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Optimization of Material Removal Rate of WEDM Process on Mild Steel Using Molybdenum Wire

Harsh Saini, Irfan Khan, Sushil Kumar, Sahil Kumar

Department of Mechanical Engineering, Maharishi Ved Vyas Engineering College, Jagadhri, Haryana, India

Abstract— *For any manufacturing process and, particularly, in process related to WEDM the correct selection of process parameters is one of the most important aspects to be taken into consideration. WEDM is capable of machining geometrically complex shapes or hard material components, such as composites, carbides, heat treated tool steels, super alloys, ceramics and heat resistant steels etc. These hard material components are widely used in die and mold making industries, aerospace, aeronautics and nuclear industries.*

This study discusses the influence of process parameters like current, Pulse on time, Pulse off Time and Voltage on the performance parameters such as material removal rate. The experiment has been conducted on Mild Steel work piece using brass wire, because Mild Steel has various industrial applications in manufacturing of frame of motorcycles, dies, automobile chassis, base of boilers and cook wares etc. The experimental layout is based on Taguchi L_{16} orthogonal array. Further, the analysis of variance [ANOVA] is used to analyze the results obtained from Taguchi method. The analysis of results obtained for material removal rate indicate that current and pulse on time has the highest impact on material removal rate. As the current and pulse on time increases, the material removal rate also increases. Pulse off time and voltage has no significant effect on material removal rate.

Keywords— Taguchi, ANOVA, WEDM, molybdenum, pulse on time, current, pulse off time.

I. INTRODUCTION

WEDM ever since its inception has shown a tremendous growth. The process of WEDM was computerized in 1974 and further in 1975 its features and capabilities were enhanced. Since WEDM involves various parameters which play an important role in the quality of the product so it became an area of interest for the researchers. The parameters which may affect the quality of the product are tool size; pulse in and off time, feed rate, current and voltage etc. A no. of papers has been published to study the effect of these parameters on the performance of the WEDM. Material removal rate was found to be increasing with increase in pulse on time and current whereas surface quality was affected [27]. Approximately 70% increase in productivity was reported by using coated electrode as compared to the uncoated electrode [24]. Various kind of design of experiment techniques such as full factorial design [19], Taguchi method [17, 20] and RSM [22] was also used to design the optimum number of experiments. Also WEDM was performed in different mediums and a medium having oxygen mist dielectric was suggested to be better. Going through the literature it was found that work related to ELCUT type wire cut machine tool along with the current, pulse on time, voltage and pulse off time as process parameters and material removal rate as response parameters is scare.

II. EXPERIMENTS

Due to the ease in availability and conductive nature a mild steel work piece having composition C 0.28%, Mn 0.44%, P 0.04% S 0.02% and Si 0.16% [wt %] were selected as work piece. Molybdenum wire having 0.25 mm diameter was selected as electrode. ELCUT 234 machine [fig.1] Molybdenum wire having 0.25 mm diameter was selected as electrode. ELCUT 234 machine [fig.1] having 3-ϕ, AC 415 v, 50 Hz was used to perform the experiments.

Fig.1: ELCUT 234 machine

An orthogonal array [OA_{16}] based on the Taguchi Design of experiments was selected based on the degree of freedom. Current, pulse on time, pulse off time and

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voltage were taken as process parameters and other parameters like wire feed rate, wire tension and flushing pressure were kept constant. De-ionized water was used as dielectric fluid to flush away the debris from the machining area.

Table.1: Observation Table

Run	I	T_{on}	T_{off}	V	MRR
1	210	100	50	70	20.10
2	210	105	55	75	21.41
3	210	110	60	80	22.76
4	210	115	65	85	23.59
5	215	100	55	80	19.94
6	215	105	50	85	22.83
7	215	110	65	70	24.05
8	215	115	60	75	24.97
9	220	100	60	85	22.06
10	220	105	65	80	24.36
11	220	110	50	75	26.12
12	220	115	55	70	27.18
13	225	100	65	75	24.10
14	225	105	60	70	27.04
15	225	110	55	85	27.68
16	225	115	50	80	28.83

During the whole machining process a constant spark gap was be maintained with the help of servo mechanism system. The observed values of material removal rate for the experiment are shown in table 1.

The cut pieces of mild steel having 10 mm × 5 mm in cross-section are shown in fig. 2:

Fig.2: Cut Pieces of Mild Steel

III. RESULTS AND DISCUSSION

The S/N ratio table along with process parameters is shown in table 2 whereas the response table for S/N ratio is shown in table 3. The rank and delta values for Current, Pulse on Time, Pulse off Time and voltage 1, 2, 4 and 3 and delta 1.76, 1.68, 0.16 and 0.24 respectively, in response table for S/N

Table.3: Response Table for S/N Ratio

Level	I	Ton	Toff	V
1	26.82	26.64	27.69	27.75
2	27.18	27.54	27.53	27.64
3	27.91	27.99	27.65	27.52
4	28.58	28.32	27.61	27.59
Delta	1.76	1.68	0.16	0.24
Rank	1	2	4	3

Similarly, from response table for means shown in table 4.3 the rank and delta values for process parameters are1, 2, 4 and 3 and 4.95, 4.59, 0.45 and 0.62 respectively any miscellaneous numbering system you use in your paper cannot be confused with a reference [4] or an equation (3) designation.

