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Modelling of Surface Roughness in Wire-EDM Using Response Surface Methodology Technique

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Abstract—*Wire EDM is one of the most important and useful machining process in metal cutting industry due to its minimum heat affected zone (HAZ) ability nears the machined surface. Surface finish of the machined surface in Wire EDM is mainly depends on the input parameter such as pulse current, voltage, pulse on time, Wire feed and type of dielectric medium. In this current work surface roughness was taken as a response characteristics for the analyse and further optimized with selected input process parameter. Response surface methodology center composite second order rotatable design was used to design the experiments. The selected process parameters for this current study were pulse on time, pulse off time, flushing pressure, wire tension, servo voltage and wire feed rate. The regression model for surface roughness was established with inclusion of all the input process parameter. Optimized values were predicted using Genetic algorithms. Finally predicted optimized value is compared with experimental value and the closeness with obtained experimental value is stated interns of percentage.*

1. INTRODUCTION:

Wire Electrical Discharge Machining (WEDM) it's been widely used in die-making industry, aerospace, medical and practically machine any electrically conductive material. It ia an unconventional machining process which uses continuously feeding electrically conductive electrode wire to cut the work piece based on the written programme. Wire electrical discharge machine commony called as WEDM and the cinductive wire is fed against the workpiece [1]. Majhi et al.(2013) have made an attempt to determine the optimal process parameters MRR, SR and TWR for EDM process. Kumar and Kumar (2013) have modelled and optimised the WEDM for the selected input process parameter. To figure out optimum surface roughness(SR), they selected the input process parameters like pulse on time, Pulse off time, Wire Speed and Wire Feed. Taguchi techniques was effectively used for optimisation of minimizing the SR. Pasam et al. (2010) conducted an experiment in WEDM to determine the relation among the responses characteristics and its input process parameter. From the study they concluded that metal removal rate, surface finish, and kerf width are most important responses to study in WEDM. Lal et al (2015) used Taguchi-based Grey relational analysis, to find the optimal input process parameter setting for machining composite material using molybdenum wire as an electrode with a diameter of 0.18 mm. Shivade and Shinde (2014) have used same technique to optimize the D3 tool steel material. Jaganathan et al. (2012) have optimised the wire EDM input process parameter and output responses characteristics such as material removal rate and surface finish for EN31 using Taguchi L27 orthogonal array (OA). Singha and Pradhan (2014) were run the experiment using Taguchi method and response surface methodology for designing the experiment and to estimate the optimum machining condition within the input process parameter range . Sinha et al. (2015) have applied Taguchi method for single objective optimisation and principal component analysis (PCA) been used for multi-objective optimisation. Huang and Liao (2003) applied Grey relational analyses for optimizing the input process parametr in the WEDM.

The main focus on this paper is to analyse the effect of selected input process parameter on the surface roughness.

2. EXPERIMENTATION

The experiment was conducted on ELEKTRA SPRINTCUT 734 four axes WEDM machine tool. High Carbon High Chromium Die Steel (HCHCR) was used as a work piece. The composition of High Carbon High Chromium Die Steel (HCHCR) work material used is given in Table 1. Molybdenum wire of 0.18 mm diameter was used an electrode material for all the run. The selected input process parameters (are pulse on time, pulse off time, servo voltage and wire feed) and their range with coded value is shown in the table 2.

Table 1 Chemical composition of High Carbon High Chromium Die Steel (HCHCR) (wt %)

