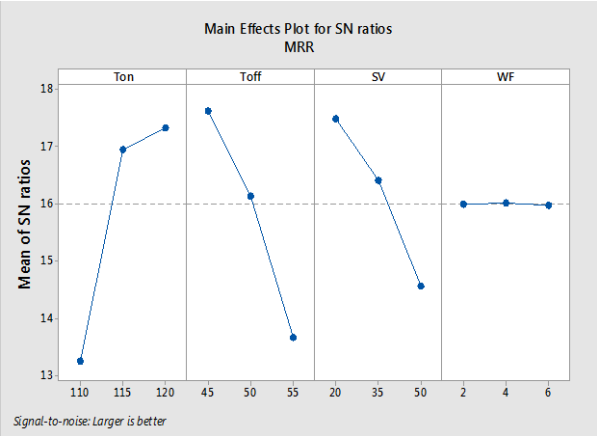


Fig.2 (a)

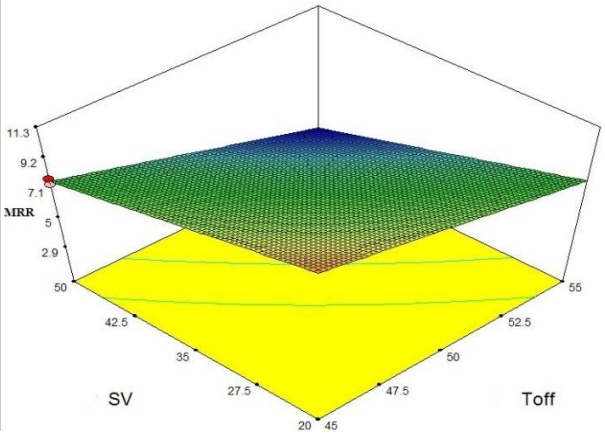


Fig.2(b)

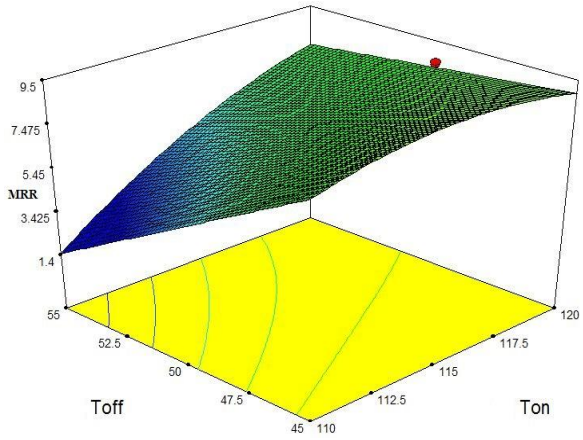


Fig.2(c)

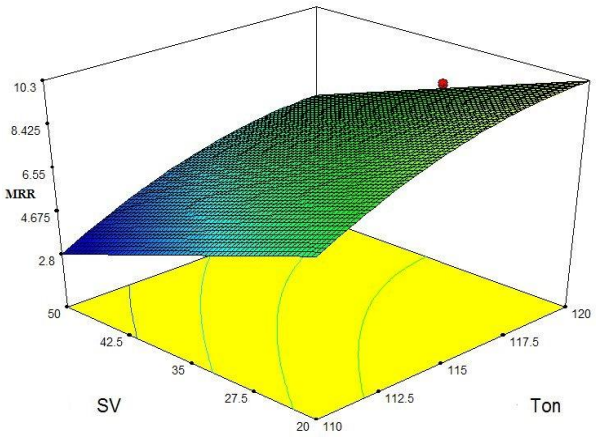


Fig.2(d)

Fig.2 Main effect plot for SN ratio (a) and the response surface plot between Ton, Toff and SV on MRR (b, c, d)

4.1 Mathematical Model of Material Removal Rate

Based upon the proposed second-order polynomial model,the effects of the process parameter taking into consideration the Cutting Rate has been calculated by computing the values of the different constants of Eq. (2)

$$\begin{aligned} Material\ Removel\ Rate\ = \ & 7.40755 + 1.64801 * \text{Ton} - 2.07444 * \text{Toff} - 2.08996 * \text{SV} - \\ & 0.982378 * \text{WF} + 1.44631 * \text{Ton} * \text{Toff} + 0.0963611 * \text{Ton} * \text{SV} - \\ & 0.323528 * \text{Toff} * \text{SV} + 0.976986 * \text{Toff} * \text{WF} - 0.764665 * \text{Ton\^2} \end{aligned} \quad (2)$$

The response table (Table 4) illustrates the average of each response characteristic for each level of each factor. The table includes ranks based on delta statistics, which compare the relative magnitude of efforts. The delta statistic is the highest minus the lowest average for each factor. Minitab 17 assigns ranks based on delta values; rank 1 to highest delta value, rank 2 to the second highest and, so on. The ranks indicate the importance of each factor to the response. The ranks and the delta values show that pulse on time have the greatest effect on MRR and is followed by pulse off time, servo voltage and wire feed in that order.

