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Parameter Optimization of EDM on En36 Alloy Steel For MRR and EWR Using Taguchi Method

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Abstract: *Machining of hard metal is very difficult process by conventional method. So we use a non conventional method for hard material the method is known as electrical discharge machining (EDM) process. And the material for machining is EN36 alloy steel. Electrical discharge machining (EDM) is one of the most widely used non-traditional machining processes. Electrical Discharge Machining (EDM) is the process of machining electrically conductive materials by using precisely controlled sparks that occur between an electrode and a workpiece in the presence of a dielectric fluid. The electrode may be considered the cutting tool. This paper investigate about the effect of EDM parameters using pulse on time, pulse off time, current and voltage on material removal rate (MRR) and also effect on electrode . In the present Work we take copper as electrode. Using Taguchi method, an L9 orthogonal array is used in the experiment and three levels corresponding to each of the variables are taken.*

Keywords: *EDM, metal removal rate (MRR),electrode wear rate(EWR), Taguchi method, EN36*

I. Introduction

Electrical Discharge Machining (EDM) is a well-known machining technique since more than fifty years. Now a days it is the most widely-used non-traditional machining process, mainly to produce injection molds and dies, for mass production of very common objects. It can also produce finished parts, such as cutting tools and items with complex shapes. EDM is used in a large number of industrial areas: automotive industry, electronics, domestic appliances, machines, packaging, telecommunications, watches, aeronautic, toys, surgical instruments. The principle of EDM is to use the eroding effect of controlled electric spark discharges on the electrodes. It is thus a thermal erosion process. The sparks are created in a dielectric liquid, generally de-ionized water or oil, between the workpiece and an electrode, which can be considered as the cutting tool. There is no mechanical contact between the electrodes during the whole process. Since erosion is produced by electrical discharges, both electrode and workpiece have to be electrically conductive. Thus, the machining process consists in successively removing small volumes of workpiece material, molten or vaporized during a discharge. The volume removed by a single spark is small, in the range of 10-6 to 10-4 mm^3, but this basic process is repeated typically 10,000 times per second. Electrical discharge machining (EDM) is a process that is used to remove metal through the action of an electrical discharge of short duration and high current density between the tool and the workpiece .

Both tool and work piece are submerged in a dielectric fluid .Kerosene/EDM oil/deionized water is very common type of liquid dielectric although gaseous dielectrics are also used in certain cases.EN36 alloy steel is an important tool and dies material, mainly because of its high hardness, strength and wears resistance over a wide range of temperatures. It has a high specific strength and cannot be easily processed by conventional machining techniques.

Table 1. Chemical composition of EN36

C %	Mn %	P %	S %	Si %	Cu %	Ni %	Cr %	V %
0.1376	0.5868	0.01207	0.01241	0.3319	0.0333	3.429	0.847	0.0245

II. Experimentation Process

A number of experiments were conducted to study the effects of various machining parameters on EDM process. These studies have been undertaken to investigate the effects of pulse on time (T-on), pulse off Time (T-off), current (Ip) and voltage (v). The work piece material for the work is EN36.The material for the electrode is copper. Have a diameter of 8mm. Experiments are conducted on brand Elektra model number es 5535 Die Sinking Machine.

In the experiment we calculate the MRR and EWR and for the calculation of MRR we have to measure the weight of workpiece after every run of experiment. Every time the material is removed from the workpiece due to heat generated by the arc, the remove debris from the workpiece as a result of that the weight of the workpiece decreases. To measure the initial and final weight of workpiece.Same with the electrode in order to measure EWR.

III. Design Of Experiments And Analysis For MRR

3.1 Design of Experiments

The experimental layout for the machining parameters using the L9 orthogonal array was used in this study.

Table No.2 Input Machining Parameters

S.NO.	INPUT PARMETERS	LEVEL		
		1	2	3
1.	Pulse on time (T_{on})	50	100	150
2.	Pulse off time (T_{off})	6	9	12
3.	Current (Ip)	6	10	14
4.	Voltage (V)	40	50	60

This array consists of four control parameters and three levels, as shown in table no. 2. In the Taguchi method, For all of the observed values are calculated based on 'larger is the better'. Each experimental trial was performed with simple one replication at each set value. Next, the optimization of the observed values was determined by comparing the standard analysis and analysis of variance (ANOVA) which was based on the Taguchi method.

