Surface Quality Analysis after EDM Drilling for AA7075

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ABSTRACT: *Electric Discharge Drill Machine (EDDM) is a spark erosion machining process to generate micro holes in hard to machine and conductive materials. This process is used in space and aerospace, medical and automobile industries. In present research work a brass rod 2 mm diameter was used as a tool electrode. The best parameters such as pulse on-time, Pulse off-time and water pressure were studied for best surface quality. This investigation presents the use of Taguchi approach for better SR in drilling of AA-7075. L_{27} Taguchi design method was selected for planning of experiments. The optimal levels and the significant drilling parameters on SR were obtained. The optimization results showed that the combination of minimum pulse on-time and maximum pulse off- time gives best SR.*

Keywords – *ANOVA, Electric discharge drilling Machining, SR, Taguchi Method.*

I. INTRODUCTION

Electrical Discharge Machining (EDM) Drilling is becoming the standard method for producing small, tight tolerance holes. It is an extremely cost effective method for producing fast and accurate holes for hard or soft conductive materials [1]. It is the process of machining electrically conductive materials by using precisely controlled sparks that occur between an electrode and a work-piece in the presence of a dielectric fluid. It is based on the erosion of material through the series of spatially discrete high-frequency electrical discharges (sparks) between the tool and the work-piece. **Figure 1** illustrates that each spark occurs between the closest points of the electrode and the work-piece. The spark removes material from both the electrode and work-piece, which increases the sparking gap (distance between the electrode and the work-piece) at that point. This causes the next spark to occur at the next-closest points between the electrode and work-piece. As EDM is a thermal process, material is removed by heat. Every discharge (or spark) melts a small amount of material from both of the electrodes. Part of this material is removed by the dielectric fluid and the remaining solidifies on the surface of the electrodes [2]. Micro-EDM is a machining process capable of drilling burr-free holes in a wide range of materials. In micro-hole drilling the diameter of the electrode is selected according to the size of hole to be drilled by considering the radial overcut of process. The deionised water is used to flush away the burrs formed due sparks between work-piece and electrode [3]. A lot of research carried by different researchers [5-13] for investigating the optimum combination of process parameters.

II. EXPERIMENTAL PROCEDURE

Experiments are performed on Electronica Make ED 300 Electric discharge drilling Machine. The goal is to obtain the best surface quality of machined surface. Holes were made in a 19 mm thick plate of Al 7075 using a 2 mm diameter electrode of Brass. In this experiment voltage and air pressure was kept constant i.e. 65V, 3kg/cm^2. The process parameters selected for drilling are given in Table 1. The levels of the parameters along with the units are also shown. The material used for experimentation Al 7075. The chemical composition of material is shown in Table 2.

TABLE I. Machining parameters and their level

Sr. No	Parameter	Unit	Level 1	Level 2	Level 3
1	Pulse on-time (A)	µs	3	6	9
2	Pulse off-time (B)	µs	3	5	7
3	Flushing pressure (C)	Kg/cm^2	3	5	7

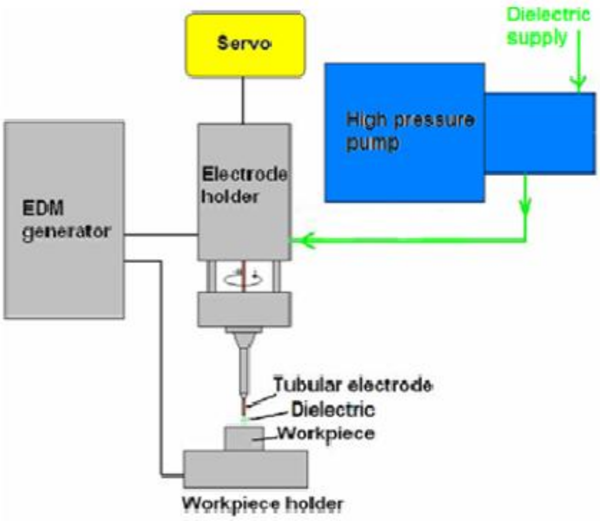

Fig. 1: Schematic diagram of EDDM [4]

Fig. 2: Machine Tool Set up

TABLE II. Chemical Composition of Al 7075

Elements	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Others	Al
% Wt	0.4	0.5	1.2-2.0	0.3	2.1-2.9	0.18-0.28	5.1-6.1	0.2	0.15	Balance

The work-piece was connected to the terminals of power supply and clamped on the machine table. Holes of 19 mm depth were drilled in all the experiments. Surface quality of the machined surface was measured using Mitutoyo make surface roughness tester (SJ201P). Three readings were taken at different location and average of three was used for analysis purpose.

