Journal of Material Science and Mechanical Engineering (JMSME)
Print ISSN: 2393-9095; Online ISSN: 2393-9109; Volume 2, Number 7; April-June, 2015 pp. 24-28

http://www.krishisanskriti.org/jmsme.html

Modelling and Multi Response Optimization of WEDM Operation of EN 24 die Tool Steel using Designed Experiments

Mukesh Kumar[1], Jatinder Kumar[2]

[1]Research Scholar, NIT, Kurukshetra
[1]Asst. ProfessorMechanical Engineering Dept. Mechanical Engineering Dept., NIT, Kurukshetra
er.mukeshdhull@gmail.com
jatin.tiet@gmail.com

Abstract: **The wire-cut EDM is one of the most important machining process for technologists in the field of moulds, dies and in precision manufacturing. The wire electrical discharge machining producing parts with in very short period, the demand over the time increases extensively. So that an extensive research work has been carried out to optimize the parameters of the process by eliminating trial and error cost for the selection of parameters during machining of materials, for getting optimum responses like best surface finish, metal removal rate, with good dimensional accuracy and with retaining the physical and chemical properties of parent material.In this paper, experimental investigation has been carried out to evaluate the various effects of Wire Electric Discharge Machining (WEDM) process parameters to optimize the quality of machined parts. The process parameters under examination are pulse on time (T_{on}), pulse off time (T_{off}), servo voltage (SV), peak current (IP) to reveal their impact for material removal rate on EN 24 Die Tool Steel by using Elektra Sprintcut 734 WEDM machine. This paper employs Response Surface methodology (RSM); Central composite second order rotatable design to develop the empirical models for response characteristics. A better surface quality and accurate dimension value can be obtained in less machining time by using zinc coated wire electrode in comparison to plain brass electrode.**

Keywords: **EN 24 Die Tool steel · WEDM · Response surface methodology · Zinc Coated wire electrode, Machining rate**

1. INTRODUCTION

The wire electric discharge machining (WEDM) process contributes a predominant role in some manufacturing sectors recently; since this process has the capacity to cut complex and intricate shapes of components in all electrically conductive materials with better precision and accuracy. Wire-electro discharge machining has been defined as the process of material removal of electrically conductive materials using the thermo-electric source of energy. The material removal is by controlled erosion through a series of repetitive sparks between electrodes, i.e., workpiece and tool In the WEDM process there is no relative contact between the tool and work material, therefore the work material hardness is not a limiting factor for machining materials by this process. The liquid dielectric medium is continuously supplied to deliver the eroded particles and to provide the cooling effect. A small diameter wire ranging from 0.05 to 0.3 mm[1] is applied as the tool electrode.

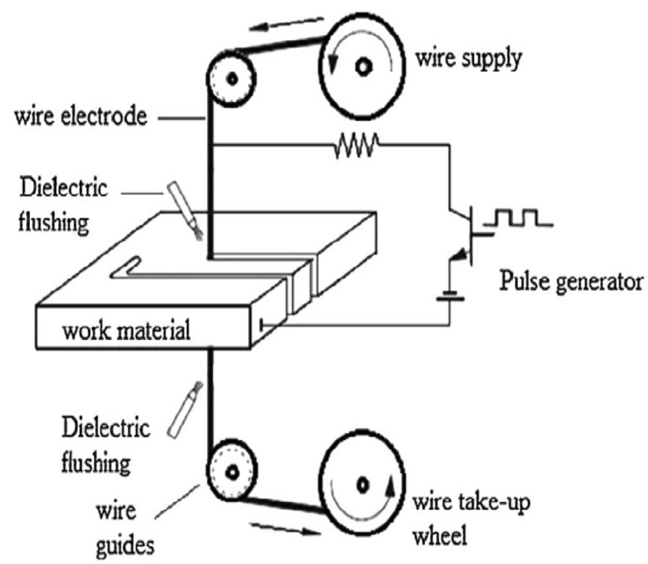

Fig. 1. Representation of WEDM process

The wire is continuously supplied from the supply spool (Fig.1), through the work-piece, which is clamped on the table by the wire traction rollers. A gap of 0.025–0.05 mm is maintained constantly between the wire and work-piece. De-ionized water is applied as the dielectric fluid. A collection tank that is located at the bottom is used to collect the used wire and then discard it.The wires once used cannot be reused again due to the variation in dimensional accuracy. The dielectric fluid is continuously flashed through the gap along the wire, to the sparking area to remove the byproducts formed during the erosion.[2] Nowadays WEDM is an important machine tool to produce complex and intricate shapes of components in areas such as tool and die making industries, automobile, aerospace, nuclear, computer and electronics industries.