3.2 Results and analysis of MRR for machined surface

The effect of parameters i.e. Pulse-on time, Pulse-off time, current and Voltage some of their interactions were evaluated using ANOVA. A confidence interval of 95% has been used for the analysis. To measure Signal to Noise ratio (S/N ratio) calculated by the formula (S/N) HB = -10 log (MSDHB) For material removal rate (MRR) the S/N ratio is larger is better. Where MSDHB = Mean Square deviation for higher the better response.

3.3 Observation table

During the conduction of all the 9 experiments with different set of input parameters observation were made for the weight lost in the gram from the workpiece in each experiment and time taken in the minute for the machining of each experiment was also observed. After the completion of all the experiments the observation reading of the weight loss and time taken were filled in orthogonal array as shown in table 3.

Table no. 3 Average Table for MRR for Material

Sl.No.	T_{on} (µs)	T_{off} (µs)	Ip (A)	Voltage (V)	MRR gm/min	SNRA1	MEAN1
1.	50	6	6	40	0.0358	-28.9223	0.0358
2.	50	9	10	50	0.0650	-23.7417	0.0650
3.	50	12	14	60	0.1211	-18.3371	0.1211
4.	100	6	10	60	0.0571	-24.8673	0.0571
5.	100	9	14	40	0.1320	-17.5885	0.1320
6.	100	12	6	50	0.0432	-27.2903	0.0432
7.	150	6	14	50	0.1173	-18.6140	0.1173
8.	150	9	6	60	0.0249	-32.0760	0.0249
9.	150	12	10	40	0.0766	-22.3154	0.0766

3.4 Analysis of variance – MRR:

The results were analyzed using ANOVA for identifying the significant factors affecting the performance measures. The Analysis of Variance (ANOVA) for the mean MRR at 95% confidence interval is given in Tables. The variation data for each factor and their interactions were F-tested to find significance of each calculated by the formula. The principle of the F-test is that the larger the F value for a particular parameter, the greater the effect on the performance characteristic due to the change in that process parameter. ANOVA table shows that pulse on time, pulses off time,current, voltage are the factors that significantly affect the MRR.current has highest contribution to MRR. Main effect plot for the mean MRR is shown in the graph which shows the variation of MRR with the input parameters. As can be seen MRR increases with increase in current .

3.5 Conformation Test
From mean of each level of every factor we will construct response table for MRR is given below:

Table no.4 Response Table for Signal to Noise Ratios (Larger is Better)

Level	Ton (A)	Toff (B)	Ip (C)	Voltage (D)
1	-23.67	-24.13	-29.43	-22.94
2	-23.25	-24.47	-23.64	-23.42
3	-24.34	-22.65	-18.18	-25.09
Delta	1.09	1.82	11.25	2.12
Rank	4	3	1	2

Table no. 5 Response Table for Means

Level	Pulse on time	Pulse off time	Current	Voltage
1	0.07397	0.07007	0.03463	0.08147
2	0.07743	0.07397	0.06623	0.07517
3	0.07293	0.08030	0.12347	0.06770
Delta	0.00450	0.01023	0.08883	0.01377
Rank	4	3	1	2

From above main effect plot of MRR we can conclude the optimum condition for MRR is
A2, B3, C3, D1 i.e. Pulse-on (100 µs.), Pulse-off (12µs),current(14 amp) and Voltage (40V).

