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Experimental Analysis of Machining Parameters for EDM of Aluminum 6061 using Brass-Silver alloy Electrode

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ABSTRACT

Electrical discharge machining (EDM) is non-traditional machining processes. EDM process is based on thermoelectric energy between the work piece and a tool electrode. A pulse discharge occurs in a small gap between the work piece and the tool electrode and removes the unwanted material from the material through melting and vaporizing. The present work aims to study the effect of EDM input parameters like pulse on time, pulse off time and current on the performance measure like Material removal rate (MRR), Electrode wear rate (EWR) and over cut during electro discharge machining of Aluminum 6061 as work piece and brass-silver alloy as electrodes. Taguchi method will be employed for experimental work .The research work is expected to find out the best material that will lead to a Maximum Material removal rate (MRR), minimum over cut and minimum Electrode wear rate (EWR). The design of experiments is based on Taguchi's L9 orthogonal array.

Keywords: Electro discharge machine, MRR, EWR, Overcut, Brass-Silver electrode

I. INTRODUCTION

EDM is widely useful technique used in manufacturing area for high precision and accuracy machining of electrical conductive material. In electro discharge machining process, electrical energy converted into thermal Energy through a series of sparks occurring between the electrode and a workpiece immersed in a dielectric and separated by a small gap. During the machining application of heat raises the temperature of work-piece in the region of electrode position, which melts and evaporates the metal from the conductive material. In this way the machining process removes small volumes of material from work piece by the mechanism of melting and vaporization during a discharge. During electrode discharge machining material removal rate, electrode wear rate, surface roughness and over cut are main output performance parameter. Peak current, pulse on time, pulse off time, voltage and flushing pressure of dielectric fluid are main input process parameter.

Basically three types of EDM.

1) Die sinking EDM
2) Wire EDM
3) Micro EDM

II. LITERATURE REVIEW

Hussain Rizvi et.al (2016) [1] evaluates the effect of Pulse Current(Ip), Pulse ON time(Ton), Pulse OFF time(Toff), Duty factor, voltage on MRR,SR, surface crack and residual stress of EDM with AISI 4340 steel. The value of MRR and SR as well as Crack and residual stress increases for higher value of pulse current and but when the pulse current is too small then the surface density is increase.

Durgesh Verma et.al (2016) [2] evaluates the effect of peak current (Ip) , pulse on time (Ton) and gap voltage (Vg) on MRR, TWR and hole enlargement

with AISI 4147 steel of 5 mm thickness and 10 mm diameter. In case of MRR, Current is the most significant factor. Major factors affecting TWR are peak current and pulse on time both.

Dr. Avinash Sarode et.al (2016) [3] evaluates the effect of Electrode Material and geometry EDM Performance for OHNS dies steel. Copper is comparatively a better electrode material as it gives better surface finish, high MRR and less electrode wear for OHNS work material, while Brass is next to copper.

Sumit Raja et.al (2015) [4] evaluate the effect of different parameter on EN 45 steel with copper electrode. The current and pulse off time are highly significant parameters, while pulse on time and voltage are less significant factor for MRR.

S. Dhanabalan Et.Al (2015) [5] evaluates the effect of different Electrode Material on titanium alloy. Higher MRR is obtained using brass and aluminum electrode. Brass electrode offer high electrode wear while aluminum and copper electrode offers low electrode wear.

Shyam Narayan Pandey et.al (2015) [6] evaluates the effect of Copper Tungsten, Copper, Brass Electrode Material on SS-202 of 76 mm in diameter and 4 mm is thickness. EWR is less in copper-Tungsten electrode.

Apurba Kumar Roy et.al (2014) [7] evaluate various Machine Process Parameters on the Surface Roughness in EDM for an EN41 Material using Grey-Taguchi. The discharge current had a larger impact over the SR. The effect of the other parameters was significantly less and it can be ignored.

Manas Ranjan Singh et.al (2014) [8] Investigate the Machinability of Inconel 718 in Electrical Discharge Machining. Tool material, current and pulse-on-time are the important parameters in the machinability of super alloy.