Speeding et al. [3] have concluded that the optimal combination of parameters for maximum cutting rate, keeping the surface roughness and waviness within the required limits, but the optimization technique is not specified. Scott et al. [4] developed a factorial design model to calculate the process performance characteristics on various control setting. The process was further optimizedby introducing the concept of a non-dominated point. Tarng et al.[5] proposed a feed-forward neural network to associate process attributes with machining performances. An algorithm simulated annealing was then applied to the neural network to obtain the optimal set of input parameters.

Liao et al. [6] proposed a mathematical model by the use of regression analysis and then solved the optimization problem by a feasible direction method. Manna and Bhattacharyya [7] optimized the machining parameters using the Taguchi and Gauss elimination method. The test results were analyzed for the selection of an optimal voltage and pulse on period was the most significant and influencing parametersfor controlling the metal removal rates. Wire tension and wire feed rate were the most significant and influencing parameters for the surface roughness. Ramakrishnan and Karunamoorthy[8] used Taguchi's robust design approach for multiresponse optimization in WEDM.

2. EXPERIMENTAL DETAILS

2.1 Work material and machining parameters

EN 24 die tool steel has been taken as a work material in the form of square plate having dimensions 150 mm×100 mm×20 mm. The chemical composition of work material are as follows:C, 0.42 %; Si, 0.31 %; Mn, 0.57 %; Cr, 1.08 %; Ni, 1.47 %; Cu, 0.077 %; Al, 0.0251 %; S, 0.028 %; P, 0.019 %; V, 0.021 % and balance Fe. The experiments were performed on Electronica ELEKTRA Sprintcut 734 CNC Wire cut machine. The four parameters, i.e. pulse on time, pulse off time, peak current and spark gap voltage were varied to investigate their effect on output responses i.e. the machining rate. Zinc coated wire of diameter 0.25 mm was used as electrode. The parameters kept constant during machining were work piece material, plate thickness 20 mm, wire feed 8 machine units, servo feed 2050 machine units and dielectric pressure 7 kg/cm2. During machining, the wire offset was set at zero. Table 1 presents the factors and their ranges.

TABLE 1: Factors and their Ranges

Symbol	Parameters	Range	Units
A	T_{on}	115-125	µs
B	T_{off}	30-60	µs
C	IP	120-220	Ampere
D	SV	20-60	Volt

Machining rate was measured as surface area removed per minute (mm^2/min). It was obtained by multiplying the workpiece material thickness with linear cutting speed which is displaying on machine tool monitor screen.

2.2 Response surface modeling of WEDM process

Response surface methodology approach is the procedure for developing an adequate relationship between input WEDM parameters and output machining characteristics[9]. In this technique, the main objective is to optimize the response surface that is influenced by various process parameters. The RSM has been applied for modeling and analysis of machining parameters in the WEDM process in order to obtain the relationship to the machining rate. In the RSM, the quantitative form of relationship between desired response and independent input variables is represented as follows:

$Y = f(T_{on}, T_{off}, Ip, SV)$

Where, Y is the desired response and f is the response function or response surface [10].For the purpose of analysis, the approximation of Y was proposed using the fitted second-order polynomial regression model which is called as the quadratic model. The quadratic model of Y is written as follows:

$$y = \beta_0 + \sum_{i=1}^{k} \beta_i x_i + \sum_{i=1}^{k} \beta_{ii} x_i^2 + \sum_{i<j} \beta_{ij} x_i x_j + \varepsilon$$

Where Y is the desired response and the xi (1, 2, k) are the independent of k quantitative process variables. β_0 is constant and βi, βii, βij are the coefficients of linear, quadratic, and cross product terms. ε is random error.

3. RESULTS AND DISCUSSION

The 30 experiments were conducted and machining rate were obtained for each experimental run (as listed in Table 2).

3.1 Mathematical model for machining rate

Using the experimental data, regression equation have been developed for correlating the machining rate and input WEDM parameters. Based on the proposed second-order polynomial model, the effect of the process variable on the machining rate has been determined by computing the values using Design expert 9.0, software and the relevant data from Table 2. The mathematical relationship for correlating the machining rate and the considered process variables is obtained as follows:

Machining rate = -1916.85 + 17.6344T_{on} + 13.7342 T_{off} + 0.8036I_p+ 21.1529 SV -0.13521T_{on} T_{off} -0.00632T_{on} I_p - 0.1936T_{on} SV -0.00295 T_{off} I_p + 0.01234 T_{off} SV + 0.0057083 I_p SV