III. RESULTS AND DISCUSSION

Table 3 shows the data for SR during the experimentation of EDDM for L_{27} orthogonal array.

TABLE III. Data Summary for Surface Roughness

Sr. No.	Surface roughness(microns)						SR (microns)	S/N Ratio
	T_{on}	T_{off}	W.P	R_1	R_2	R_3		
1	3	3	3	6.12	6.11	6.13	6.12	-15.735
2	3	3	5	6.12	6.08	6.04	6.08	-15.6781
3	3	3	7	6.14	6.13	6.12	6.12	-15.735
4	3	5	3	5.68	5.72	5.70	5.72	-15.1479
5	3	5	5	5.72	5.74	5.68	5.72	-15.1479
6	3	5	7	5.76	5.74	5.75	5.74	-15.1782
7	3	7	3	5.84	5.80	5.88	5.84	-15.3283

8	3	7	5	5.85	5.82	5.79	5.82	-15.2985
9	3	7	7	5.85	5.83	5.84	5.84	-15.3283
10	6	3	3	6.09	6.12	6.15	6.12	-15.735
11	6	3	5	6.08	6.06	6.10	6.08	-15.6781
12	6	3	7	6.07	6.09	6.11	6.09	-15.6923
13	6	5	3	5.90	5.96	5.93	5.93	-15.4611
14	6	5	5	5.97	6.00	5.94	5.97	-15.5195
15	6	5	7	5.90	5.91	5.92	5.91	-15.4317
16	6	7	3	5.80	5.84	5.82	5.82	-15.2985
17	6	7	5	5.83	5.81	5.85	5.83	-15.3134
18	6	7	7	5.84	5.85	5.86	5.85	-15.3431
19	9	3	3	6.20	6.23	6.26	6.23	-15.8898
20	9	3	5	6.28	6.26	6.30	6.28	-15.9592
21	9	3	7	6.23	6.25	6.27	6.25	-15.9176
22	9	5	3	6.09	6.15	6.12	6.12	-15.735
23	9	5	5	6.15	6.12	6.18	6.15	-15.7775
24	9	5	7	6.12	6.14	6.16	6.14	-15.7634
25	9	7	3	6.02	6.04	6.00	6.02	-15.5919
26	9	7	5	6.00	6.01	6.02	6.01	-15.5775
27	9	7	7	6.06	6.02	6.04	6.04	-15.6207

From Table 4, it is clear that B has maximum contribution (47.6%) in SR during machining of al-alloy on EDDM. A has 41.4%, A*B has 9.9% and remaining 1.1% is due to residual errors. Table 5 and Table 6 give the pooled analysis of variance for mean and response table.

TABLE IV. Analysis of Variance for Means

Source	**DF**	**Seq SS**	**Adj MS**	**F**	**P**	%
A	2	0.298785	0.149393	391.61	0.000	41.2%
B	2	0.343696	0.171848	450.48	0.000	47.6%
C	2	0.000207	0.000104	0.27	0.769	0.02%
A*B	4	0.071770	0.017943	47.03	0.000	9.9%
A*C	4	0.002059	0.000515	1.35	0.332	0.20%
B*C	4	0.001681	0.000420	1.10	0.418	0.23%
Residual Error	8	0.003052	0.000381			0.42%
Total	26	0.721252				

TABLE V. Pooled Analysis of Variance for Means

Source	**DF**	**Seq SS**	**Adj MS**	**F**	**P**	%
A	2	0.298785	0.149393	384.15	0.000	41.4%
B	2	0.343696	0.171848	441.90	0.000	47.6%
A*B	4	0.071770	0.017943	46.14	0.000	9.9%
Residual Error	18	0.007000	0.000389			1.1%
Total	26	0.721252				