Prasad et.al (2014) [9] Analysis the effect of EDM Process Parameters on AISI D2 Steel. Most significant & effective factors in the MRR of AISI D2 steel machined by copper tool are the pulse current and pulse on time, Which increases MRR, surface roughness and tool wear.

Subramanian Gopalakannan et.al (2012) [10] evaluate Effect of Electrode Materials copper, copper-tungsten and graphite on Electric Discharge Machining of 316 L and 17-4 PH Stainless Steels. Copper electrode gives the better MRR than graphite whereas the copper-tungsten gives lowest MRR value.

III. EXPERIMENTAL PROCEDURE

A. Work piece material

The work piece material used in this experiment is Aluminum 6061 with a dimension of 200mm×70mm ×13mm.

Fig. 1: Aluminum 6061 Work Piece

Table 1: Chemical composition of Aluminum 6061

Sr. No.	ELEMENTS	PERCENTAGE
1	Aluminum	97.48
2	Silicon	0.63
3	Copper	0.21
4	Manganes	0.11
5	Magnesium	1.08
6	Zink	0.01
7	Iron	0.26
8	Chromium	0.11

B. Electrode Material

In this experiment Brass-Silver alloy electrode is selected as electrode material. The electrode having the size of 22mm×11mm was prepared out of the rectangular for performing the experiments.

Fig 2: Brass-Silver alloy electrode

Table 2: Chemical composition of Brass-Silver alloy Electrode

SR. NO.	ELEMENT	PERCENTAGE
1	Copper	42.71
2	Zink	26.32
3	Silver	29.33
4	Tin	0.26
5	Lead	0.21
6	Nickel	0.42
7	Cadmium	0.15
8	Other Alloy	0.60

C. Design of Experiment

The experiment was carried out using a CNC EDM Machine (SPARKONIX MOS 25 A). Three machining parameters like peak current, pulse on time and pulse off selected with three levels as shown in table. The initially weight of work piece was taken using digital weighting machine. The work piece and tool were charged positive and negative respectively. The dielectric fluid was used for flushing purpose. The work piece on which the EDM process was carried out was Aluminum 6061 material with Brass-Silver alloy as electrodes of rectangular shape.

Table 3: Machining parameters

Sr. No.	Parameter	Level 1	Level 2	Lev el 3
1	Current (amp.)	12	18	24
2	T_{on}(µs)	7	7	7
3	T_{off}(µs)	6	6	6

IV. TAGUCHI METHOLOGY

Taguchi method is one of the most efficient tools for the analysis of machining process data. The DoE is based on Taguchi L9 orthogonal array was taken for conducting the experiments. The levels of the process parameters are given in table 4. L9 orthogonal array has 9 rows corresponding to 9 experimental runs. In the present research work three input factors had been taken for conducting the experiments, those are Peak current (Ip), Pulse on time (Ton), Pulse off time (Toff). The S/N ratios has been calculated based on the Taguchi Technique. In the present study MRR is considered as the larger is better type because of the larger MRR represents higher rate of cutting work piece, EWR is considered as the smaller is better type because of the smaller EWR represents higher efficiency of the machine and over cut also considered as the smaller the better type because of smaller the values of overcut gives lower economy and better precision. Higher the S/N ratio lead to better the performance responses.

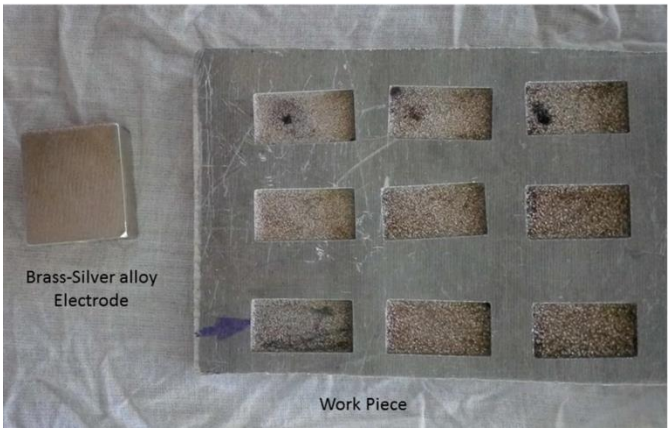

Fig 3: Work piece after Machining with Brass-Silver alloy Electrode

Below Table show the experimental result for material removal rate, electrode wear rate and overcut.

