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Experimental Investigation of Machining Parameters for EDM Using D2 tool Steel

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Abstract

In this paper, the optimization of responses i. e., Material Removal Rate (MRR), Tool Wear Rate (TWR) and Over-Cut (OC) of Electric discharge machining (EDM) has been accomplished using L_{27} orthogonal array based on Taguchi design. The influence of machining parameters i.e. Discharge current, pulse on time, duty cycle and voltage has been analysed on AISI D2 tool steel as a workpiece.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 optimized for a given machining condition by analysis of variance (ANOVA) analysis.

Keywords: Material removal rate, tool wear rate, over-cut, Taguchi design, orthogonal array.

1. Introduction

Electric Discharge Machining (EDM) is one of the machining process, which is 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 impossible to machine with traditional machining processes. [1]. In EDM process a series of rapidly 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 create 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 improving 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), Tool Wear Rate (TWR), Surface Roughness (SR), 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[7-11].

AISI D2 tool steel has a growing range of applications like plastic molds, frames for plastic pressure dies, hydro forming tools, which offer difficulty in conventional machining in the hardened condition. In this paper, optimisation attributes such as MRR, TWR and OC measured from machining of D2 tool steel in EDM has been work out by using Taguchi orthogonal array design.

2. Experimental Equipment, Material And Method

2.1. Conduct of Experiment

The primary experiments were conducted on Electronica Electraplus PS 50ZNC 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 12 mm was used as tool electrode. The selected workpiece material for this experiment is AISI D2 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

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the effects of Ip, T_{on}, T_{au} and V on MRR, OC and TWR. 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 Taguchi method

Taguchi strategies provide a powerful and efficient method for designing products that operate reliably and optimally over a variety of conditions. Taguchi proposed several methods to experimental designs that are sometimes called "Taguchi Methods." These methods utilize two, three, four, five, and mixed-level fractional factorial designs. Taguchi refers to experimental design as "off-line quality control" because it is a method of ensuring good performance in the design stage of products or processes. 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} OA based on Taguchi design 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 than the Taguchi design two type of design are available. In the two type of design L_{27} and L_9. In this experiment L_{27} Orthogonal array are selected for design. The flow chart of the experiment is shown in Fig.1. Experimental observation data are described in Table 2.

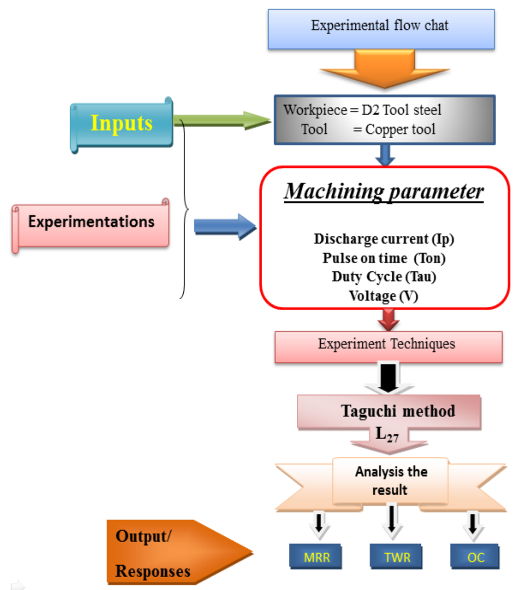

Fig.1 Flow chart of Experiment

Table 2 Observation Table

S. N.	**Ip (A)**	**T_{on} (µs)**	**T_{au} (%)**	**Volt. (V)**	**MRR**	**TWR**	**OC**
					(mm^3/min)		**(mm)**
1	1	100	70	40	1.6701	0.0210	0.0178
2	1	100	70	45	1.8217	0.0107	0.1950
3	1	100	70	50	1.1682	0.0157	0.0067
4	1	300	80	40	3.5758	0.0112	0.0210
5	1	300	80	45	3.3618	0.0400	0.0935
6	1	300	80	50	3.3792	0.0214	0.1684
7	1	500	90	40	2.6642	0.0479	0.1934
8	1	500	90	45	2.1048	0.0025	0.0180
9	1	500	90	50	2.8917	0.0342	0.0267
10	3	100	90	45	4.4107	0.0351	0.1017
11	3	100	90	50	4.1529	0.0571	0.1650
12	3	100	90	40	4.7622	0.0298	0.1450
13	3	300	70	45	6.3248	0.1768	0.1885
14	3	300	70	50	5.8389	0.1920	0.1650
15	3	300	70	40	5.9219	0.0326	0.1734
16	3	500	80	45	5.1892	0.0507	0.1955
17	3	500	80	50	5.3039	0.0694	0.2027
18	3	500	80	40	5.1873	0.1330	0.1409
19	5	100	80	50	6.3649	0.1918	0.3185
20	5	100	80	40	6.2726	0.1393	0.3122
21	5	100	80	45	6.2623	0.1274	0.4127
22	5	300	90	50	10.6580	0.5593	0.4193
23	5	300	90	40	8.5987	0.3356	0.3550
24	5	300	90	45	9.0170	0.2664	0.3617
25	5	500	70	50	7.4812	0.4315	0.3400
26	5	500	70	40	6.9490	0.3271	0.5010
27	5	500	70	45	7.4909	0.4474	0.5246

3. Results and Discussions

3.1 Influence of MRR

In the process of Electrical discharge machining, the influence of various machining parameters like Ip, T_{on}, T_{au} and V have a significant effect on MRR, as shown in the main effect plot for MRR in Fig 2. The discharge current (Ip) is directly proportional to MRR. This is expected because an increase in pulse current produces a strong spark, which produces the higher temperature, causing more material to melt and erode from the work piece. Besides, it is clearly evident that the other factor does not influence much as compared to Ip and similar conclusions were shown by Ghoreishi and Tabari[8].

