International Journal of Current Engineering and Technology
ISSN 2277 - 4106

Research Article

Optimization of Machine Process Parameters on Overcut in EDM for EN19 Material using RSM

Shashikant[Á], Apurba Kumar Roy[Á] and Kaushik Kumar[Á*]

[Á]Birla Institute of Technology, Mesra, Ranchi -835215, INDIA

Accepted 10 March 2014, Available online 01 April 2014, **Special Issue-3, (April 2014)**

Abstract

EDM (Electro-discharge Machining) is a nonconventional machining process utilizing an electric spark discharge from the electrode (-) towards the work piece (+) through the dielectric fluid. The Dimensional accuracy in this is very important consideration for the accuracy of the finished product. The objective of this experimental study is to determine parameters that offer the best dimensional accuracy in electrical discharge machining (EDM). Discharge current, pulse on time, pulse off time and gap voltage are taken as machining parameters for blind hole operation on EN 19 steel. The experimental investigations are carried out using copper electrode. CCD design of experiment of Response Surface Methodology (RSM) is used to identify the effect of machining parameters on overcut. Machining parameters are optimized for minimum overcut. ANOVA analysis is carried out to identify the significant parameters that affect the dimensional accuracy. Confirmation tests are performed on at predicted optimum process parameters and results are verified. It is observed that the discharge current has greatest impact over the overcut followed by gap voltage, however the impact of the other two input parameters namely pulse on time, pulse off time, was very less.

Keywords: *Anova, EDM, EN19, Optimization, Overcut, RSM.*

1. Introduction

Since its development in the mid 1940's, electrical discharge machining (EDM) provides an effective manufacturing technique that enables production of parts made of hard material with complicated profile that are difficult to produce by Conventional Machining Processes. An advantage of the EDM process is the negligible machining force compared to that of the traditional machining processes; hence a softer material can act as a tool for work piece materials of any hardness. Consequently, the EDM process is free of vibration and chatter problem and is widely practiced in the precision mold and die machining industries for metals and conductive ceramic materials of high strength and stiffness e.g. in the production of aerospace components, medical appliances, automotive parts, etc. Several theories were proposed by early investigators to account for the erosion mechanism of the EDM process. It has been accepted generally that the metal removal phenomenon is predominantly thermal in nature [McGeough, (1988), Guitrau (1997)]. For a commercial EDM machine, the manufacturer provides a database of setup parameters for commonly used work and electrode materials under typical operating conditions. Such a database cannot meet the growing new EDM applications, including machining new advanced materials and miniature features. EDM electrodes is more plausible than making special cutting tools since they can be made from soft materials, e.g. copper alloys or graphite, which are easy to machine with less production cost. At present, EDM parameter selection is still an experience dominated process in the industry. In some cases, selected parameters are conservative and far from the optimum, and at the same time selecting optimized parameters requires many costly and time consuming experiments. Many researchers have tried to optimize the machining performance by adapting different optimization techniques. Semi-empirical models of MRR for various work piece and tool electrode combinations have been presented by Wang and Tsai (2001). Tosun et al. (2004) have presented an investigation on the effect and optimization of machining parameters on the kerf (cutting width) and material removal rate in wire electrical discharge machining operations. Luis et al. (2005) have studied the influence of pulse current, pulse time, duty cycle, open-circuit voltage and dielectric flushing pressure, over the performance and other response variables on tungsten carbide materials. Palanikumar (2008) has modeled the surface roughness in machining of glass fiber reinforced plastic (GFRP) composite materials using RSM. Tsai and Wang (2001) and Jaharah et al (2008) have investigated the machining performance of the surface roughness, electrode wear rate and material

*Corresponding author Kaushik Kumar and Apurba Kumar Roy are working as Assiciate Professors; Shashikant is Research Scholar

removal rate of copper electrode in EDM of tool steel. Kuppan et al. (2008) have developed response surface model and shown the influencing parameters on material removal rate. Chiang (2008) has developed mathematical models to see the effects of machining parameters on the performance characteristics of the material removal rate (MRR), electrode wear ratio, and surface roughness in EDM process of ceramic material. Patel et al. (2009) have studied the machining characteristics, surface integrity and material removal mechanisms of advanced ceramic composite in EDM. Parashar et al. (2010) have carried out statistical and regression analysis of material removal rate using design of experiments for WEDM operations.

