COMPARATIVE STUDY OF ALUMINUM ALLOY 6061 TOOL WITH GRAPHITE, COPPER AND BRASS TOOLS IN EDM

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ABSTRACT

The machining behavior of Aluminum Alloy 6061 using Electro Discharge Machining (EDM) is the aim to investigate with three different tool materials are Copper, Graphite and Brass. The machinability of Aluminum Alloy 6061 in EDM is to be analyzed in terms of Material Removal Rate (MRR), Tool Wear Rate (TWR) and Surface roughness (Ra) by considering the following EDM process parameters viz. Pulse On Time (Ton), Current (I), Voltage (V), Pulse Off Time (Toff). Dielectric flashing circulation pressure is kept constant through out the process. Taguchi method of L9 orthogonal array is used to determine the optimal factors of electro discharge machining process is used to investigate feasibility of design of experiment techniques.

KEYWORDS: Aluminum Alloy 6061; Electro Discharge Machining (EDM); Material Removal Rate (MRR); Surface Roughness (Ra); Taguchi Design Orthogonal Array

Received: Jun 08, 2020; **Accepted:** Jun 28, 2020; **Published:** Sep 03, 2020; **Paper Id.:** IJMPERDJUN20201039

1. INTRODUCTION

Education and knowledge are important keys for human being. The correlation between education and the prosperity of society is well established. The importance of education has been universally acknowledged and accepted, but the phenomenon of exclusion of larger sections of the population and the drop outs from the formal education systems is one constraint. Academic and professional up-gradation, the professional training that would enhance the performance in traditional occupations and the intellectual growth, is required in today's time.

Electric discharge machining is a thermo electric nontraditional machining process. Material is removed from the work piece through localized melting and vaporization of material. Electric sparks are generated between two electrodes when the electrodes are held at as small distance from each other in a dielectric medium and a high potential difference is applied across them. Localized regions of high temperatures are formed due to the sparks occurring between the two electrodes surfaces. Work piece material in this localized zone melts and vaporizes. Most of the molten and vaporized material is carried away from the inter electrode gap by the dielectric flow in the form of debris particles.

In this process a high strength aluminum alloy 6061 is used as electrode tool on EDM operations on EN8 carbon steel work material. A comparative study is done on MRR, TWR and surface roughness by taking different

electrodes viz. Graphite, Copper and Brass. Input parameters considered are Pulse on Time, Current, Voltage and Pulse Off Time. Design Of Experiment (DOE) is carried out to perform good accurate and more efficient experiments. Taguchi's robust design is an important tool for the design of experiments with a structured approach to improve the performance. Taguchi design and orthogonal array (OA) are two major tools used in this experiment.

2. MATERIALS AND METHODOLOGIES

Electrode tool material having 10 mm solid diameter and 100 mm length aluminum alloy 6061 is used as electrode tool on EDM operations on EN8 carbon steel work material. A comparative study is done on MRR, TWR and surface roughness by taking different electrodes viz. Graphite, Copper and Brass. Input parameters considered are pulse-on. Composition of Al alloy and EN8 work material are given in Table 1 and Table 2.

The Taguchi optimization method was selected to maximize the mechanical properties of work piece. The four variable parameter Pulse on Time (T_{on}), Current (I), Voltage (V) and Pulse off Time (T_{off}) and their three levels were selected, the EDM process parameter are given in the Table 3.

Table 4 shows after conducting 9 operations according to DOE initial and final weight of each work piece is measured, to find out MRR. Weights of each tool before and after operation is measured to find out TWR of electrodes and surface roughness of work pieces are measured.

After considering process parameters for each electrode and operations are performed. A total of 36 trials are done.

Table 1: Electrode Material Composition

Component	Amount (wt. %)
Aluminum	Balance
Magnesium	0.8–1.2
Silicon	0.4–0.8
Copper	0.150.4
Zinc	0.050.25
Manganese	0.050.15
Iron	0.05–0.7
Chromium	0.04–0.35

Figure 1: Al6061, Brass, Copper, Graphite.

Table 2: EN8 Specification

Carbon	0.360.44 %
Silicon	0.100.40 %
Manganese	0.601.00 %
Sulphur	0.050 Max

Phosphorus	0.050 Max
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Figure 2: Work Piece after Polishing.

Table 3: EDM Process Parameter and Three Levels

S. NO	Process Parameters	Unit	Level 1	Level 2	Level 3
1	Pulse On Time	μs	200	500	900
2	Current	amps	6	8	10
3	Voltage	Volts	30	40	45
4	Pulse Off Time	μs	100	200	500

Table 4: Design of Experiments as Per Taguchi L9 Orthogonal Array

Units	(μs)	(A)	(V)	(μs)
S.NO	Pulse On Time	Current	Voltage	Pulse Off Time
1	200	6	30	100
2	200	8	40	200
3	200	10	45	500
4	500	6	30	500
5	500	8	40	100
6	500	10	45	200
7	900	6	30	200
8	900	8	40	500
9	900	10	45	100

2.1. Mechanism of Material Removal Rate

Mechanism behind metal removal of EDM process is based on the transformation of electrical energy to thermal energy that categorized it to electro thermal process. At a given moment at least point suitable Voltage is created produces electrostatic comes up short for emission of electrons from the cathode there electrons accelerated towards the anode after getting velocity of electrons collides with the dielectric particles breaking them into negative and positive particles because of that spark is created with high temperature causes dissolving and vaporization of material from the work piece.