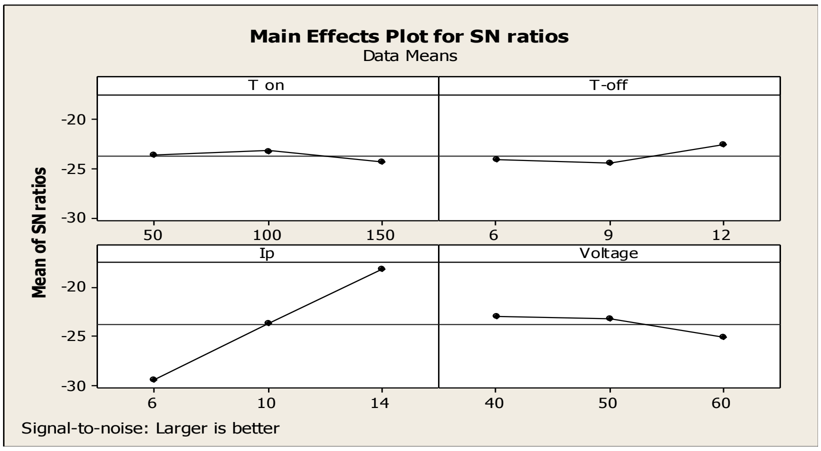

Figure 1: Main Effect Plot for S/N Ratio of MRR

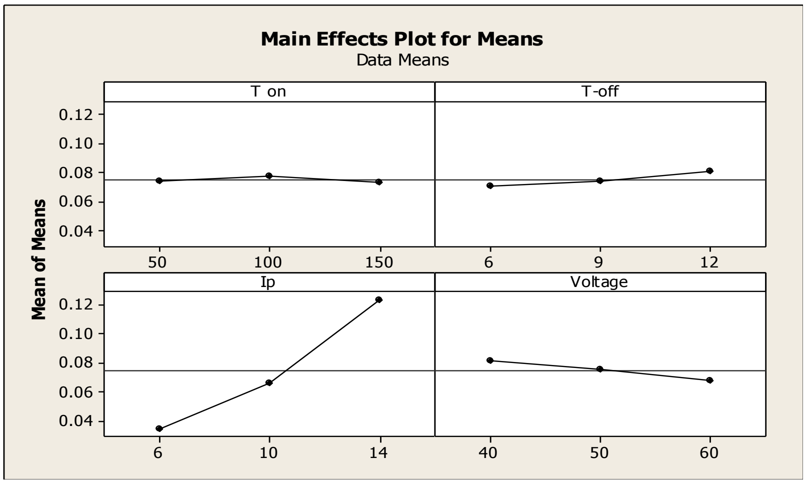

Figure 2 : Main Effect Plot for Means of MRR

The table 6 showing the s/n ratio of MRR where we check the value of p which is less than of 0.05 and in the table 0.00 for current and 0.074 of voltage .which have been showing current factor have more contribution for removing the material after that voltage have been giving there contribution for that.

Table no.6 ANOVA for S/N Ratio of MRR

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Ton	1	0.670	0.670	0.670	0.56	0.496
Toff	1	3.316	3.316	3.316	2.77	0.172
Current	1	189.832	189.832	189.832	158.33	0.000
Voltage	1	6.943	6.943	6.943	5.79	0.074
Error	4	4.796	4.796	1.199		
Total	8	205.557				

Seq SS= Sum of squares, DOF= degree of freedom, Adj MS= adjusted mean square or variance
** Significant at 95% confidence level.
S = 1.09499 R-Sq = 97.67% R-Sq(adj) = 95.33%

Table no. 7 ANOVA for Mean Ratio of MRR

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Ton	1	0.0000016	0.0000016	0.0000016	0.02	0.901
Toff	1	0.0001571	0.0001571	0.0001571	1.73	0.259
Current	1	0.0118370	0.0118370	0.0118370	130.11	0.000
Voltage	1	0.0002843	0.0002843	0.0002843	3.12	0.152
Error	4	0.0003639	0.0003639	.0000910		
Total	8	0.0126439				

S = 0.00953820 R-Sq = 97.12% R-Sq(adj) = 94.24%
** Significant at 95% confidence level
Seq SS= Sum of squares, DOF= degree of freedom, Adj MS= adjusted mean square or variance.

3.6 Optimal design for MRR

In the experimental analysis, main effect plot of S/N ratio is used for estimating the S/N ratio of MRR with optimal design condition. As shown in the graphs, there are highest values which effect the material removal rate which are the pulse-on (A2), pulse off (B3), current (C3) and voltage (D1) respectively. After evaluating the optimal parameter settings, the next step of the Taguchi approach is to predict and verify the enhancement of quality characteristics using the optimal parametric combination.

IV. Design Of Experiments And Analysis For Ewr

4.1 Design of Experiments

The experimental layout for the machining parameters using the L9 orthogonal array was used in this study.