Overcut usually defined as "the difference between the size of the electrode and the size of the cavity created during machining" [600100-133773-overcut html] and as shown in the figure 1, is required to kept minimum for better dimensional accuracy of finished product. Researchers have tried to minimize the same using various techniques [Yan et al. (1999) and Sanchez et al. (2002)]. The overcut is greatly influenced by the machining parameters. Therefore, there is a need to identify the optimal machining parameters on achieving the desired machining performance characteristics. In the current paper, the effect and optimization of machining parameters viz. pulse current (Ip), pulse on time (Ton), pulse off time (Toff) and voltage (V) on overcut is studied in electrical discharge machining (EDM) of EN19 steel.

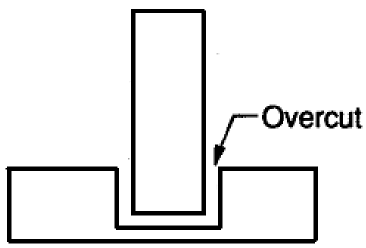

Fig. 1. Schematic sketch of overcut

2. Response Surface Methodology

Response surface methodology comprises a group of statistical techniques for empirical model building and model exploitation. It helps the experimenter to find the optimum setting for the input variables that optimizes the predicted response, the response surface for the variance consists of a second degree polynomial with respect to the controllable factors. It also used to improve the robustness of the process and the product.

$$\mu = \beta_o + \sum_{i=0}^{q}\beta_i\chi_i + \sum_{i=1}^{q}\beta_{ii}\chi_i^{\,2} + \sum_{i=1}^{q-1}\sum_{j=i+1}^{q}\beta_{ij}\chi_i\chi_j \qquad (1)$$

Where μ is the expected response, given are the level of the factors coded to be -1 & 1 and responses from different runs are assumed to be independent with constant variance σ2 [Allen (2006)].

3. Experiment Setup

Experiments were conducted on die sinking EDM machine (EMT-43 Manufacturer Electronica Machine Tools). The tool electrode (positive polarity) of electrolytic pure copper with 25 mm x25 mm size and work-piece material EN19 with round cylinder of diameter 25 mm and of thickness 15 mm was used. Commercial grades EDM oil was used as dielectric fluid. The process variables with their values on different levels are listed below (table1).

Table1. Input parameters along with their levels

Variable	Coding	Level		
		2	3	4
Pulse on time(Ton) (μS)	A	300	400	500
Pulse off time (Toff)(μS)	B	1700	1600	1500
Discharge current (Ip)(A)	C	10	15	20
GapVoltage (Vg) (V)	D	30	40	50

The experiments (31 tests) were conducted, with the help of Design of experiment (DOE) [Minitab (2003), Montgomery (2000)] for the three levels of four parameters. The central composite design was used since it gives a comparatively accurate prediction of all response variable averages related to quantities measured during experimentation. The overcut were measured and tabulated in table 2.

Table 2. Experimental results

Exp. No.	A	B	C	D	Over Cut
1	-1	-1	-1	1	0.19
2	0	0	2	0	0.26
3	0	0	0	0	0.24
4	0	0	0	0	0.24
5	-1	1	-1	1	0.14
6	0	0	-2	0	0.21
7	-1	1	1	-1	0.18
8	-1	-1	1	-1	0.13
9	-1	-1	1	1	0.15
10	-1	1	-1	-1	0.10
11	1	1	1	1	0.21
12	2	0	0	0	0.21
13	0	0	0	0	0.24
14	0	0	0	-2	0.08
15	0	0	0	2	0.13
16	1	1	-1	1	0.12
17	1	-1	-1	-1	0.18
18	1	1	-1	-1	0.13
19	-1	1	1	1	0.21
20	0	0	0	0	0.24
21	0	-2	0	0	0.09
22	1	-1	-1	1	0.17
23	0	2	0	0	0.08
24	0	0	0	0	0.24
25	1	-1	1	1	0.14
26	-2	0	0	0	0.22
27	1	-1	1	-1	0.17
28	1	1	1	-1	0.20
29	0	0	0	0	0.24
30	-1	-1	-1	-1	0.14
31	0	0	0	0	0.24

