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Process Parameter Effect on Surface Roghness in Wire EDM

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Abstarct : *Machining parameters selection is an important aspect in wire electrical discharge machining (WEDM) operation. These parameters have an important effect on surface roughness. The experiments were conducted on the EN31 die steel with copper wire electrode. The effect of various WEDM parameters such as feed, Ton and gap voltage has been investigated to yield the response in terms of surface roughness. In this work mathematical models have been developed for relating the surface roughness with machining parameters. The optimum value has been determined with the help of main effect plot and ANOVA.*

Keywords: *Surface finish, WEDM, feed, Ton, Gap voltage*

I. INTRODUCTION

Industries always face problems in manufacturing of components due to complex job profile or higher surface finish or strength of materials. This challenge has been accepted and unconventional methods of machining have been developed to suit the requirements of industry. Wire EDM is a method to cut conductive materials with a thin electrode that follows a programmed path. The electrode is a thin wire. As the wire feeds from reel to reel, it uses sparks of electrical energy to progressively erode an electrically conductive work-piece along a path determined by the relative motion of the machine's axis. Typical wire diameters range from 0.1 – 0.3 mm. There is no physical contact between the wire and the part being machined.

Wire EDM is an accurate and no burrs generated. Since no cutting forces are present, wire EDM is ideal for delicate parts. No tooling is required so delivery times are short. Pieces over 400 mm thick can be machined. Tools and parts are machined after heat treatment. Dimensional accuracy is held and not affected by heat treat distortion.

Researchers Lin *et. al.* [2002], Liao *et. al.* [2004], Vipin *et. al.* [2010], Sivakiran *et. al.* [2012], Kumara and Ravikumar [2013], Ranganath and Vipin [2014], Ranganath *et. al.* [2014], Jai Prakash *et. al.* [2016], worked on optimization, modeling, analysis of the surface roughness and ANOVA in EDM / Wire EDM.

Experimental Set Up

The experiments for the present case have been conducted on EZEECUT PLUS WIRE EDM as shown in Fig.1. Surface roughness is measured by the Surtronic 3+ instrument. The composition of the work which was EN-31 steel has chemical composition as C: 1.02%, Si: 0.30%, P: .05 max, S: 0.05 max, Cr: 1.40%, and rest Fe and electrode material was copper wire.

Fig. 1: Ezeecut Plus Wire EDM

Fig. 2: Surtronic 3+ instrument

Experimental conditions and results

In this work Central Composite Design is used for designing the levels of independent variables. The levels of independent variables and coding identifications are presented in Table 1.

Table 2 shows the experimental conditions together with the measured surface roughness values by using CCD Design.

Table 1: Levels of independent variables

Level	lowest	Low	Medium	High	Highest
coding	-√2	-1	0	1	√2
Feed (mm/min)	30	35	40	45	50
Ton (sec)	10	15	20	25	30
Gap Voltage (V)	5	10	15	20	25

Table 2: Experimental conditions and results of WEDM test

Trial No.	Coding			Feed (mm/ min)	Ton (μsec)	Gap Voltage (V)	Surface Roughness (μm)
	x_1	x_2	x_3				
1	-1	-1	-1	35	15	10	4.70
2	1	-1	-1	45	15	10	5.10
3	-1	1	-1	35	25	10	5.76
4	1	1	-1	45	25	10	6.08
5	-1	-1	1	35	15	20	4.76
6	1	-1	1	45	15	20	4.90
7	-1	1	1	35	25	20	5.60
8	1	1	1	45	25	20	5.90
9	0	0	0	40	20	15	5.14
10	0	0	0	40	20	15	5.14
11	0	0	0	40	20	15	5.16
12	0	0	0	40	20	15	5.14
13	-√2	0	0	30	20	15	5.11
14	√2	0	0	50	20	15	5.78
15	0	-√2	0	40	10	15	4.40
16	0	√2	0	40	30	15	6.10
17	0	0	-√2	40	20	5	5.70
18	0	0	√2	40	20	25	5.30
19	-√2	0	0	30	20	15	4.90
20	√2	0	0	50	20	15	5.66
21	0	-√2	0	40	10	15	4.40
22	0	√2	0	40	30	15	6.18
23	0	0	-√2	40	20	5	5.72
24	0	0	√2	40	20	25	5.38

Result and discussion

The regression equation developed with the help of MINITAB SOFTWARE [Vipin and Kumar (2009)] is as

log Roughness = - 0.0187 + 0.244 log feed + 0.314 log Ton - 0.0445 log Gap voltage (1)

S = 0.01083 R-Sq = 94.4% R-Sq(adj) = 93.5%

Table 3: Analysis of Variance

Source	DF	SS	MS	F	P
Regression	3	0.039278	0.013093	111.71	0.000
Residual Error	20	0.002344	0.000117		
Lack of Fit	11	0.002096	0.000191	6.91	0.004
Pure Error	9	0.000248	0.000028		
Total	23	0.041622			

The analysis of variance (ANOVA) is shown in Table 3. The ratio of lack of fit to pure error i.e F-statistics is 6.91, whilst the P-statistics is 0.004. The R-square value of 94.4% of the variability in the surface roughness was explained by the model with factors feed, Ton and gap voltage. Therefore, the model is adequate for determination of surface roughness prediction.

$$\text{Roughness} = \frac{0.9579 * \text{feed}^{0.244} * \text{Ton}^{0.314}}{\text{Gap voltage}^{0.0445}} \quad (2)$$

The R-square value 94.4% of the variability in the surface roughness was explained by the model with factors feed, Ton and gap voltage. Based on the mathematical model, it can be concluded that Ton is a dominant factor in the surface roughness of WEDM.