Table 4: Experimental result for MRR

Sr. No.	Current (amp.)	Ton (µs)	Toff (µs)	MRR (mm^3/min)
1	8	7	6	21.298

2	8	6	5	20.135
3	8	5	4	16.940
4	14	7	5	46.695
5	14	6	4	43.290
6	14	5	6	51.573
7	20	7	4	71.237
8	20	6	6	77.112
9	20	5	5	74.375

Table 5: Experimental result for EWR

Sr. No.	Current (amp.)	Ton (µs)	Toff (µs)	EWR (gm/min)
1	8	7	6	0.07348
2	8	6	5	0.09413
3	8	5	4	0.11594
4	14	7	5	0.18427
5	14	6	4	0.23939
6	14	5	6	0.25993
7	20	7	4	0.34600
8	20	6	6	0.34348
9	20	5	5	0.33480

Table 6: Experimental result for Overcut

Sr. No.	Current (amp.)	Ton (µs)	Toff (µs)	Over cut (mm)
1	8	7	6	0.32
2	8	6	5	0.28
3	8	5	4	0.26
4	14	7	5	0.33
5	14	6	4	0.26
6	14	5	6	0.32
7	20	7	4	0.45
8	20	6	6	0.42
9	20	5	5	0.47

V. ANALYSIS OF RESULTS

The response table and main effect plot are obtained for material removal rate, electrode wear rate and over cut where the rank of each input process parameter is signified.

A. Taguchi Analysis for Brass-Silver alloy Electrode for MRR

Table 7: Response table for Signal to Noise Ratio

Level	Current (amp.)	Pulse On Time (µs)	Pulse Off Time (µs)
1	19.46	47.63	43.82
2	47.19	46.85	47.07
3	74.24	46.41	49.99
Delta	54.78	1.22	6.17
Rank	1	3	2

Table 8: Response Table for Means

Level	Current (amp.)	Pulse On Time (µs)	ulse Off Time (µs)
1	25.74	32.09	31.45
2	33.45	32.18	32.30
3	37.41	32.34	32.85
Delta	11.67	0.25	1.40
Rank	1	3	2

The rank of the input parameter signifies the effects of the input process parameter over material removal rate. From the table, it can be seen that the peak current had larger impact over the material removal rate followed by pulse on time and pulse off time.