4. Results and Discussion

The results for EN 19 tool steel in EDM are presented in table 3. Using RSM technique second order response model of the overcut results was developed. It was observed from the adequacy test by ANOVA that linear terms, Pulse on time (Ton), Pulse off time (Toff) , Discharge current (Ip), Voltage (V) and interaction terms (Toff with Ip) & (Ip with V) and square terms V2 are significant.The fit summary recommended that the quadratic model is statistically significant for analysis of overcut . For the appropriate fitting of Overcut, the non-significant terms (where, p-value is greater than 0.05) are eliminated by backward elimination process.

Table 3 .ANOVA table for Overcut (Before elimination)

Term	Coef	SE Coef	T	P
Constant	0.24	0.005183	46.308	0
A	0.003333	0.002799	1.191	0.251
B	0.000833	0.002799	0.298	0.77
C	0.014167	0.002799	5.061	0
D	0.009167	0.002799	3.275	0.005
A*A	-0.00625	0.002564	-2.437	0.027
B*B	-0.03875	0.002564	-15.112	0
C*C	-0.00125	0.002564	-0.487	0.633
D*D	-0.03375	0.002564	-13.162	0
A*B	-0.00125	0.003428	-0.365	0.72
A*C	0.00125	0.003428	0.365	0.72
A*D	-0.00875	0.003428	-2.552	0.021
B*C	0.025	0.003428	7.293	0
B*D	0.005	0.003428	1.459	0.164
C*D	-0.005	0.003428	-1.459	0.164
R-Sq = 96.71% R-Sq(pred) = 81.06% R-Sq(adj) = 93.83%				

ANOVA table after elimination of non-significant factors is presented in Table 4. Results for the reduced model indicate that the model is significant (R2 and adjusted R2 are 92.57% and 90.31%, respectively), and lack of fit is non-significant (p-value is less than 0.05)

Table 4.ANOVA table for Overcut (After elimination)

Term	Coef	SE Coef	T	P
Constant	0.238723	0.004447	53.687	0
A	0.003333	0.002783	1.198	0.244
B	0.000833	0.002783	0.299	0.768
C	0.014167	0.002783	5.091	0
D	0.009167	0.002783	3.294	0.003
A*A	-0.00612	0.002535	-2.413	0.025
B*B	-0.03862	0.002535	-15.234	0
D*D	-0.03362	0.002535	-13.261	0
A*D	-0.00875	0.003408	-2.567	0.018
B*C	0.025	0.003408	7.335	0
R-Sq = 95.73% R-Sq(pred) = 87.30% R-Sq(adj) = 93.91%				

The mean effect plot (Figure 2), signifying the levels which would result in the evaluation of the optimized values of the parameters, was plotted. Subsequently the analysis of variance for overcut was tabulated (Table 5)

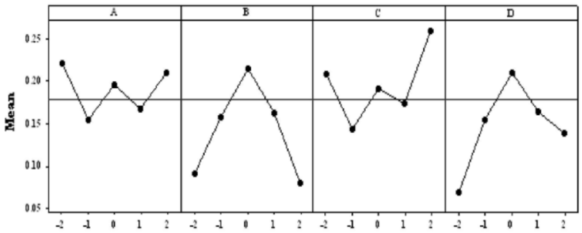

Fig 2. Main Effects plot for overcut

Table 5. Analysis of Variance for Over Cut

Source	DF	SS	MS	F	P
Regression	9	0.087581	0.009731	52.36	0
Linear	4	0.007117	0.001779	9.57	0
Square	3	0.069239	0.02308	124.18	0
Interaction	2	0.011225	0.005613	30.2	0
Residual Error	21	0.003903	0.000186		
Lack-of-Fit	15	0.003903	0.00026	*	*
Pure Error	6	0	0		
Total	30	0.091484			

Conclusion

The present study develops overcut models for four different machining parameters viz, pulse current, pulse on time, pulse off time and voltage in the EDM process on EN19 using RSM. It was found that pulse off time, discharge current, voltage and some of their interfaces have a significant effect on over cut in the studied range. The Optimum Combination obtained was Ton = 200 µs, Toff = 1400µs, Ip = 10 amp, V=20 V. A confirmation test (Table 6) also shows the ability of the model to predict the overcut. Finally, an attempt has been made to estimate the optimum machining conditions to produce the best possible overcut within the experimental constraints.