Table no. 8 Input Machining Parameters

S.NO.	INPUT PARMETERS	LEVEL		
		1	2	3
1.	Pulse on time (T_{on})	50	100	150
2.	Pulse off time (T_{off})	6	9	12
3.	Current (Ip)	6	10	14
4.	Voltage (V)	40	50	60

4.2 Results and analysis of EWR

9 experiments are conducted for the L_9 experimental design. The results of each experiment is repeated three times it means for every experiment there is three values of EWR as shown in the table no. So the analysis is based on the three responses of EWR. For the results of EWR, firstly S/N ratio is to be calculated

The effect of parameters i.e. Pulse on time, Pulse off time, Current and Voltage some of their interactions were evaluated using ANOVA. A confidence interval of 95% has been used for the analysis. To measure Signal to Noise ratio (S/N ratio) calculated by the formula

(S/N) LB = -10 log (MSDLB)

Where MSDHB=1/r$\sum_{i=1}^{r} = (y_i^2)$, r = the number of tests in a trial

yi = observed value of response characteristics
For Electrode wear rate (EWR) the S/N ratio is smaller is better.
Where MSDLB = Mean Square deviation for smaller the better response.

4.3 Observation table

During the conduction of all the 9 experiments with different set of input parameters observation were made for the weight lost in the gram from the electrode in each experiment and time taken in the minute for the machining of each experiment was also observed. After the completion of all the experiments the observation reading of the weight loss and time taken were filled in orthogonal array as shown in table 9.

Table no. 9 Average Table for EWR for Material

Sl.No.	Ton	Toff	Ip	Voltage	EWR	SNRA2	MEAN2
1.	50	6	6	40	0.00089	61.0122	0.00089
2.	50	9	10	50	0.00406	47.8295	0.00406
3.	50	12	14	60	0.01690	35.4423	0.01690
4.	100	6	10	60	0.00085	61.4116	0.00085
5.	100	9	14	40	0.00650	43.7417	0.00650
6.	100	12	6	50	0.00063	64.0132	0.00063
7.	150	6	14	50	0.00364	48.7780	0.00364
8.	150	9	6	60	0.00036	68.8739	0.00036
9.	150	12	10	40	0.00290	50.7520	0.00290

4.4 Analysis of variance – EWR

The results were analyzed using ANOVA for identifying the significant factors affecting the performance measures. The Analysis of Variance (ANOVA) for the mean EWR at 95% confidence interval is given in Table. The variation data for each factor and their interactions were F-tested to find significance of each calculated by the formula. The principle of the F-test is that the larger the F value for a particular parameter, the greater the effect on the performance characteristic due to the change in that process parameter. ANOVA table shows that current, pulse on time, pulses off time, voltage are the factors that significantly affect the EWR. Current has highest contribution to EWR. Main effect plot for the mean EWR is shown in the graph 4 which shows the variation of EWR with the input parameters**.**

4.5. Conformation test - EWR

From mean of each level of every factor we will construct response table for EWR is given below. From table 10 main effect plot of EWR conclude the optimum condition for EWR are A2, B1, C1, D3 i.e.), Pulse-on time (100 µs), Pulse-off time (6 µs), Current (6 A) and Voltage (60 V).

Table no. 10. Response Table for Signal to Noise Ratios (smaller is Better)

Level	Ton (A)	Toff (B)	Ip (C)	Voltage (D)
1	48.09	57.07	64.63	51.84
2	56.39	53.48	53.33	53.54
3	56.13	50.07	42.65	55.24
Delta	8.29	7.00	21.98	3.41
Rank	2	3	1	4

Table no. 11 Response Table for Means

Level	Pulse on time	Pulse off time	Current	Voltage
1	0.007283	0.001793	0.000627	0.003430
2	0.002660	0.003640	0.002603	0.002777
3	0.002300	0.006810	0.009013	0.006037
Delta	0.004983	0.005017	0.008387	0.003260
Rank	**3**	**2**	**1**	**4**

From above main effect plot of EWR we can conclude the optimum condition for EWR is A2, B1, C1, D3 i.e. Pulse-on (100µs), Pulse-off (6 µs), Current (6amp.), Voltage (60V).