TABLE VI. Response Table for Means

Level	A	B
1	5.889	6.152
2	5.956	5.933
3	6.138	5.897
Delta	0.249	0.256
Rank	2	1

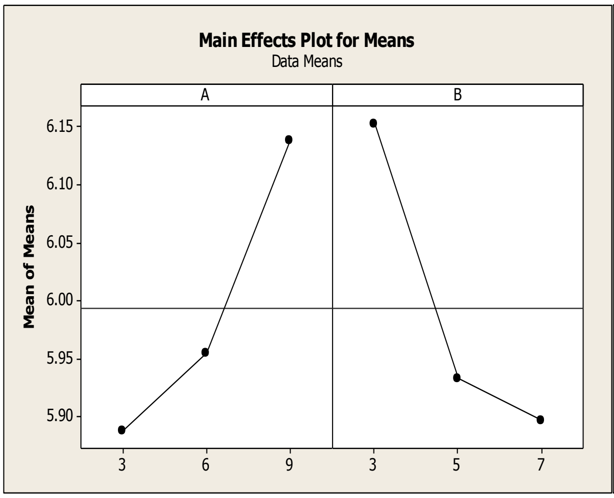

Fig. 3: Main Effects Plot for Means

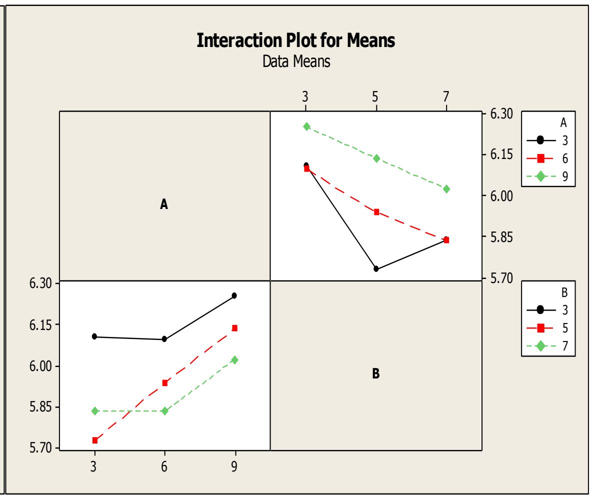

Fig. 4: Interaction Plot for Means

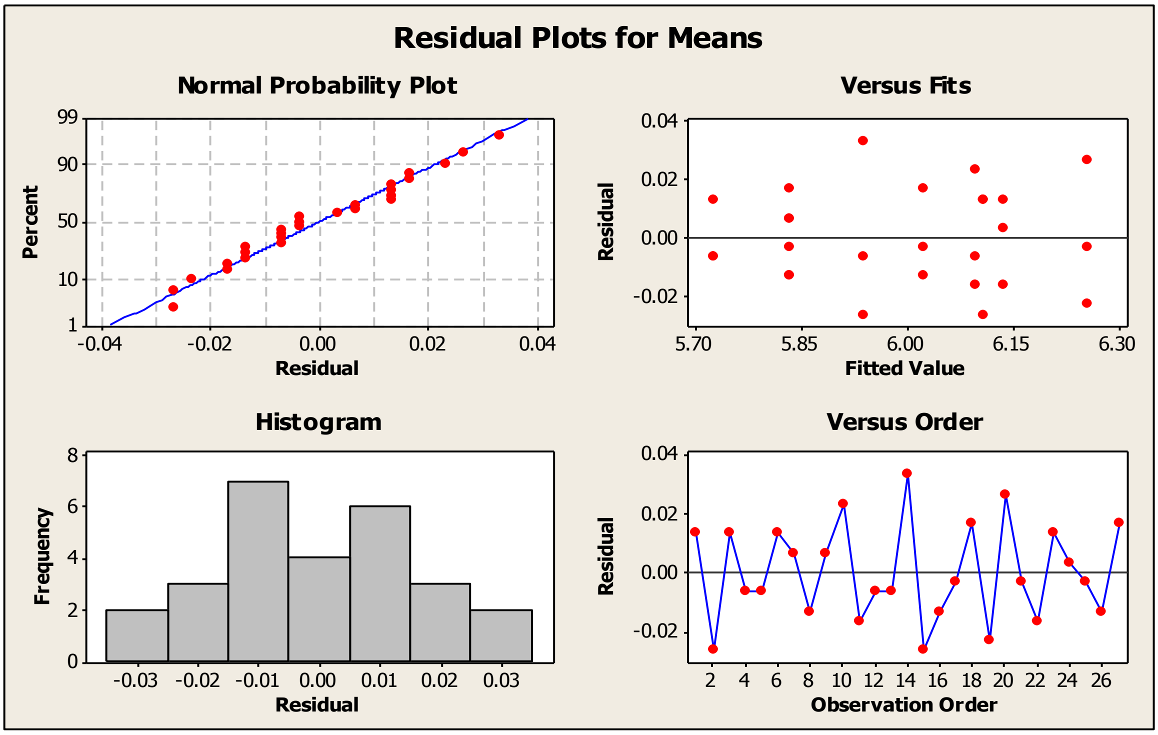

Fig. 5: Residual Plots for Means (SR)

Figure 3 show that when A (T_{on}) is increases the SR increases from 5.9 to 6.1. When A increase the spark timing increases and discharge energy increases which increases the SR. When B (T_{off}) increases from level 1(3) to level 3(7), the SR observed to be decreased due to decrease of spark energy and reduce the size of craters. Figure 4 shows the interaction plot for mean. It is evident from Table 5 and Figure 4 that interaction of pulse on-time and pulse off-time has the significant contribution on SR. Figure 5 shows the residual plots for means, these demonstrate the normal probability plot, predicted v/s residual, histogram & time study test. These tests must be verified/ok for a significant model. Figure 5 shows the normal probability plot as the residual falls on a straight line during normal probability test. So it verifies the normality of the test. Predicted v/s residual test shows that the residuals and predicted values are scattered randomly, there is no clustering so that the test is verified. Histogram- From histogram it is found that the solution found parabolic. It is the best solution found by quadratic equation. Time study- as there is no order form during time order study of observation order so this test is also verified. From these four tests it is investigated that the model is significant.