Using the experimental data, regression equations have been developed for correlating the output performance characteristics and input WEDM parameters. Analysis of variance (ANOVA) has been applied on the experimental data to select the adequate model. Design expert 9.0, a statistical tool, has been utilised to analyse the experimental data. Two-factor interaction (2FI) models have been suggested for machining rate. In Table 3, a p-value for the model terms that are less than 0.05 (i.e. α = 0.05, or 95% confidence level) indicates that the obtained models are considered to be statistically significant.[11] It shows that the terms in the model have significant effect on responses. The p value for lack of fit is 0.6642, F value of the model is 35.48 suggesting that this model adequately fits the data. The other importantcoefficient R^2, which is called determination coefficient in the resulting ANOVA table, is definedas the ratio of the explained variation to the total variation and is a measure of the degree of fit. When R^2 approaches unity, the response model fits better to the actual data and shows less difference between the predicted and actual values. The obtained values are predicted R^2 of 0.8440 is in reasonable agreement with the adjusted R^2 of 0.9224. In has been concluded from table 3, the model terms A, B, C, D, AB and AD are significant model terms for machining rate. Figure 2 shows the normal probability plot of residuals for machining rate. Most of the residuals are found around the straight line, which means that errors are normally distributed.

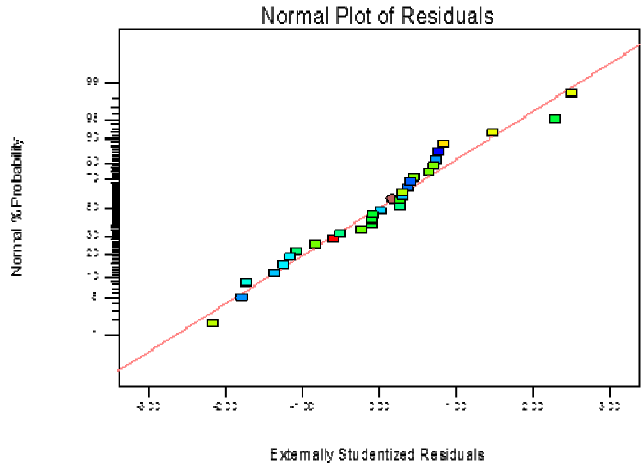

Fig. 2. Normal probability plot of residuals

3.2 Effect of WEDM parameters on machining rate

The effect of two control factors or process parameters on the response variables are called the interaction effect. For the interaction plot, the two parameters vary keeping other three process parameters at the central value and observe the effect on the response characteristics. This plot is called the three-dimensional surface plot (i.e., 3D surface plot). So the significant interactions are shown in Figs. 3 and 4. The interaction effect (combined effect) of T_{on} and T_{off} on machining rate (as shown in Fig. 3) shows that machining rate goes to a maximum value 17.80 mm^2/min at a high value of T_{on} (122) and a low value of T_{off} (37), while it reaches at a minimum level 6.40 mm^2/min, where T_{on} is minimum (117) and T_{off} is maximum (52). A higher value of discharge energy creates violent sparks between the workpiece and moving electrode, these sparks causes a faster erosion of material and a faster cutting speed is observed.

TABLE 2: Design of experiments and results for wire EDM output response

			Process	Parameters		Response
Standard no.	**Run no.**	**A:Ton**	**B:Toff**	**C:Current**	**D:SV**	**Machining rate(mm^2/min)**
25	1	120	45	170	40	11.36
11	2	117	52	140	50	5.60
27	3	120	45	220	40	13.97
13	4	117	37	190	50	15.74
5	5	117	37	190	30	13.91
16	6	122	52	190	50	7.21
24	7	120	45	170	60	7.75
9	8	117	37	140	50	10.13

17	9	115	45	170	40	6.98
15	10	117	52	190	50	6.14
6	11	122	37	190	30	20.26
12	12	112	52	140	50	5.31
10	13	122	37	140	50	14.12
28	14	120	45	170	40	11.36
26	15	120	45	170	60	7.68
14	16	122	37	190	50	15.10
8	17	122	52	190	30	9.87
21	18	120	45	120	40	9.92
29	19	120	45	170	40	11.38
4	20	122	52	140	30	8.42
7	21	117	52	190	30	6.92
22	22	120	45	220	40	14.03
18	23	125	45	170	40	14.91
3	24	117	52	140	30	6.27
19	25	120	40	170	40	15.85
2	26	122	42	140	30	16.66
30	27	120	45	170	60	11.08
20	28	120	60	170	40	3.78
1	29	117	37	140	30	12.58
23	30	120	45	170	20	13.76

