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Analysis of Machining Parameters on EDM of EN 31 Tool Steel Using Full Factorial Design

Tikendra kumar[1], Sanjay Kumar vaidya
[1] M-Tech (Production) Research Scholar,Chouskey Engineering college bilaspur 495004
[2]Prof. Dept. of MechanicalEngg.Chouskey Engineering College bilaspur 495004

Abstract
The present work deals with the structures of electrical discharge machining of EN31 tool steel. A second-order mathematical model, in terms of machining parameters, was developed for electrode wear ratio (EWR) and dimensional accuracy (over cut) using full factorial design. The experimental plan was based on the face centered, central composite design. The experimental results indicate that the proposed models could adequately, describe the performance indicators within the limits of the factors that are being investigated. Finally, the responses have been analyzed by using analysis of variance (ANOVA) techniques.
Key words: EDM, Electrode Wear Ratio, Over Cut , Full Factorial Design, ANOVA.

1. Introduction

Electric Discharge Machining (EDM) is one of the machining process, in which we used to produce critical shape on any type of hard or brittle conductive material and it can also be well applied for materials that are impracticable to machine with traditional machining processes. [1]. In EDM process a series of instantly recurring spark is generated between the tool and workpiece within a constant spark gap. These sparks cause the ionization of dielectric medium at a critical voltage and form an ionized channel called the plasma channel, which acts as the heat foundation causing melting and vaporization of the workpiece [2-4].

Since its introduction, EDM has always been a major area of research for enhance the quality of machining. A number of researchers have performed theoretical as well as experimental investigations in order to analyse and improve the different quality characteristics such as Material Removal Rate (MRR), Electroad Wear Rate (EWR),Over Cut (OC), surface hardness, white layer thickness [5-6]. The Design Of Experiment (DOE) techniques based studies applied so for mainly focused for the optimization of the single quality characteristics[7-13].

1.1 *Conduct of Experiment*

The primary experiments were conducted on Electronica (Model-Xpert-1) work tank internal dimensions-900mm*600mm*400mm die sinking machine. In this experiment the tool and workpiece was set as anode and cathode respectively. An electrolytic pure copper with a diameter of 20 mm was used as tool electrode. The selected workpiece material for this experiment is EN31 tool steel. Commercial grade EDM oil (specific gravity = 0.763 freezing point = 940C) was used as dielectric fluid. Lateral flushing with a pressure of 0.25kgf/cm^2 was used.

Experiments were conducted considering the effects of various machining parameters on EDM process. These studies were undertaken to investigate the effects of Ip, T_{on}, T_{au} and V on MRR, OC and EWR. The selected control parameters and their values at different levels are listed in Table 1

Table 1 Machining parameters and their levels

Machining Parameter	Symbol	Unit	Levels		
			Level 1	Level 2	Level 3
Discharge current	(Ip)	A	1	3	5
Pulse on time	(T_{on})	µs	100	300	500
Duty Cycle	(T_{au})	%	70	80	90
Voltage	(V)	V	40	45	50

2.2 Design of experiment using Full factorial

Full factorial experiment is an experiment whose design consists of two or more factors, each with discrete possible values or "levels", and whose experimental unit take on all possible combinations of these levels across all such factors. A full factorial design also called as a fully crossed design. Such an experiment allows the

examiner to study the effect of each factor on the response variable, as well as the effects of interactions between factors on the response variable. In the experiment using four factors and each are three levels then total number of trials to be showed is 27.

In this study, an L_{27} based on full factorial are used machining parameters like pulse current, pulse on time, duty cycle and voltage setting were diverse to conduct 27 different trials and the measurements weights of the work piece were taken for calculation of MRR. Minitab software was used to analysis the findings. In this experiment Minitab software design are selected is 3 level design and number of factors is four.The flow chart of the experiment is shown in Fig.1.Experimental observation data are described in Table 2