2.2. Formula of MRR Calculation

MRR is calculated as the proportion of the change of weight of the workpiece before and after machining to the product of machining period and density of workpiece material.

$$\text{MRR} = \frac{W_1 - W_2}{t \times \rho}$$

Whereas: W1= Weight of workpiece before machining. W2= Weight of workpiece after machining.

t =Machining period=10 min. ρ =Density of EN8 workpiece

2.3. Formula of TWR Calculation

TWR is calculated as the extent of the change of weight of the electrode tool before and after machining to the product of machining period and density of the tool material.

$$\text{TWR} = \frac{W_3 - W_4}{t \times \rho}$$

Whereas: W_3 = Weight of electrode tool before machining, W_4 =weight of electrode tool after machining.

T = Machining period=10 min. ρ =Density of electrode tool

The calculation of material removal rate has been done by using electronic sense of balance weight machine as shown below. For each weight measurement first clean the tool and workpiece with a cloth or cotton to prevent from extra weight. This weighing machine having capability to weigh up to 300 g with accuracy of 0.001 g.

Figure 3: Work Piece after Machining

3. EXPERIMENTAL RESULTS

It is observed that from Table VI the order of effect of input process parameters for graphite is Pulse on Time, Current, Voltage, and Pulse off Time. From Figure 4 MRR is maximum at Pulse on Time 200 μ s, Current 8 A, Voltage 45volts and Pulse off Time 200 μ s.

It is observed that from Table 7 the order of effect of input process parameters of graphite for surface roughness are Voltage, Pulse on Time, Pulse off Time and Current. From Figure 5 surface roughness is minimum at Pulse on Time 900 μ s, Current 6A, Voltage 30volts and Pulse off Time 100 μ s.

It is observed that from Table VIII the order of effect of input process parameters for Al6061 are Pulse on Time Current, Voltage, and Pulse off Time. From Figure 6 MRR is maximum at Pulse on Time 500 μ s, Current 8 A, Voltage 30volts and pulse-off time 100 μ s.

It is observed that from Table 9 the order of effect of input process parameters of Al6061 for surface roughness are Current, Pulse off Time, Voltage and pulse on time. From Figure 7 surface roughness is minimum at Pulse on Time 900 μ s, Current 10A, Voltage 30volts and Pulse off Time 100 μ s.

It is observed that from Table 10 the order of effect of input process parameters of copper for surface roughness

are Voltage, pulse-on, Current and Pulse off Time. From Figure 8 surface roughness is minimum at Pulse on Time 500 μ s, Current 6A, Voltage 30volts and Pulse off Time 500 μ s.

It is observed that from Table 11 the order of effect of input process parameters of copper for surface roughness are Voltage, pulse-on, Current and Pulse off Time. From Figure 9 surface roughness is minimum at Pulse on Time 200 μ s, Current 10A, Voltage 45volts and Pulse off Time 100 μ s.

It is observed that from Table 12 the order of effect of input process parameters for brass are Current, Voltage, Pulse off Time and Pulse on Time. From Figure 10 MRR is maximum at Pulse on Time 200 μ s, Current 10A, Voltage 30volts and Pulse off Time 100 μ s.

It is observed that from Table 13 the order of effect of input process parameters of brass for surface roughness are Current, Pulse on Time, Pulse off Time and Voltage. From Figure 11 surface roughness is minimum at Pulse on Time 900 μ s, Current 10A, Voltage 30volts and Pulse off Time 100 μ s.

Table 5: Response Parameters Values

S.No	Response Parameters							
	Graphite		Al 6061		Copper		Brass	
	MRR	SR	MRR	SR	MRR	SR	MRR	SR
1	0.03632	5.732	0.02777	3.95	0.01709	3.11	0.0235	2.67
2	0.0641	2.616	0.03205	3.293	0.00427	2.738	0.05555	3.608
3	0.10256	4.387	0.06196	3.819	0.01495	5.473	0.05128	4.088
4	0.01709	3.608	0.06196	2.258	0.01282	1.872	0.01495	2.53
5	0.0876	5.473	0.21581	4.071	0.01709	2.872	0.04487	5.111
6	0.07692	5.26	0.18803	4.237	0.01923	2.895	0.05555	5.026
7	0.02777	6.829	0.05341	3.562	0.0235	3.9	0.01709	2.405
8	0.06196	5.454	0.15598	4.012	0.04487	3.124	0.047	4.765
9	0.02991	5.59	0.1517	4.523	0.02564	3.6	0.07264	5.806

Table 6: Response Table of Graphite for MRR

Level	T _{ON} (μ s)	I(A)	V(V)	T _{OFF} (μ s)
1	0.06766	0.02707	0.05840	0.05128
2	0.06054	0.07123	0.03704	0.05627
3	0.03989	0.06980	0.07265	0.06054
Delta	0.02778	0.04416	0.03561	0.00926
Rank	3	1	2	4

Figure 4: Material Removal Rate.