C	Cr	Si	V	Mn	Mo
1.54	12	0.32	0.91	0.34	0.76

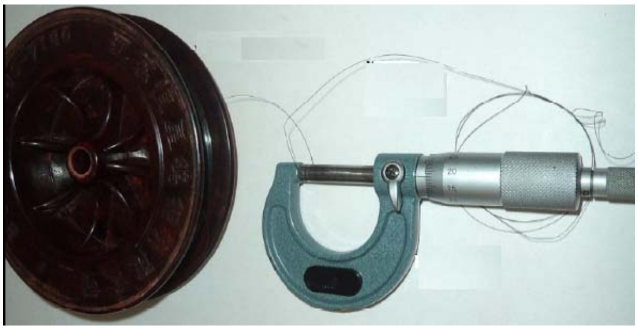

Figure 1: Molybdenum Wire Electrode

The photographic view of the molybdenum wire electrode is shown in the figure Fig.1. The other Fixed parameter details is shown in the table 3. The SR was measured by using Mitutoyo-SJ-201P surface tester on the work-piece at four different spot after machining. 4 mm is chosen as an evaluation length for the measurement. The average value is taken for the analysis. Initially number of Trial runs has been conducted to fix range of input process parameter range for design of experiment. The resolution of the Mitutoyo-SJ-201P machine is 0.01mm. The surface roughness tester machine which used for this study is shown in figure.2.

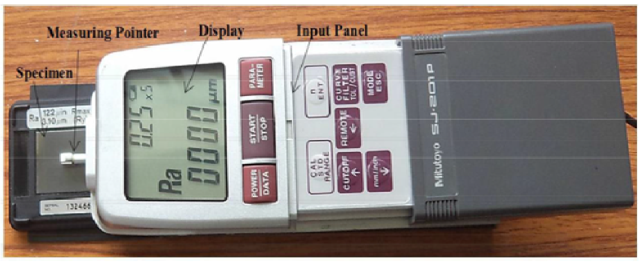

Figure 2. Surface roughness tester

Table 2: Input variable and their levels

Variables	Symbol	Levels				
		-2	**-1**	**0**	**1**	**2**
Pulse on Time- Ton (µs)	A	105	110	115	120	120
Pulse off time T-off (µs)	B	35	40	45	55	10
Servo Voltage (volt)- Sv	C	10	15	20	25	30
Wire feed rate (m/min)- Wf	D	4	6	8	10	12

Table 3: Fixed Parameters

S. No	Fixed parameter	Set value
1	Wire material	Molybdenum wire of diameter of 0.25 mm
2	Peak current	230 Amps
3	Pulse in peak voltage	2
4	Servo feed setting	250

3. DEVELOPING THE DESIGN MATRIX

Response surface methodology was used for to design the experiment. This is used for experimental modelling of polynomials as limited approximations to get exact input and output interaction. Centre composite second order routable design was selected for record the readings. This is an effective technique comprises of two subset points, first one which approximate linear and two factor interaction effects and second subset create curvature effect. It is effective method to predicts the interaction and required minimal runs to predict errors It comprises of 16 corner points, 8 axial points and 6 central points. The design shown in the table 3.. Accordingly, the 30 experimental runs were conducted to evaluate the linear quadratic and two way interactive effect of the WEDM variable on the responses.

Table 4: Design of experiments

Run	Ton	Toff	Sv	W_f	SR
1	2	0	0	0	3.411
2	1	1	-1	1	3.32
3	-1	1	1	-1	2.91
4	-1	1	-1	-1	2.89
5	-1	-1	1	-1	2.89
6	-2	0	0	0	2.82
7	1	1	1	-1	3.32
8	1	1	-1	-1	3.29
9	1	-1	-1	-1	3.252
10	1	1	1	1	3.25
11	0	0	0	-2	3.087
12	0	0	0	2	3.05
13	0	0	0	0	3.04
14	0	0	0	0	3.04
15	0	0	0	0	3.04
16	-1	1	-1	1	3.02
17	-1	1	1	1	3.011
18	-1	-1	1	1	3.01
19	-1	-1	-1	1	2.991
20	-1	-1	-1	-1	2.95
21	0	0	0	0	3.141
22	0	0	2	0	3.11
23	0	0	0	0	3.11
24	0	0	0	0	3.11
25	0	2	0	0	3.11
26	1	-1	-1	1	3.218
27	1	-1	1	-1	3.191
28	1	-1	1	1	3.19
29	0	-2	0	0	3.159
30	0	0	-2	0	3.152

4. DEVELOPMENT OF MATHEMATICAL MODELS

Using the experimental result which is obtained from the central composite rotatable design of experiments and applying regression analysis, the modelling of the selected response with a small quantity of independent input process parameter can be gained. The response surface exists expressed as follows.

$$y = a_0 + \sum_{i=1}^{n} a_i x_i + \sum_{i=1}^{n} a_{ii} x_i^2 + \sum_{i<j}^{n} a_{ij} x_i x_j + \varepsilon \quad (1)$$

In this equation,

y - the corresponding response surface,

x_i and x_j - the coded values of input variables and the coefficients

a_i, a_{ii}, and a_{ij} - the linear terms, quadratic terms and interaction effects respectively.

