Optimization of different process parameters of EDM by using ANNOVA technique

Kiranpreet Singh Kang, Rajbir Singh Mavi , Ripendeep Singh Sidhu
Assistant Prof. Department of Mechanical Engineering,
Chandigarh University, Gharuan, Mohali
kiranpreetkang87@gmail.com, rajveermavi@cumail.com, Ripen.sidhu@yahoo.com

Abstract:

This study presents analysis of different parameters of EDM. In this work four parameters Current, Tool, Workpiece and Pulse On time are varied. L18 orthogonal array is used. MRR, TWR and surface roughness are calculated after experiments. F test is applied and plots for MRR, TWR and SR are constructed. In this study the tool comes out factor which has maximum effect on all three outputs. The current comes out to be second most important factor. Value of current is directly proportional to MRR, TWR and SR. The work pieces are mainly significant in Surface roughness.

Keywords: EDM, MRR, TWR & Surface Roughness

I Introduction

Electrical discharge machining (EDM) is a thermal process with a complex metal-removal mechanism, involving the formation of a plasma channel between the tool and work piece[1]. It has proved especially valuable in the machining of super-tough, electrically conductive materials such as the new space-age alloys that are difficult to machine by conventional methods [2]. The word unconventional is used in sense that the metal like tungsten, hardened stainless steel tantalum, some high strength steel alloys etc. are such that they can’t be machined by conventional method but require some special technique . The conventional methods in spite of recent advancements are inadequate to machine

such materials from stand point of economic production[3]. In EDM process there are large number of parameters which affect MRR and TWR. A number of input process parameters can be varied in the EDM process. Each parameter has its own impact on output parameters such as material.

II Experimental Analysis

The objective of this experimentation is to calculate MRR, TWR and Surface Roughness by using three tools and three type of work pieces, Six levels of current and three levels of pulse on time by applying L18 orthogonal array. The readings are then analyzed by using Taguchi methods. The design variables can be summarized as follows:

(a) Three die steel materials; namely D2 high-carbon high chromium die steel, D3 die steel and H13 hot work die steel are used.
(b) Three electrode materials; namely Copper, Copper-Tungsten and Brass are used.
(c) Six levels of peak current (2 amp, 3 amp, 4amp, 5amp, 6amp and 7amp) are used.
(e) Three levels of pulse on-time are used (10µs, 20µs and 50µs)
(f) The pulse off-time is kept fixed. (57 µs)

Apart from these variable parameters, some parameters are kept constant on EDM machine which are enlisted below:

1. Open Circuit Voltage is 135 ± 5% Volts.
2. Straight polarity is used i.e. workpiece is connected to positive and tool is connected to negative.
3. Machining Time of 10 minutes is taken.
4. EDM oil is used as dielectric medium.
5. Electrode Quill Movement is 10 : 4.

In this study Taguchi methods, orthogonal arrays and analysis of variance is used for design of design of experiments and calculation of MRR, TWR and Surface Roughness.

A Experimental set up

Experiments are conducted on the Electrical Discharge Machine model T- 3822 of Victory Electromech Company available in Machine Tool Lab of Thapar University Patiala. On this machine large number of input parameters can be varied i.e. Discharge voltage, Current, Pulse On Time, Pulse Off Time, electrode gap, Polarity, Type of flushing, Type of tool and type of workpiece. Each of these parameters effect the output parameters i.e. MRR, TWR and Surface Roughness. Current, Pulse On time, Tools and Workpiece are the four parameters which are varied in this study. Some parameters like discharge voltage , pulse off time , electrode gap , polarity and type of dielectric are fixed during experimentation.

A specially designed tank of mild steel is used for storing dielectric medium and to support the workpiece during experimentation.

Figure1 Electric Discharge Machine used for experimentation.

Apart from EDM machine some other equipments and instruments are used for calculating MRR, TWR and Surface Roughness (SR) and for specimen preparation. Following are the instruments used:

a) Surface Grinder is used for specimen preparation. This machine is available at workshop of Thapar University Patiala. The workpiece which are purchased from market are in bad condition. To make the surface of workpiece smooth and flat surface grinder is used.
b) A Electronic Weighing Machine is used for measuring initial weight and final weight of both workpiece and tool which are used for calculating MRR and TWR. This machine can weigh up to 500 g.
c) A Surface roughness tester is used for measuring surface roughness of each cut. A Mutitoy6, model SJ400, Germany is available at Metrology Lab of Thapar University. It uses stylus method of measurement. It has profile resolution of 12 nm and can measure surface roughness up to 100µm.