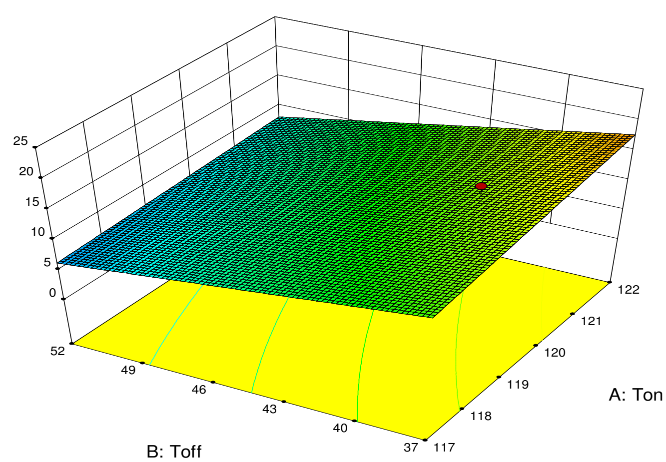

Fig. 3 Interactions of T_{on} and T_{off}

The 3D interaction plot of T_{on} and SV (Fig. 4) shows that machining rate attains a maximum value of 14.80 mm^2/min at a higher value of T_{on} (117) and lower SV value (30). The effect of T_{on} is already explained (i.e., higher T_{on} is essential for better machining rate). If SV is higher, the higher will be the discharge waiting time. To obtain the higher discharge wait time, machining speed needs to be slowed down. So lower value of SV favors productivity.

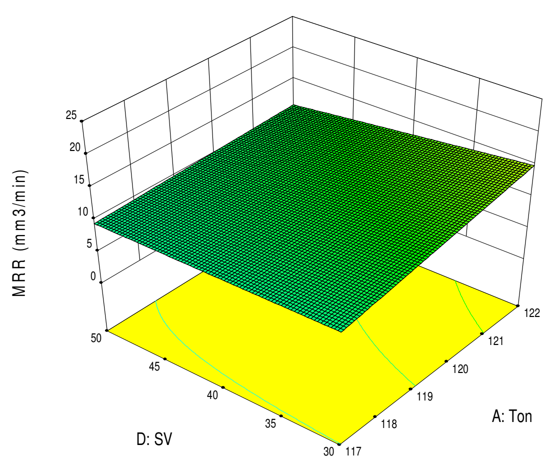

Fig. 4 Interactions of T_{on} and SV

4. CONCLUSIONS

In present work, experimental investigation has been reported on machining performance of EN 24 die tool steel on WEDM. Response surface methodology (RSM), a statistical technique, has been utilised to investigate the influence of four important WEDM parameters – pulse on time (T_{on}), pulse off time (T_{off}), servo voltage (SV) and peak current (IP) – on machining rate. From the analysis, it is concluded that:

(a) T_{on} is the most significant process parameter among all the input WEDM parameters

(b) For machining rate, two-factor interactions of T_{on} and T_{off}, and T_{on} and SV play a significant role for response variable.

(c) The machining rate obtained ranged between 3.78 mm^2/min and 20.26 mm^2/min. The maximum machining rate was obtained when the parameters were set at pulse on time=122µs, pulse off time= 37µs, peak current=190 A, spark gap voltage=30 V.

(d) The predicted values of R^2(0.8440)match reasonably wellwith the experimental values ofR^2(0.9224).

REFERENCES

[1] Jangra, K., *Study of unmachined area in intricate machining after rough cut in WEDM.* International Journal of Industrial Engineering Computations, 2012. **3**(5): p. 887-892.

[2] S. Kalapakjian, S.R.S., *Manufacturing Engineering And Technology*. 5 ed2009: Prentice Hall.

[3] Spedding, T.A. and Z. Wang, *Parametric optimization and surface characterization of wire electrical discharge machining process.* Precision Engineering, 1997. **20**(1): p. 5-15.

[4] Scott D., B., S.Rajurkar, K.P, *Analysis and optimization of parameter combinations in wire electrical discharge machining.* International Journal of Production Research, 1991. **29**: p. 2189-2207.

[5] Tarng, Y.S.M., S.C.; Chung, L.K., *Determination of optimal cutting parameters in wire electrical discharge machining.* . International Journal of Machine Tools and Manufactre, 1995. **35**: p. 1693-1701.

[6] Liao YS, H.J., Su HC *A study on the machining parameters optimization of wire electrical discharge machining.* JMater Process Technol 1997. **71**: p. 487–493.

[7] Manna A, B.B., *Taguchi and gauss elimination method: a dual response approach for parametric optimization of CNC wire cut EDM of PRAISiCMMC.* Int J Adv Manuf Technol 2006. **28**: p. 68-75.

[8] Ramakrishnan R, K.L., *Multi response optimization of wire EDM operations using robust design of experiments..* Int J Adv Manuf Technol 2006. **29**: p. 105-112.

[9] Myers, R. and D. Montgomery, *Response surface methodology, 1995.* John Wiley& Sons, Inc.

[10] Montgomery, D.C. and J. Wiley, *Design and analysis of engineering experiments.* John Wiley & Sons, New York, 2001.

[11] Muthusamy, S., S. Kanagarajan, and S. Ponnusamy, *Efficiency of RAPD and ISSR markers system in accessing genetic variation of rice bean (Vigna umbellata) landraces.* Electronic Journal of Biotechnology, 2008. **11**(3): p. 32-41.