Developing the final model

As determined by the procedures were the final mathematical models in terms of process parameter are given below:

SR = +3.10 + 0.15 * A + 9.208E-003 * B - 0.010 * C + 0.010 * D + 0.021* A * B -6.187E-003 * A * C - 0.029

* A * D + 6.313E-003* B * C +4.062E-003* B * D -1.062E-003 * C * D

Adequacy of the developed model is checked using ANOVA technique. ANOVA result is shown in table 5. IT found that model is significant and lack of fit is not significant. F ratio was greater than the tabulated values at 95 % confidence level. R^2 and adjusted R^2 values are 91.49% & 89.27% respectively.

Table 5: ANOVA for SR

Source	Sum of Square	df	Mean Square	F Value	p-value	
					Prob > F	
Model	0.55	10	0.055	30.13	< 0.0001	significant
A-A	0.52	1	0.52	285.32	< 0.0001	
B-B	2.04E-03	1	2.04E-03	1.11	0.305	
C-C	2.46E-03	1	2.46E-03	1.34	0.2608	
D-D	2.46E-03	1	2.46E-03	1.34	0.2608	
AB	7.18E-03	1	7.18E-03	3.92	0.0623	
AC	6.13E-04	1	6.13E-04	0.33	0.5698	
AD	0.014	1	0.014	7.44	0.0133	
BC	6.38E-04	1	6.38E-04	0.35	0.5621	
BD	2.64E-04	1	2.64E-04	0.14	0.7083	
CD	1.81E-05	1	1.81E-05	9.86E-03	0.9219	
Residual	0.035	19	1.83E-03			
Lack of Fit	0.024	14	1.75E-03	0.85	0.6331	not significant
Pure Error	0.01	5	2.06E-03			
Cor Total	0.59	29				

5. CONFIRMATION EXPERIMENTS

In order verify the developed surface roughness regression model, confirmation experiment was conducted. One set of values of input process parameter (pulse on time, pulse off time, servo voltage and wire feed) is taken to feed in the developed equation. The experiment was conducted for the same reading. The experiment values were compared with predicted value. The errors values are in satisfactory level. The comparison value is shown in table 5.

Table 5: Optimum process parameter

Process parameter				SR (µm)		Error
Ton	Toff	Sv	Wf	predicted	Experimental	
120	55	10	10	3.31	3.24	2.16%

6. EFFECT OF WORKING PARAMETERS ON THE SURFACE ROUGHNESS

Figure 3 shows the relationship between pulse on time and pulse off time while keeping other two parameter as a constant (servo voltage & wire feed). From the graph it observed that an increase in pulse current lead to increase in Surface roughness value. It is due to supplying of electrical energy for longer duration will produce cracks and void on the machined surface. While considering the pulse off time in the graph, It found that increase in pulse off time would reduce the surface roughness. This due to allowing the time for reaching fresh dielectric medium on the surface which having minimum carbon content.

Figure 4 shows the variation of surface roughness with respect to the servo voltage and wire feed. From the shown graph it was noticed that increase in wire feed would increase the surface roughness. This is due to increase in wire speed increase the number of spark with respect to time. This make the work surface more voids on the side. In other aspect of the graph increase in servo voltage would reduce the surface roughness. This is due to voltage have inverse relationship with pulse current so that surface roughness getting reduced..