B Selection of Orthogonal Array & Parameter Assignment

In this experiment, there are four parameters three parameters at three levels each and one parameter has 6 levels. Current has six levels so it has degrees of freedom and pulse on time, tools and work pieces has 3 levels each so these have 2 degrees of freedom each, hence total DOF for the experiment is 11. The DOF of an orthogonal array selected for an experiment should be more than the total DOF for that experiment[5]. The difference should also not be very high, otherwise the cost and effort involved in conducting the extra experiments is wasted. Out of the standard orthogonal arrays available in Taguchi design, L18 orthogonal array has 17 degrees of freedom and it can accommodate 11 degrees of freedom, so it has been selected for this work. Amongst the parameters of this design, Current is assigned first column, work pieces are assigned to second column, pulse on time is assigned to third column and tools are assigned to fourth column.

Table 1 L18 Orthogonal Array used in experimentation

Trial	**Current**	**Work-piece**	**Pulse On Time**	**Tool**
1	2	D2	20	Cu
2	2	D3	50	CuW
3	2	H13	10	Brass
4	3	D2	20	CuW
5	3	D3	50	Brass
6	3	H13	10	Cu
7	4	D2	50	Cu
8	4	D3	10	CuW
9	4	H13	20	Brass
10	5	D2	10	Brass
11	5	D3	20	Cu
12	5	H13	50	CuW
13	6	D2	50	Brass
14	6	D3	10	Cu
15	6	H13	20	CuW
16	7	D2	10	CuW
17	7	D3	20	Brass
18	7	H13	50	Cu

III Results

A. Results for MRR

The effect of above parameters on the MRR is evaluated using ANOVA by MINITAB 16 software. The results of MRR for each of 18 trials is calculated from weight difference of workpiece before and after the experiment for each trial. The formula for MRR is given by:

$$MRR= (W_i – W_f / \rho \times t) \times 1000 \ (mm^3 / min)[6]$$

Where W_i = Initial weight of workpiece in gms,

W_f = Final weight of workpiece in gms

,ρ = Density of workpiece in gms/ mm

t = Time period of trials in minute

Table 2 Results for MRR

Trial	Current	Work -piece	Pulse On Time	Tool	MRR
1	2	D2	20	Cu	1.3160
2	2	D3	50	CuW	0.7895
3	2	H13	10	Brass	0.5196
4	3	D2	20	CuW	0.6580
5	3	D3	50	Brass	0.7890
6	3	H13	10	Cu	2.9870
7	4	D2	50	Cu	4.6050
8	4	D3	10	CuW	3.0263
9	4	H13	20	Brass	1.0392
10	5	D2	10	Brass	1.1840
11	5	D3	20	Cu	3.4210
12	5	H13	50	CuW	4.5466
13	6	D2	50	Brass	1.3180
14	6	D3	10	Cu	5.2630
15	6	H13	20	CuW	3.8970
16	7	D2	10	CuW	5.6842
17	7	D3	20	Brass	1.4473
18	7	H13	50	Cu	3.8960

B. Analysis of Variance for MRR

The results are analyzed by using ANOVA in MINITAB16 software. The analysis of variance at 99% confidence level is given by F test in table 3. The principle of F test is that larger the value of F of parameter more is the significance of parameter on the MRR. ANOVA table shows that tool has the highest value(F= 9.48). It means tool is the most significant factor for MRR and current with F= 3.40 is second most important factor. From table it is clear that workpiece has least effect on MRR.

Table 3 ANOVA for MRR

Source	DOF	Adj SS	Adj MS	F	P
Current	5	19.4180	3.8836	3.40	0.084

Work-piece	2	0.5064	0.2532	0.22	0.808
Pulse On	2	4.0090	2.0045	1.75	0.252
Tool	2	21.6942	10.8471	9.48	0.014
Residual error	6	6.8625	1.1437		
Total	17	52.4901			