Table 6. Conformation test result and comparison with predicted result

T_{ON}	T_{OFF}	I_P	V	Overcut		
				Experi-mental	**Pred-icted**	**% Error**
400	1600	15	40	0.24	0.239	0.53

References

J. A. McGeough., (1988) Advanced Methods of Machining, *Chapman and Hall*.

E.B. Guitrau (1997) The EDM handbook. *Hanser Gardner, Cincinnati*

P.J. Wang and K.M. Tsai: (2001) Semi-empirical model on work removal and tool wear in Electrical Discharge Machining, *Journal of Materials Processing Technology*, Vol. 114 (1), pp. 1-17

N. Tosun, C. Cogun and G. Tosun: (2004) A study on kerf and material removal rate in wire electrical discharge machining based on Taguchi method *Journal of Materials Processing Technology*, Vol. 152, pp. 316–322

C.J. Luis, I. Puertas and G. Villa: (2005) Material removal rate and electrode wear study on the EDM of silicon carbide *Journal of Materials Processing Technology*, Vol. 164–165, pp. 889–896

K. Palanikumar (2008) Application of Taguchi and response surface methodologies for surface roughness in machining glass fiber reinforced plastics by PCD tooling *The International Journal of Advanced Manufacturing Technology*,Vol.36, No.1-2, pp.19-27.

K.M. Tsai and P.J. Wang (2001) Semi-empirical model of surface finish on electrical discharge machining, *International Journal of Machine Tools and Manufacture*, Vol. 41, pp. 1385-1403

A.G. Jaharah, C.G. Liang, S.Z. Wahid, M.N.A. Rahman and C.H.C. Hassan: (2008) Performance of Copper Electrode in Electical Discharge Machining (EDM) of AISIi H13 Hardened Steel *International Journal of Mechanical and Materials Engineering (IJMME)*, Vol. 3 (1), pp. 25-29

P. Kuppan, A. Rajadurai and S. Narayanan: (2008) Influence of EDM process parameters in deep hole drilling of Inconel 718 *International Journal of Advanced Manufacturing Technology*, Vol. 38, pp. 74–84

K.T. Chiang: (2008) Modeling and analysis of the effects of machining parameters on the performance characteristics in the EDM process of Al2O3 + TiC mixed ceramic. *International Journal of Advanced Manufacturing Technology*, Vol. 37, pp. 523–533

K.M. Patel, P.M. Pandey and P.V. Rao (2009): Determination of an optimum parametric combination using a surface roughness prediction model for EDM of Al2O3/SiCw/TiC ceramic composite. *Materials and Manufacturing Processes*, Vol. 24, pp. 675-682.

V. Parashar, A. Rehman, J.L. Bhagoria and Y.M. Puri: (2010) nvestigation and Optimization of Material Removal Rate for Wire Cut Electro Discharge Machining of SS 304L using Taguchi Dynamic Experiments *International Journal of Engineering Science and Technology*, Vol. 2(5), pp. 1021-1028

http://www.toolingu.com/definition-600100-133773-overcut.html.

B.H. Yan, F.Y. Huang, H.M. Chow, J.Y. Tsai (1999) Micro-hole machining of carbide by electric discharge machining, *Journal of Materials Processing Technology*, Vol.87, pp. 139–145.

J.A. Sanchez, D.L. Lopez de Lacalle, A. Lamikiz, U. Bravo (2002) Dimensional accuracy optimisation of multi-stage planetary EDM *International Journal of Machine Tools and Manufacture* Vol. 42, pp. 1643–1648.

T.T. Allen, (2006) Introduction to Engineering Statistics and Six Sigma *Springer-Verlag* London Limited

Minitab User Manual Release 14 (2003), MINITAB Inc, *State College*, PA, USA.

Montgomery DC (2000) Design and Analysis of Experiments, 5th edn. *John Wiley & Sons*, Inc., Hoboken, NJ