B. Main Effect Plot for Means and S/N Ratio for Material removal rate

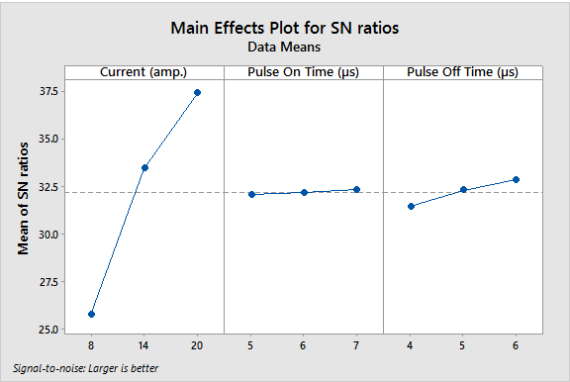

Fig 4: Main effects Plot for S/N Ratio for MRR

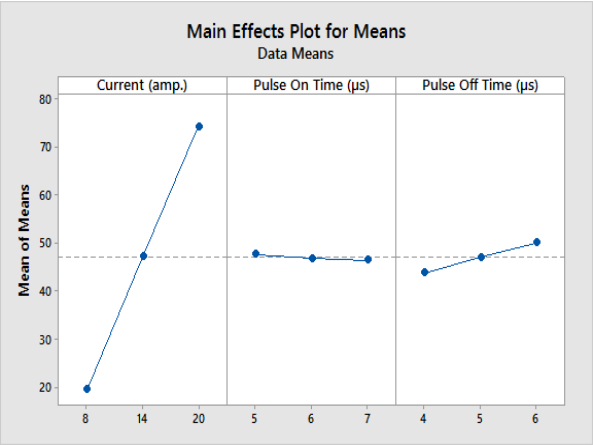

Fig 5: Main Effect Plot for means for MRR

Different plots like main effects plot for S/N ratio and main effect plot for means were obtained, which indicate the effect of input process parameter individually on the material removal rate. From the figure 4 it can be easily find out that the peak current graph shows a larger inclination and hence is the most significant, followed by pulse on time and pulse off time. Fig 5 shows that material removal rate increase with an increase in the current from 8 to 20 Amperes. MRR is high at low level of pulse on time and reduces when pulse on time is increase. Also Material removal rate increase when value of pulse off time increase from 4 to 6 µs.

C. Taguchi Analysis for Brass-Silver alloy Electrode for EWR

Table 9: Response table for Signal to Noise Ratio

Level	Current	Pulse On Time	Pulse Off Time
1	20.639	13.307	13.451
2	12.937	14.075	14.907
3	9.335	15.529	14.554
Delta	11.304	2.221	1.456
Rank	1	2	3

Table 10: Response Table for Means

Level	Current (amp.)	Pulse On Time (µs)	Pulse Off Time (µs)
1	0.09452	0.23689	0.23378
2	0.22786	0.22567	0.20440
3	0.34143	0.20125	0.22563
Delta	0.24691	0.03564	0.02938
Rank	1	2	3

The rank of the input parameter signifies the effects of the input process parameter over electrode wear rate. From the table, it can be seen that the peak current had larger impact over the electrode wear rate followed by pulse on time and pulse off time.

D. Main Effect Plot for Means and S/N Ratio for Electrode wear rate

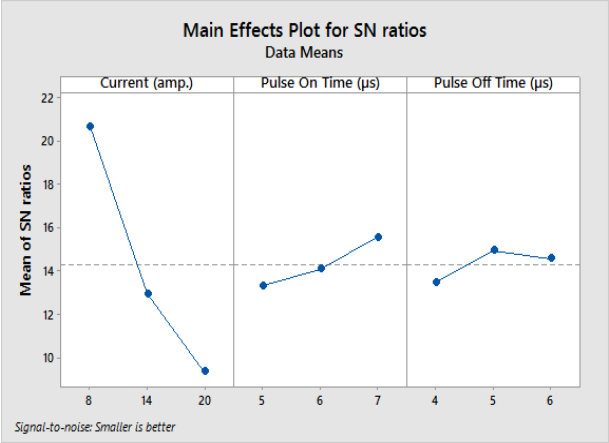

Fig 6: Main effects Plot for S/N Ratio for EWR

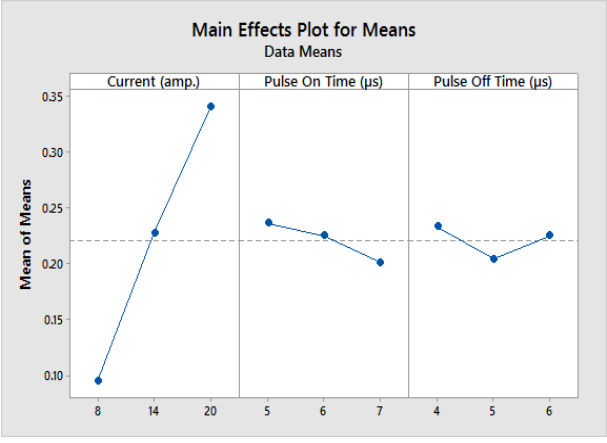

Fig 7: Main Effect Plot for means for EWR

Different plots like main effects plot for S/N ratio and main effect plot for means were obtained, which indicate the effect of input process parameter

individually on the electrode wear rate. From the figure 6 it can be easily find out that the peak current graph shows a larger inclination and hence is the most significant, followed by pulse on time and pulse off time. Fig 7 shows that electrode wear rate increase with an increase in the current from 8 to 20 Amperes. EWR is high at high level of pulse on time and reduces when pulse on time is increase. Also electrode wear rate increase when value of pulse off time decrease from 4 to 5 µs.