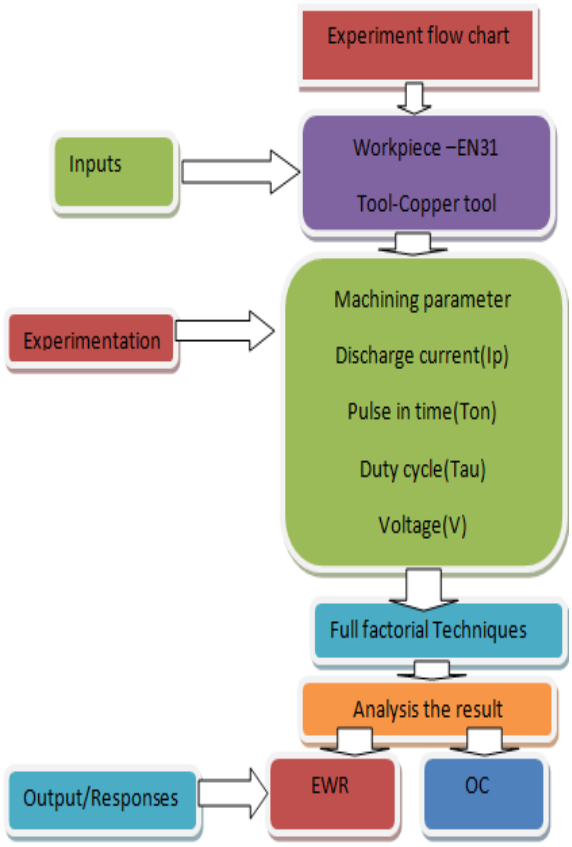

Table 2 Observation Table

S. N.	Ip (A)	T_{on} (µs)	T_{au} (%)	Volt. (V)	OC (mm)	EWR= (MRR/TWR)
1	1	100	70	40	0.0178	79.529
2	1	100	70	45	0.0195	170.252
3	1	100	70	50	0.0067	74.408
4	1	300	80	40	0.0210	119.260
5	1	300	80	45	0.0935	84.045
6	1	300	80	50	0.1684	157.907
7	1	500	90	40	0.0934	55.620
8	1	500	90	45	0.0180	132.920
9	1	500	90	50	0.0267	84.553
10	3	100	90	45	0.1017	125.661
11	3	100	90	50	0.1650	72.730
12	3	100	90	40	0.1450	159.805
13	3	300	70	45	0.1885	35.774
14	3	300	70	50	0.1650	30.411
15	3	300	70	40	0.1734	151.653
16	3	500	80	45	0.1955	102.351
17	3	500	80	50	0.2027	76.425
18	3	500	80	40	0.1409	39.002
19	5	100	80	50	0.3185	33.185
20	5	100	80	40	0.1322	45.029
21	5	100	80	45	0.4127	49.155
22	5	300	90	50	0.4193	19.056
23	5	300	90	40	0.3550	25.622
24	5	300	90	45	0.3617	33.848
25	5	500	70	50	0.4900	17.388
26	5	500	70	40	0.5010	21.244
27	5	500	70	45	0.5246	16.743

IIIRESULTS AND DISCUSSIONS

3.1 Influence of EWR

The Main effect plot for of EWR is shown in Fig. 2. The discharge current (Ip) and pulse on time is inversely proportional to EWR in the range of 1 to 5A. This is expected because an increase in pulse current produces strong spark, which produces the higher temperature, causing more material to melt and erode from the work piece. The duty cycle and voltage have no significant effect on EWR. The residual plot of EWR is shown in Fig. 3, where each plot exhibits the error between four different machining parameters like Ip, T_{on} and T_{au} and V. This implies that the effect of one factor is dependent upon another factor. It is also confirmed by the ANOVA table (Table 3).

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Table 3 Analysis of variance for EWR

Source	DF	Seq SS	Adj MS	F	P
Ip (A)	2	29517	14758.6	10.13	0.001
Ton (µs)	2	3890	1944.9	1.34	0.288
Tau (%)	2	1788	893.8	0.61	0.552
Volt.(V)	2	1812	906.0	0.62	0.548
Residual Error	18	26215	1456.4		
Total	26	63222			

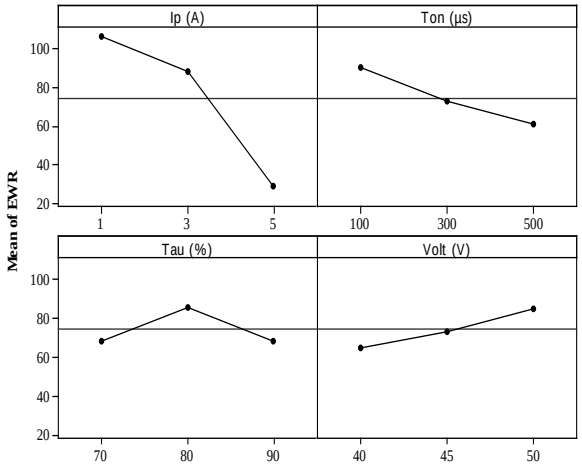
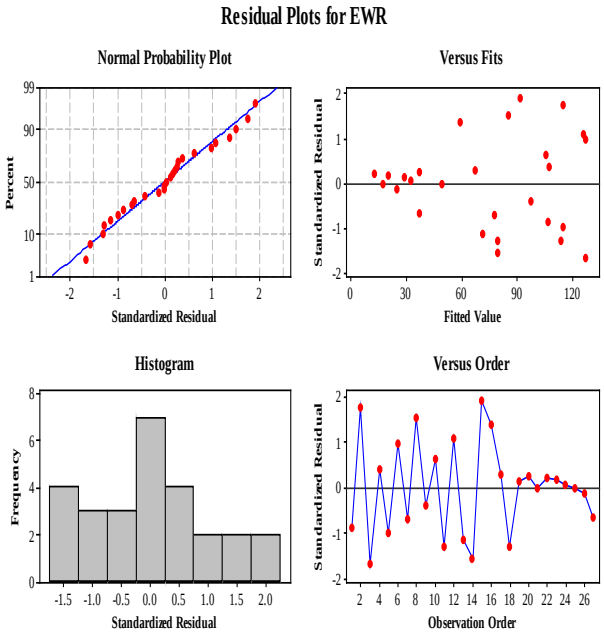