Table 7: Response Table of Graphite For Surface Roughness

Level	T _{ON} (μ s)	I(A)	V(V)	T _{OFF} (μ s)
1	4.245	5.285	5.482	5.598

2	4.675	4.514	3.833	4.902
3	5.958	5.079	5.563	4.378
Delta	1.713	0.770	1.730	1.220
Rank	2	4	1	3

Figure 5 Surface Roughness.

Table 8: Response Table of Al6061 for MRR

Level	T _{ON} (μs)	I (A)	V (V)	T _{OFF} (μs)
1	0.04060	0.04772	0.12393	0.13177
2	0.15527	0.13462	0.08191	0.09117
3	0.12037	0.13390	0.11040	0.09330
Delta	0.11467	0.08689	0.04202	0.04060
Rank	1	2	3	4

Figure 6: Material Removal Rate.

Table 9: Response Table of Al6061 for Surface Roughness

Level	T _{ON} (μs)	I(A)	V(V)	T _{OFF} (μs)
1	3.780	3.257	4.066	4.181
2	3.522	3.884	3.450	3.790
3	4.032	4.193	3.817	3.363
Delta	0.510	0.936	0.616	0.818
Rank	4	1	3	2

Figure 7: Surface Roughness.

Table 10: Response Table of Copper for MRR

Level	T _{ON} (μs)	I (A)	V (V)	T _{OFF} (μs)
1	0.01211	0.01781	0.02707	0.01994
2	0.01638	0.02208	0.01425	0.01567
3	0.03134	0.01994	0.01852	0.02422
Delta	0.01923	0.00427	0.01282	0.00855
Rank	1	4	2	3

Figure 8: Material Removal Rate.

Table 11: Response Table of Copper for Surface Roughness

Level	T _{ON} (μs)	I(A)	V(V)	T _{OFF} (μs)
1	3.704	2.961	3.043	3.194
2	2.546	2.911	2.737	3.178
3	3.541	3.920	4.012	3.420
Delta	1.158	1.009	1.276	0.243
Rank	2	3	1	4

Figure 9: Surface Roughness.

Table 12 Response Table of brass for MRR

Level	T _{ON} (μs)	I (A)	V (V)	T _{OFF} (μs)
1	0.04345	0.01852	0.04202	0.04701
2	0.03846	0.04915	0.04772	0.04274
3	0.04558	0.05983	0.03775	0.03775
Delta	0.00712	0.04131	0.00997	0.00926
Rank	4	1	2	3

Figure 10: Material Removal Rate.**Table 13: Response Table of Copper for Surface Roughness**

Level	T _{ON} (μs)	I(A)	V(V)	T _{OFF} (μs)
1	3.455	2.535	4.154	4.529
2	4.222	4.495	3.981	3.680
3	4.325	4.973	3.868	3.794
Delta	0.870	2.438	0.286	0.849
Rank	2	1	4	3

Figure 11: Surface Roughness.**Table 14: Tool Wear Rate**

Units	(Grams)	(Grams)	(Grams)	(Gm / Mm ³)
S.No	Initial Weight	Final Weight	Difference	TWR
Graphite	22.90	22.48	0.42	0.3092
Al6061	85.26	85.07	0.19	0.1172
Copper	118.71	118.23	0.48	0.089
Brass	97.03	95.48	1.55	0.2959

4. RESULTS AND CONCLUSIONS

In this experimentation on EDM to know the effect of machining outputs taken for consideration are material removal rate and surface roughness of the EN8 work piece using the AL6061 tool with side flushing method have been investigated. Both these outputs are important in industrial applications.

The experiment depends upon various parameters settings such as peak Current (I_p), pulse on time (T_{on}), Pulse off time (T_{off}), Voltage (V) and Electrode material have been selected. Based on L9 orthogonal array by taguchi design, experiment was conducted and MINITAB software is used for the analysis of experiment.

- Compared to graphite has highest material removal rate and greater surface finish than all remaining electrodes.
- Compared to Brass, Al6061 is giving lesser tool wear rate and more material removal rate. Surface roughness is also less compared to brass.
- Compared to copper, has slightly more material removal rate and less tool wear rate than Al6061. Surface roughness is less in case of Al6061 when compared to copper. Also Al6061 is commercially cheaper than copper.

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