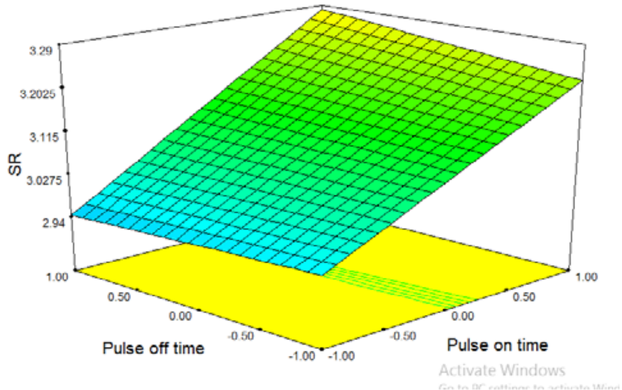

Figure 3. SR vs Pulse on time & Pulse off time

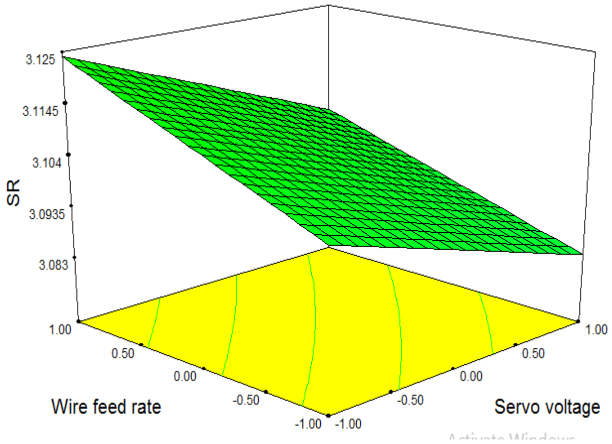

Figure 4. SR vs servo voltage & Wire feed rate

7. CONCLUSION:

In this study influence of process parameter on surface roughness was investigated and following conclusion were made:

(i) Wire cut electric discharge machining process has showed its adequacy to machine High Carbon High Chromium Die Steel (HCHCR) work material under acceptable surface finish (Ra) of 3.41 µm.

(ii) The investigation of the selected response(Surface roughness) using response surface methodology – CCD method has the advantage of explaining the effect of each input parameter on the value of the resultant response characteristics.

(iii) The list of 30 different input process parametric combinations will act as technical information for effective machining of High Carbon High Chromium Die Steel (HCHCR) work material.

(iv) ANOVA results show that model is significant and pulse on time has a significant effect on Surface roughness rather than a other parameter.

Reference

[1] Ho, K.H., Newman, S.T., Rahimifard,S., & Allen, R. “State of art in wire electric discharge machining (WEDM*)” International Journal of Machine Tools and Manufacture,* 2004, pp.1247-1259.

[2] Majhi SK, Pradhan MK, Soni H “Application of integrated RSM-Grey-entropy analysis for optimization of EDM parameters. In: Proceedings of the International Conference on Advanced Research in Mechanical Engineering” Coimbatore, ISBN: 978-93-83060-03-0, 2013.

[3] Kumar K, Kumar RR “ Modelling and optimization of WEDM”. Int J Mod Eng Res, 2015, pp. 1645–1648

[4] Pasam VK, Battula SB, Valli MP, Swapna M “Optimizing surface finish in WEDM using the Taguchi parameter design method.” J Braz Soc Mech Sci Eng 49(2010), pp.155–166

[5] Lal S, Kumar S, Khan ZA, Siddiquee AN “Multi-response optimization of wire electrical discharge machining process parameters for Al7075/Al2O3/SiC hybrid composite using Taguchi-based Grey relational analysis”. J Eng Manuf , 2015, pp.229–237.

[6] Shivade AS, Shinde VD “Multi-objective optimization in WEDM of D3 tool steel using integrated approach of Taguchimethod & Grey relational analysis”. J Ind Eng Int, 2014, pp. 140-49

[7] Jaganathan P, Kumar N, Sivasubramanian R “Optimization of WEDM parameters using Taguchi method”, Int J Sci Res, 2012, pp. 1–4

[8] Pradhan MK ‘Estimating the effect of process parameters on surface integrity of EDM AISI D2 tool steel by response surface methodology coupled with Grey relation analysis”, Int J Adv Manuf Technol, 2013, pp.2051–2062

[9] Sinha P, Kumar R, Singh GK, Thomas D, Srivastava T “ Optimization of wire EDM of AISI D3 tool steel using orthogonal array with principal component analysis”, Mater Today Proc, 2015, pp.2512–2521.

[10] Huang JT, Liao YS “Optimization of machining parameters of Wire-EDM based on Grey relational and statistical analyses”, Int J Prod Res, 2003, pp.1707–1720.