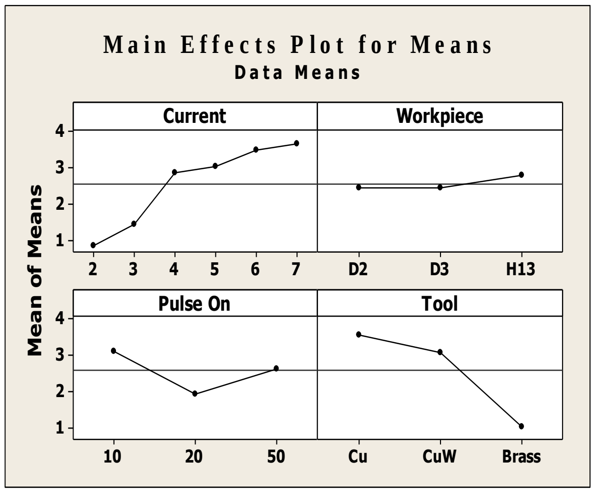

Figure 2 Plots showing ANOVA for MRR

The Plots in figure 2 shows the effect of selected parameters on the MRR. From the plots it is clear that MRR increase with increase in current level. Workpiece has very less effect on MRR, only H13 material shows little higher MRR. The Pulse on time shows that MRR is higher at 10µs and is lower at 20 µs. the tools shows significant effect on MRR. Copper tool has highest MRR and Brass tool shows very MRR.

C. Results for TWR

Table 4 Results for TWR

Trial	Current	Work -piece	Pulse On	Tool	TWR
1	2	D2	20	Cu	0.05618
2	2	D3	50	CuW	0.05714
3	2	H13	10	Brass	0.11760
4	3	D2	20	CuW	0.05714
5	3	D3	50	Brass	0.35290
6	3	H13	10	Cu	0.11236
7	4	D2	50	Cu	0.11236
8	4	D3	10	CuW	0.11428
9	4	H13	20	Brass	0.70588
10	5	D2	10	Brass	0.94117
11	5	D3	20	Cu	0.11236

12	5	H13	50	CuW	0.11428
13	6	D2	50	Brass	0.70588
14	6	D3	10	Cu	0.33707
15	6	H13	20	CuW	0.11428
16	7	D2	10	CuW	0.22857
17	7	D3	20	Brass	0.82350
18	7	H13	50	Cu	0.11230

The effect of selected parameters on the TWR is evaluated using ANOVA by MINITAB 16 software. The results of TWR for each of 18 trials is calculated from weight difference of tool before and after the experiment for each trial. The formula for TWR is given by:

$$TWR= (W_i – W_f / \rho \times t) \times 1000 \ (mm^3 / min)$$

D. Analysis of Variance for TWR

The results are analyzed by using ANOVA in MINITAB16 software. The analysis of variance at 99% confidence level is given by F test in table 5. The principle of F test is that larger the value of F of parameter more is the significance of parameter on the TWR. ANOVA table shows that tool has the highest value(F= 21.76). It means tool is the most significant factor for TWR and current with F= 3.98 is second most important factor. From table it is clear that workpiece and Pulse on time has very less effect on TWR.

Table 5 ANOVA for TWR

Source	**DOF**	**Adj SS**	**Adj MS**	**F**	**P**
Current	5	347.50	69.50	3.98	0.061
Workpiece	2	25.14	12.57	0.72	0.525
Pulse On	2	33.88	16.94	0.97	0.432
Tool	2	760.42	380.21	21.76	0.002
Residual error	6	104.83	17.47		
Total	17				

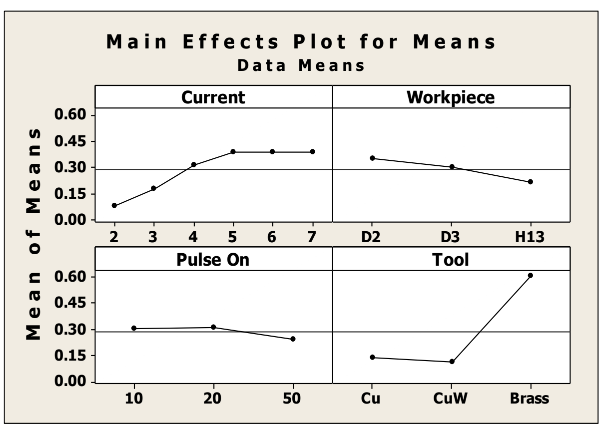

Figure 3 Plots for TWR

The plots shows that the most important parameter which effect the TWR is tool. Brass tool shows maximum TWR and Copper Tungsten tool shows very little TWR. Apart from Tool, Current also effect the TWR. The TWR increases with increase in current level. Pulse on time has very little effect on TWR. TWR decreases with increase in Pulse on time. The D2 material shows higher TWR and H13 shows lower TWR.