The ANOVA for MRR is shown in Table. 3. In this table insignificant factors for 95% of confidence interval i.e. factors having p-value more than 0.05 is shown in '*' in P column. In the subsequent stage non-significant terms are eliminated from the backward elimination process

Table 3 Analysis of Variance for MRR

Source	DF	Seq SS	Adj MS	F	P
Ip (A)	2	120.015	60.0074	252.05	0.000
Ton (µs)	2	21.930	10.9650	46.06	0.000
Tau (%)	2	1.489	0.7443	3.13	0.068*
Volt.(V)	2	0.163	0.0815	0.34	0.715*
Residual Error	18	4.285	0.2381		
Total	26	147.882			

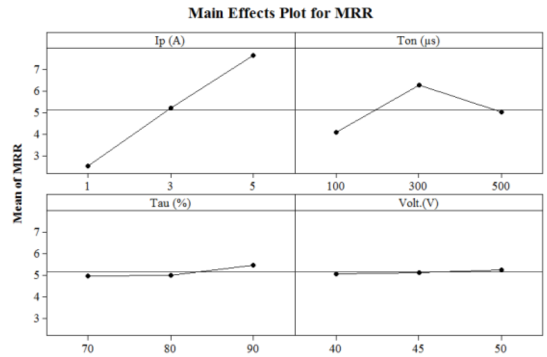

Fig.2 Main effect plots for MRR

3.2 Influence of TWR

Main effect plot for TWR is shown in Fig. 3, which indicates that Ip is directly proportional to TWR. As Ip increases, the pulse energy increases and thus more amount of heat energy is produced at the work piece-tool interface that leads to increase melting and evaporation of the electrode. One can interpret that Ip has a significant direct impact on TWR. Pulse on time is inversely proportional to the tool wear rate. At higher Ton, more energy is released between inter electrode gap resulting in dissociation of dielectric fluid, thus carbon particles are released. These particles get deposited on the copper tool forming the protective layer that reduces TWR. The ANOVA for TWR is shown in Table. 4.

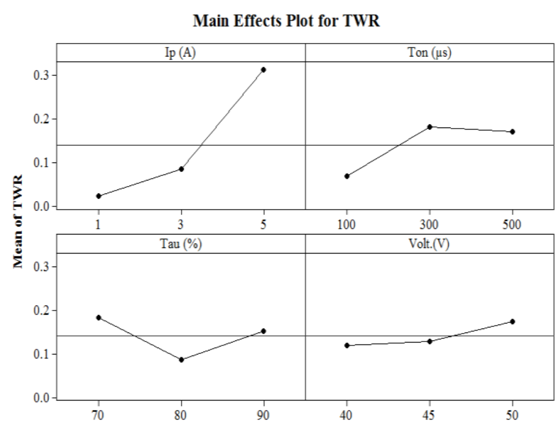

Fig.3 Main effect plots for TWR

Table 4 Analysis of Variance for TWR

Source	DF	Seq SS	Adj MS	F	P
Ip (A)	2	0.42213	0.211064	46.91	0.000
Ton (µs)	2	0.06897	0.034483	7.66	0.004
Tau (%)	2	0.04375	0.021875	4.86	0.020
Volt.(V)	2	0.01569	0.007845	1.74	0.203*
Residual Error	18	0.08098	0.004499		
Total	26	0.63152			

3.3 Influence of OC

The over cut is measured between the width of the electrode and the size of the cavity in the EDM process. 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, work time and lift time onover cut is presented in the main effect plot shown in Fig.4. This indicates that the discharge current is directly proportional to the over cut. General explanation for higher overcut is the high current with straight polarity that is large erosion. As spark energy is high at high current, the crater formed on the work material is large in depth and hence results in increment of overcut. OC increases gradually with the increase in pulse on time, aspulse on time is responsible for maintaining continuation of spark at tool and workpiece interface. The duty cycle and voltage has no significant effect over overcut according to the ANOVA (Table 5).

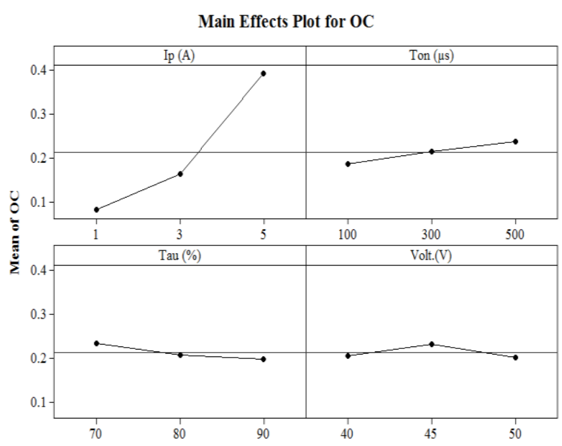

Fig.4 Main effect for OC

Table 5 Analysis of Variance for OC

Source	DF	Seq SS	Adj MS	F	P
Ip (A)	2	0.469736	0.234868	49.67	0.000
Ton (µs)	2	0.012284	0.006142	1.30	0.297*
Tau (%)	2	0.006427	0.003213	0.68	0.519*
Volt.(V)	2	0.004949	0.002475	0.52	0.601*
Residual Error	18	0.085119	0.004729		
Total	26	0.578514			

4. Conclusions

From the main effect plot of responses , it can be concluded that MRR is directly proportional to the discharge current and pulse on time, and decreases with the duty cycle whereas voltage slightly increases it.

TWR is directly proportional to discharge current and inversely proportional to pulse on time, whereas voltage has no significant effect on it.

OC is directly proportional to the discharge current and pulse on time .The duty cycle and voltage has no significant on it.

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