Fig.2 Main effect plots for EWR



3.2 Influence of OC

In the process of machining minimum over cut is required for better result. The effect of various machining parameters such as discharge current, pulse on time, duty cycle and voltage on over cut is presented in the main effect plot shown in Fig.3. and error are plotted are Fig 4. In the analysis of overcut discharge current, pulse on time and duty cycle has significantly affected. Voltage is not affected significantly that is confirm by ANOVA table of over cut (Table 4).

Table 4 Analysis of variance for overcut

Source	DF	Seq SS	Adj MS	F	P
Ip (A)	2	0.606477	0.303239	150.20	0.000
Ton (µs)	2	0.027473	0.013736	6.80	0.006
Tau (%)	2	0.018263	0.009131	4.52	0.026
Volt.(V)	2	0.001100	0.000550	0.27	0.765
Residual Error	18	0.036339	0.002019		
Total	26	0.689653			

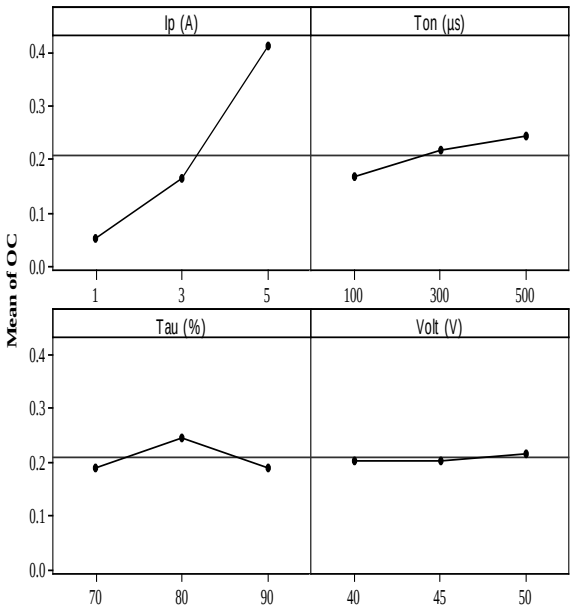
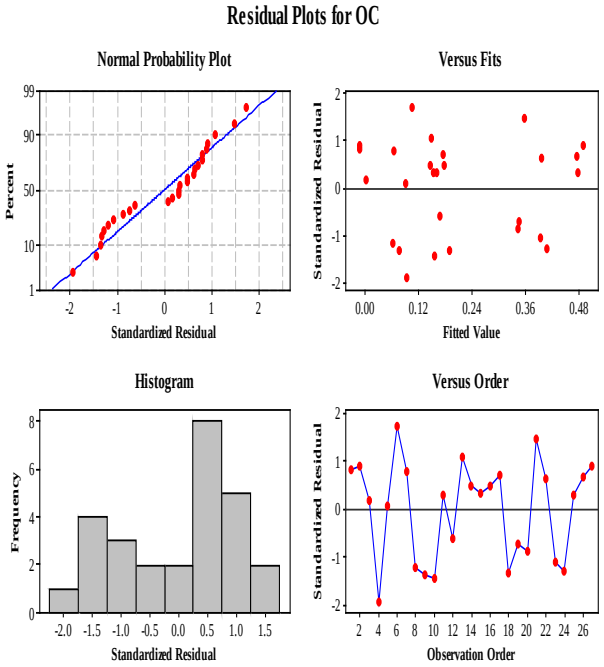


Fig.3 Main effect plot for OC



CONCLUSIONS

In the present work of study the effect of machining responses are electrode wear rate and over cut of the EN31 tool steel component using full factorial design with internal flushing system have been investigated for EDM process.

1. Pulse current is most influencing factor for EWR and then pulse duration and the voltage and duty cycle has no significant affected.
2. In the case of the dimensional accuracy, the measurement of over cut discharge current and pulse duration is given the significant effect. Then the duty cycle has slightly effect the dimensional accuracy, but voltage has no significant affected.

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