E. Taguchi Analysis for Brass-Silver alloy Electrode for Overcut

Table 11: Response table for Signal to Noise Ratio

Level	Current (amp.)	Pulse On Time (µs)	Pulse Off Time (µs)
1	10.885	9.385	10.112
2	10.409	10.097	9.082
3	7.010	8.821	9.110
Delta	3.875	1.277	1.031
Rank	1	2	3

Table 12: Response Table for Means

Level	Current (amp.)	Pulse On Time (µs)	Pulse Off Time (µs)
1	0.2867	0.3500	0.3233
2	0.3033	0.3200	0.3600
3	0.4467	0.3667	0.3533
Delta	0.1600	0.0467	0.0367
Rank	1	2	3

The rank of the input parameter signifies the effects of the input process parameter over overcut. From the table, it can be seen that the peak current had larger impact over the material removal rate followed by pulse on time and pulse off time.

F. Main Effect Plot for Means and S/N Ratio for Overcut

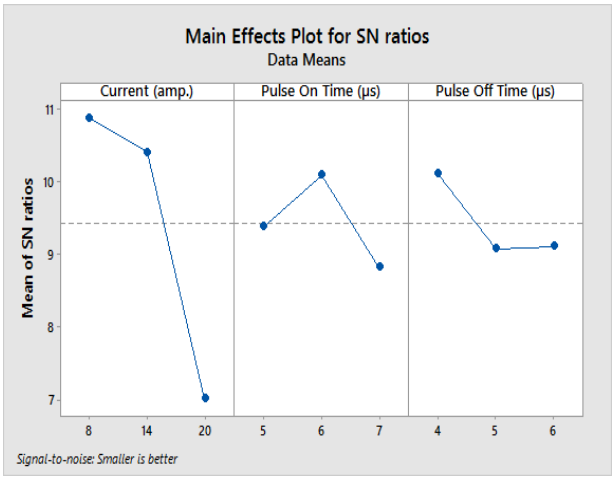

Fig 8: Main effects Plot for S/N Ratio for Overcut

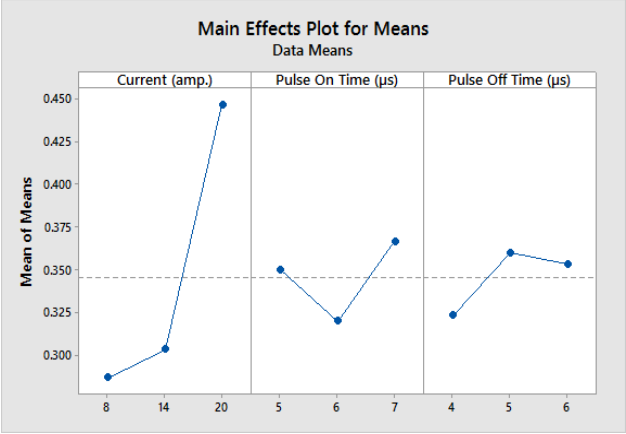

Fig 9: Main Effect Plot for means for Overcut

Different plots like main effects plot for means and main effect plot for S/N ratio were obtained, which indicate the effect of input process parameter individually on the overcut. From the figure 8 it can be easily find out that the peak current graph shows a larger inclination and hence is the most significant, followed by pulse off time and pulse on time. Figure 9 shows that over cut increase with an increase in the current from 8 to 20 A. So that current is the most significant factor for over cut compare to pulse on time and pulse off time. Here the over cut is increase with increase the pulse on time 6 to 7. Over cut is increase when pulse off time increase from 4 to 5 µs but overcut is decrease when pulse off time increase from 5 to 6 µs.

VI. CONCLUSION

The present article conclude the effect of the input parameter like current, pulse on time and pulse off time over material removal rate, electrode wear rate and overcut for Aluminum 6061 material using brass-silver alloy electrode. It was found out that the current had a larger effect over material removal rate, electrode wear rate and over cut. The effect of the other parameter like pulse on time and pulse off time was significantly less compared to current MRR, EWR and overcut is increase with increase the value of current. The optimum value of material removal rate is 77.112. The optimum value of electrode wear rate is 0.07348 (mm 3/min). The optimum value of over cut is 0.26 mm.

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