Table4. Response Table for Signal-to-noise ratios of MRR

Level	Ton	Toff	SV	WF
1	13.25	17.63	17.50	16.00
2	16.96	16.14	16.41	16.01
3	17.34	13.68	14.56	15.99
Delta	4.09	3.95	2.94	0.03
Rank	1	2	3	4

5. CONCLUSION

In this work, two performance parameters (Surface Roughness and Material Removal Rate) are investigated by varying the four Process(machining) parameters on AISI D2 steel with Brass wire as electrode in wire electric discharge machine. The performance parameters included pulse on time (T_{on}), Pulse off time (T_{off}), Servo voltage (SV) and Wire feed rate (WF). Experiments were conducted according to L_{27} Orthogonal Array Design. The optimum parameters value combination was found which would yield minimum Surface Roughness (SR) and maximum Material Removal Rate (MRR). The following conclusions have been drawn:

1. Regression Equation has been successfully used to develop the Material Removal rate, Surface Roughness model.
2. The two main significant factors that affect the Surface Roughness are pulse on time and Servo voltage respectively.
3. The two main significant factors that affect the Material Removal Rate are Pulse on time and Pulse off time respectively.
4. The optimum parameters of combination setting is Pulse on time 112.99 µs, Pulse off time 45µs, Servo Voltage 20 volts , and Wire feed 4.85mm/min for maximizing MRR, minimize the SR.

REFERENCES

[1] Chattopadhyay, K.D., Verma, S., Satsangi, P.S., Sharma, P.C., "Development of empirical model for different process parameters during rotary electrical discharge machining of copper–steel (EN-8) system", Journal of materials processing technology 20(9)2008:1454-1465.

[2] Chikalthankar, S. B., Nandedkar, V. M., Borde, S. V. "Experimental Investigations of EDM Parameters", 2013, International Journal of Engineering Research and Development 7(5)2013:31-34.

[3] Datta, Saurav, Mahapatra, Siba Sankar, "Modeling, Simulation and Parametric Optimization of Wire EDM Process using Response Surface Methodology coupled with Grey-Taguchi Technique", International Journal of Engineering, Science and Technology 2(5)2010:162-183.

[4] El-Taweel, T. A., "Multi-response Optimization of EDM with Al-Cu-Si-TiC P/M Composite Electrode", International Journal of Advance Manufacturing Technology 442009,:100-113

[5] Gopalakannan, S., Senthilvelan, T., Ranganathan, S., "Modeling and Optimization of EDM Process Parameters on Machining of Al 7075-B4C MMC using RSM", International Conference on Modeling, Optimization and Computing 382012:685-690.

[6] Lakshmanan, Singaram, Kumar, Mahesh, "Optimization of EDM Parameters using Response Surface Methodology for EN31 Tool Steel Machining EDM Process", International Journal of Engineering Science and Innovative Technology 2(5)2013:64-71

[7] Nikalje, A. M., Kumar, A., Sai Srinadh, K. V. "Influence of Parameters and Optimization of EDM Performance Measures on MDN 300 Steel using Taguchi Method", International Journal of Advance Manufacturing Technology 692013:41-49.

[8] Puertas, I., Lusis, C.J., "A study on the machining parameters optimization of electrical discharge machining", Journal of materials processing technology, 2003, 521-526.

[9] Puri, A. B., Bhattacharya, B., "Modeling and Analysis of White Layer Depth in a Wire-Cut EDM Process through Response Surface Methodology", International Journal of Advance Manufacturing Technology, 2005, 301-307.

[10] Sahoo, Manabhanjan, N. Pramanik, Rudra, Sahoo, Dipti R. "Experimental Investigation of Machining of Tungsten carbide by EDM and Its Mathematical Expression", International Journal of Mechanical and Production Engineering2(1)2013:138-150.

[11] Sahoo, Manabhanjan, N. Pramanik, Rudra, Sahoo, Dipti R. "Experimental Investigation of Machining of Tungsten carbide by EDM and Its Mathematical Expression", International Journal of Mechanical and Production Engineering2(1)2013:138-150.

[12] Shah, C. D., Mevada, J. R., Khatri, B. C., "Optimization of Process Parameter of Wire Electrical Discharge Machine by Response Surface Methodology on Inconel-600", International Journal of Emerging Technology and Advanced Engineering 3(4)2013:260-267.

[13] Sharma, Neeraj, Khanna, Rajesh, Gupta, Rahuldev, "Multi Quality Characteristics of WEDM Process Parameters with RSM", International Conference on Design and Manufacturing 64, 2013:710-719.

[14] Subrahmanyam, S. V., Sarcar, M. M. M.,2013, "Evaluation of Optimal Parameters for machining with Wire cut EDM Using Grey-Taguchi Method", International Journal of Scientific and Research Publications 3(3)(2013):1-9

[15] T, Rajmohan, R., Prabhu, G., Subba Rao, K., Palanikumar, "Optimization of Machining Parameters in Electrical Discharge Machining (EDM) of (304) stainless steel", International Conference on Modeling, Optimization and Computing (ICMOC): 2012, 103-1036.