Table.4: Response Table for Means

Level	I	Ton	Toff	V
1	21.97	21.55	24.47	24.59
2	22.95	23.91	24.05	24.15
3	24.93	25.15	24.21	23.97
4	26.91	26.14	24.02	24.04
Delta	4.95	4.59	0.45	0.62
Rank	1	2	4	3

The response table shows the relative importance of each process parameters towards the response. It is clears from these tables that the process parameter having greatest delta value gets highest rank. The rank indicates the relative significance of each process parameters to the response. Current gets rank 1 followed by pulse on time, voltage and pulse off time. So from the results based on delta value and rank it is conclude that current has the highest effect on material removal rate [MRR] followed by the pulse on time, voltage and lastly pulse off time.

3.1 Regression Equation

The regression equation for material removal rate as shown by equation [3.1] is calculated in MINITAB 17 software. The regression equation shows the significant effect of each process parameter on the material removal rate. From this equation, it is clears that the current and pulse on time have positively affect the material removal rate whereas pulse off time and voltage have negative effect on response i.e. material removal rate.

MRR = -770.9 + 0.3365I + 0.3004Ton - 0.0236Toff - 0.0367V …………. [3.1]

3.2 Analysis of variance [ANOVA]

The analysis of variance for S/N ratio and means are shown in table 5 and table 6 respectively. In an examination of variance table, the P value determines the most important process parameter. The parameter whose P value is less than 0.05 will be most effective factor. Current and pulse on time are significantly affect the

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material removal rate. From these tables it is concluded that Current is the most significant parameter for MRR followed by Pulse on Time. The main effect plot for S/N ratio and means are shown in fig. 3 and 4 respectively.

Table.5: Analysis of Variance for S/N Ratio

Sour	D	Seq	Adj	F	P	%
I	3	7.348	2.449	416.	0.00	52.90
Ton	3	6.352	2.117	360.	0.00	45.73
Toff	3	0.054	0.018	3.11	0.18	0.39
V	3	0.118	0.039	6.73	0.07	0.85
Error	3	0.017	0.005			
Total	15	13.89				

Table.6: Analysis of Variance for Means

Sour	D	Seq	Adj	F	P	%
I	3	57.81	19.27	752.	0.00	54.30
Ton	3	47.14	15.71	613.	0.00	44.28
Toff	3	0.499	0.166	6.50	0.07	0.47
V	3	0.934	0.311	12.1	0.03	0.88
Error	3	0.077	0.025			
Total	15	106.4				

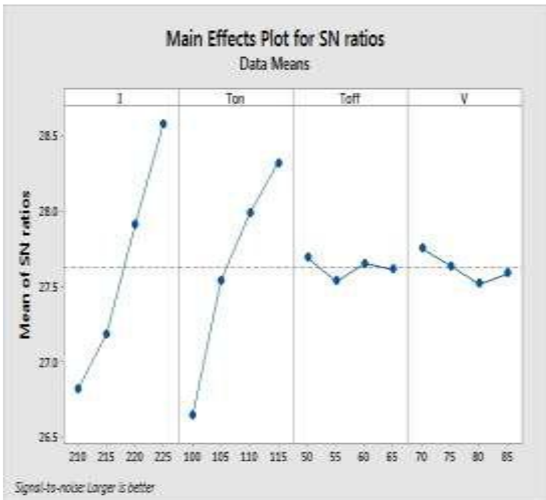

Fig.3: Main Effects Plot for S/N Ratio

From these graphs it is clears that as the current and pulse on time increases, the material removal rate also increases. As we increase the current and Pulse on time is show better value of MRR. These changes occur due to the fact that at the starting of electric discharge, the diameter of plasma channel is small, and lightweight electrons move towards the surface of work piece [positive pole] under the influence of electric field and cause the melting and evaporation of work piece material. As time going on, the diameter of plasma channel increases and more electrons move towards the anode and thus, more material is removed from the work piece.

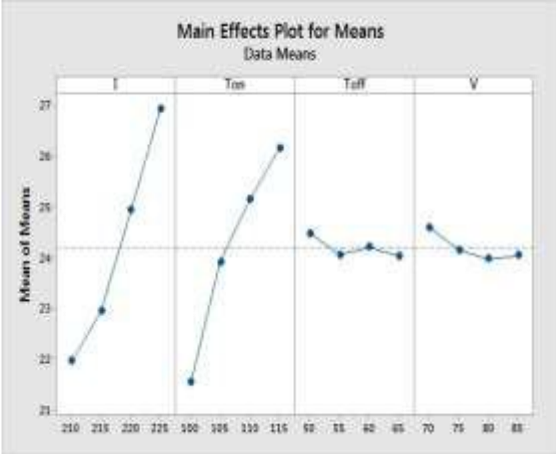

Fig.4: Main Effects Plot for Means

IV. CONCLUSIONS

The main aim of this study was to find optimum values of process parameters for the maximum values of material removal rate by using Current, Pulse on Time, Pulse off Time and voltage as the process parameters. From this study, the following conclusions are drawn:

1. The material removal rate increases with the increase in current and Pulse on Time. As we increase the Current, the discharge energy also increase and the number of discharges within a period of time becomes more which results to more material removal rate.
2. As the voltage and pulse off time increases, the material removal rate decreases.
3. The pulse off time and voltage has no significant effect on material removal rate.
4. The material removal rate is maximum at fourth level of Current [225 Amp], Pulse on Time [115 µs] and first level of pulse off time and voltage i.e. and 50 µs and 70 V respectively.

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