The present work objective is to minimize the surface roughness of the machined work-piece. The main effects plot for Data means for roughness is given in Fig.3. The variation of individual response depicts the three control parameters viz., feed, Ton and gap voltage. The parameter and response values are represented by the x and y-axis. Central horizontal lines signify the mean value of the surface response. This plot gives information on the individual dependency of response on each control parameter. This is used to determine the optimal design for experiments to minimize surface roughness.

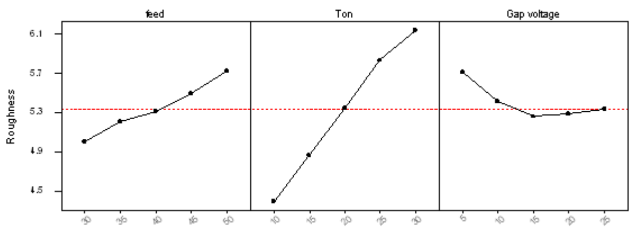

Fig. 3: Main effects plot – Data means for roughness

From the graph, the ordinates represent the measured response values and abscissa denotes the various levels for the variables, surface roughness is minimum for feed (30 mm/min.), Ton (10μsec), and gap voltage (15V).

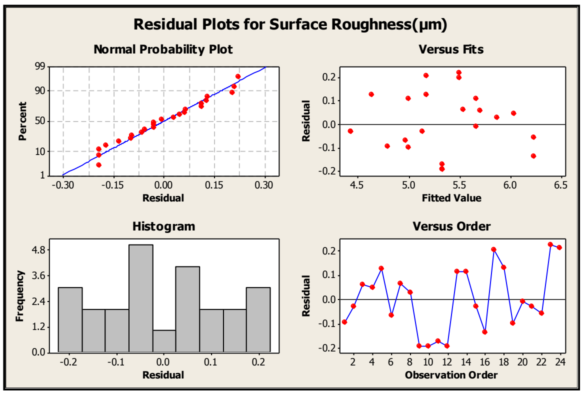

Fig. 4: Residual plots for surface roughness

Residual analysis is used for checking the performance of the developed model. The Residual plots for surface roughness are shown in Fig. 4. These fall on a straight line implying that errors are distributed normally. This concluded that all the values are within the control range. It indicates that there is no obvious pattern and unusual structure. The residual analysis does not indicate any model inadequacy.

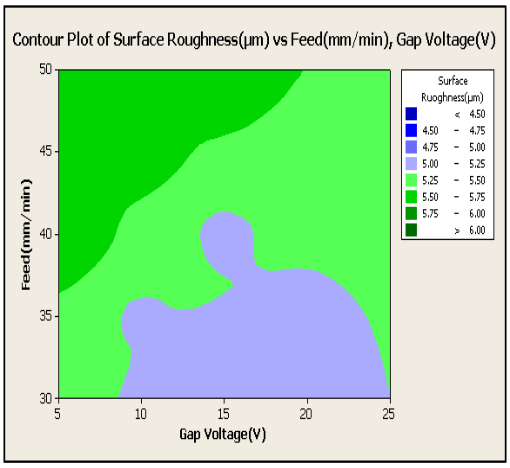

Fig 5: Contour plot between feed and gap voltage

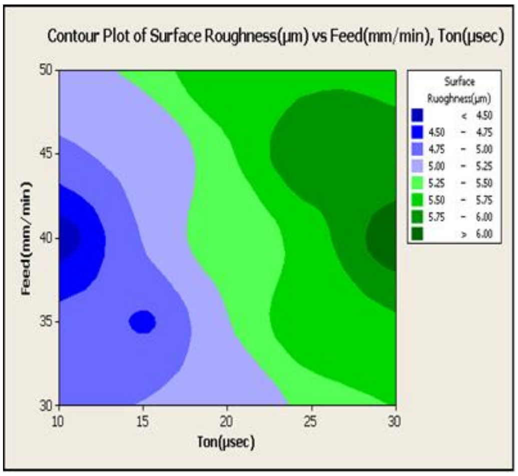

Fig 6: Contour plot between feed and Ton

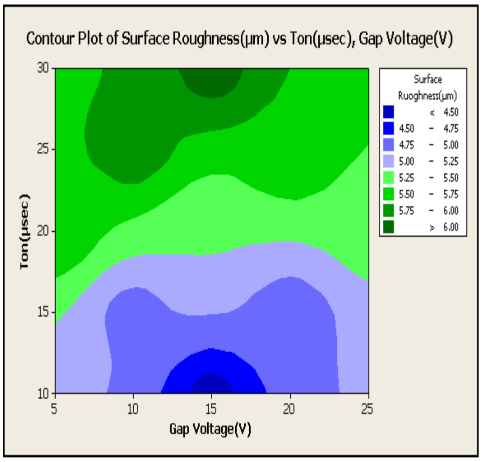

Fig 7: Contour plot between Ton and gap voltage

The contour plots of surface roughness vs feed, Ton and gap voltage are shown in Fig. 5, Fig. 6 and Fig. 7. From these graph it can be distinguished that the area where parameter combination is less / more affected the surface roughness. These contours are useful for selecting the optimum parameter of machining in WEDM.

CONCLUSIONS

(1) The surface roughness equation developed with the help of MINITAB software.
(2) The surface roughness equation shows that the Ton is the main influencing factor, followed by feed and gap voltage in the operation model.
(3) The optimal combination of control variables for minimum Surface Roughness is feed (30 mm/min.), Ton (10µsec), and gap voltage (15V).
(4) Residual analysis verified the performance of the developed model.

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