From figure 4 showing the main effects plot for Means of EWR obtaining the optimal parameters. This shows that smaller the values of parameters better the EWR. Here A is pulse-on time which is minimum at A2, B1 is pulse-off time, C1 is current and D3 is voltage.

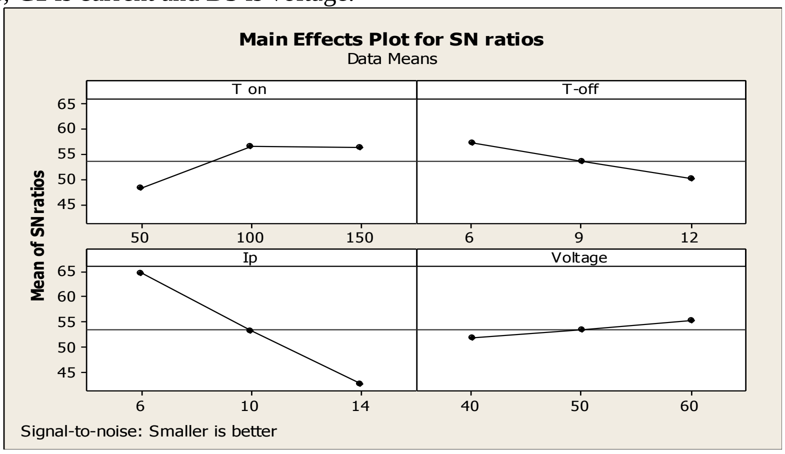

Figure 3: Main Effect Plot for S/N Ratio of EWR

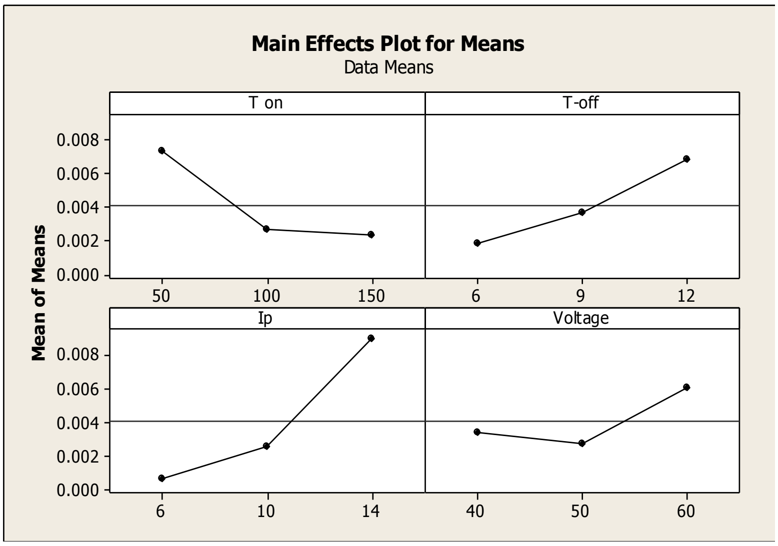

Figure 4: Main Effect Plot for Means of EWR

The table12 showing the s/n ratio of EWR where we check the value of p which is less than of 0.05 and in the table 0.001 for current, 0.031 for pulse-on time and0.047 for pulse-off time .which have been showing current factor have more contribution for EWR and after that pulse-on time giving there contribution for that.

Table no. 12. ANOVA for S/N Ratio of EWR

Source	**DF**	**Seq SS**	**Adj SS**	**Adj MS**	**F**	**P**
Ton	1	96.96	96.96	96.96	10.55	0.031
Toff	1	73.46	73.46	73.46	8.00	0.047
Current	1	724.62	724.62	724.62	78.88	0.001
Voltage	1	17.41	17.41	17.41	1.90	0.241
Error	4	36.75	36.75	9.19		
Total	8	949.21				

Seq SS= Sum of squares, DOF= degree of freedom, Adj MS= adjusted mean square or variance
** Significant at 95% confidence level.
S = 3.03100 R-Sq = 96.13% R-Sq(adj) = 92.26%

Table no. 13 ANOVA for Mean Ratio of EWR

Source	**DF**	**Seq SS**	**Adj SS**	**Adj MS**	**F**	**P**
Ton	1	0.0000373	0.0000373	0.0000373	5.43	0.080
Toff	1	0.0000378	0.0000378	0.0000378	5.50	0.079
current	1	0.0001055	0.0001055	0.0001055	15.38	0.017
Voltage	1	0.0000102	0.0000102	0.0000102	1.49	0.290
error	4	0.0000274	0.0000274	0.0000069		
Total	8	0.0002181				

S = 0.00261954 R-Sq = 87.42% R-Sq(adj) = 74.84%
** Significant at 95% confidence level
Seq SS= Sum of squares, DOF= degree of freedom, Adj MS= adjusted mean square or variance.