E. Results for Surface Roughness

In this experiment Surface Roughness of each cut is measured by a Surface Roughness Tester is used for measuring surface roughness of each cut. A Mutitoy6, model SJ400, Germany is available at Metrology Lab of Thapar University. It uses stylus method of measurement. In this experiment surface roughness (Ra) is measured at one position i.e. centre of cut made by each trial. Surface roughness (Ra) for each of 18 trials is shown in table 6.

Table 6 Results for Surface Roughness (Ra)

Trial	Current	Work-piece	Pulse On	Tool	SR (Ra)
1	2	D2	20	Cu	6.20
2	2	D3	50	CuW	6.10
3	2	H13	10	Brass	5.09
4	3	D2	20	CuW	6.40
5	3	D3	50	Brass	5.10
6	3	H13	10	Cu	6.90
7	4	D2	50	Cu	7.10
8	4	D3	10	CuW	7.40
9	4	H13	20	Brass	6.50
10	5	D2	10	Brass	5.39
11	5	D3	20	Cu	7.98
12	5	H13	50	CuW	7.70
13	6	D2	50	Brass	6.30
14	6	D3	10	Cu	8.27
15	6	H13	20	CuW	8.40
16	7	D2	10	CuW	8.59
17	7	D3	20	Brass	7.10
18	7	H13	50	Cu	9.88

F. Analysis of Variance for Surface Roughness

The results are analyzed by using ANOVA in MINITAB16 software. The analysis of variance at 99% confidence level is given by F test in table 7. The principle of F test is that larger the value of F of parameter more is the significance of parameter on the SR. ANOVA table shows that tool has the highest value(F= 67.90). It means tool is the most significant factor for SR and current with F= 35.62 is second most important factor. From table it is clear that Pulse on time (F= 0.44) has negligible effect on SR.

Table 7 ANOVA for SR

Source	DOF	Adj SS	Adj MS	F	P
Current	5	14.8454	2.96908	35.62	0.000
Workpiece	2	1.6884	0.84421	10.13	0.012
Pulse On	2	0.0742	0.03709	0.44	0.660
Tool	2	11.3190	5.65951	67.90	0.000
Residual error	6	0.5001	0.08336		
Total	17				

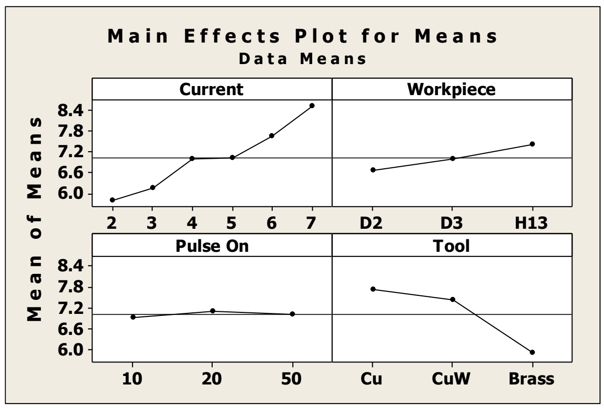

Figure 4 Plots for Surface Roughness

The plots shows that with increase in value of current the surface roughness increases. The Brass tool shows the minimum surface roughness and Cu shows highest Surface Roughness. As discussed earlier plots also shows that Pulse On Time has negligible effect on SR. The D2 material has lowest SR and H13 material shows highest SR.

IV. Conclusion

In this experimental work four parameters Current, Tool, Workpiece and Pulse On Time are varied. Six levels of current are used, three different tools, three different work pieces and three levels of Pulse on time are used. L18 orthogonal array is used. MRR, TWR and surface roughness are calculated after experiments. After applying ANOVA by using MINITAB16 software F test is applied and plots for MRR, TWR and SR are constructed. In this study the tool comes out factor which has maximum effect on all three outputs. The Cu tool shows highest MRR and SR and Brass shows lowest MRR and SR. CuW tool shows minimum TWR and Brass shows highest TWR. The current comes out to be second most important factor. Value of current is directly proportional to MRR, TWR and SR. It means that with increase in current MRR, TWR and SR increases. The work pieces are mainly significant in Surface roughness. The D2 shows lowest SR and H13 shows highest SR. The on time has small effect on MRR, TWR and SR.

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