4.5 Optimal design for EWR

In the experimental analysis, main effect plot of S/N ratio is used for estimating the S/N ratio of EWR with optimal design condition. As shown in the figure 4 there are highest values which affect the electrode wear rate which are the pulse-on (A2), pulse off (B1), current (C1) and voltage (D3) respectively. After evaluating the optimal parameter settings, the next step of the Taguchi approach is to predict and verify the enhancement of quality characteristics using the optimal parametric combination

V. CONCLUSION

In the present study, for EDM process the effect of pulse on time, pulse off time,current and voltage has been investigated. The effect of input parameter on output response Material removal rate was analyzed for work material EN36alloy steel. L9 orthogonal array based on Taguchi design and ANOVA was performed for analyzing the result.

- The material removal rate (MRR) mainly affected by peak current (Ip). Pulse on time(Ton) has least effect on it.

- The electrode wear rate (EWR) is mainly influenced by peak current (Ip). The effect of voltage (V) is less on EWR and has least effect on it.
- Optimum parameters of input factors are as follows;
  For MRR –A2, B3, C3, D1 i.e, Pulse-on time (100 μs.), Pulse-off time(12μs),current(14 amp) and Voltage (40V).
- For EWR- A2, B1, C1, D3 i.e. Pulse-on time (100μs), Pulse-off time (6 μs), Current (6amp.), Voltage (60V).

References

[1]. Shaaz Abulais," Current Research trends in Electric Discharge Machining(EDM):Review", International Journal of Scientific & Engineering Research, Volume 5, Issue 6, June-2014.

[2]. Ujjval Prajapati, Jaimin Prajapati, Paras Modi, Kapil S Banker," A Review of Parameter Optimization of Electro Discharge Machine By Using Taguchi Method",International Journal for Scientific Research & Development| Vol. 2, Issue 04, 2014.

[3]. Sushil Kumar Choudhary, Dr. R.S Jadoun," Current Advanced Research Development of Electric Discharge Machining (EDM): A Review", International Journal of Research in Advent Technology, Vol.2, No.3, March 2014, E-ISSN: 2321-9637

[4]. M. Manjaiah, S. Narendranath and S. Basavarajappa," A Review On Machining Of Titanium Based Alloys Using Edm & Wedm, Rev. Adv. Mater. Sci. 36 (2014) 89-111

[5]. Kumar Sandeep," Current Research Trends in Electrical Discharge Machining: A Review", Research Journal of Engineering Sciences, ISSN 2278 – 9472,Vol. **2(2),** 56-60, February **(2013)** Res. J. Engineering Sci.

[6]. Amandeep singh, Neel kanth grover, Rakesh Sharma," Recent Advancement In Electric Discharge Machining, A Review", International Journal of Modern Engineering Research (IJMER) Vol.2, Issue.5, Sep-Oct. 2012 pp-3815-3821, ISSN: 2249-6645.

[7]. P. J. Pawar," Multi-Objective Optimization Of Wire Electric Discharge Machining Process Using Shuffled Frog Leaping Algorithm", International Journal Of Manufacturing Technology And Industrial Engineering (Ijmtie) Vol. 1, No. 1, January-June 2011, Pp. 43-47.

[8]. Kuldeep Ojha, R. K. Garg, K. K. Singh," MRR Improvement in Sinking Electrical Discharge Machining: A Review", Journal of Minerals & Materials Characterization & Engineering, Vol. 9, No.8, pp.709-739, 2010.

[9]. H. Singh and R. Garg," Effects of process parameterson material removal rate in WEDM", journal of Achievements in Materialsand Manufacturing Engineering, VOLUME 32, ISSUE 1January 2009.