Mean Surface roughness is calculated as

$\mu_{sr} = \overline{A_1} + \overline{B_3}$ - (T)

Where, T = overall mean of surface roughness = (∑R1+∑R2+∑R3)/81= 5.919859μm

Where R1, R2, and R3 values are taken from the Table 5.10 and the values of $\overline{A_1}$ and $\overline{B_3}$ are estimated from the experimental data reported in the table 5.18.

$\overline{A_1}$ = average value of material removal at the third level of pulse width =5.889 μm

$\overline{B_3}$ = average value of of material removal at the first level of time between two pulses =5.897

Substituting the values of various terms in the above equation (5.5).

μ_{sr} = 5.889 +5.897-5.919859 = 5.867

The 95 % confidence intervals of confirmation experiments (CI_{CE}) and population (CI_{POP}) are calculated as from equation 5.2 and 5.3

Where, Fα (1, Fe) = The F ratio at the confidence level of (1-α) against DOF 1 and error degree of freedom fe.

η_{eff}= 81 / (1+18) =4.26 (As from equation 5.4)

N = Total number of results = 27 x 3 =81,

R = Sample size for confirmation experiments = 3

Ve = Error variance = **0.000389**

Fe = error DOF = 18

$F_{0.05}$ (1, 8) 4.41 [Tabulated F value]

So, CI_{CE} = ±0.0312, and CI_{POP} = ±0.0200

Therefore, the predicted confidence interval for confirmation experiments is:

Mean μ_{sr} - CI_{CE} < μ_{sr} < Mean μ_{sr} + CI_{CE} i.e. 5.8358 < μ_{sr} <5.8982

The 95% confidence interval of the population is:

Mean μ_{sr} – CI_{POP} < μ_{sr} < Mean μ_{sr} + CI_{POP} i.e. 5.847 < μ_{sr} < 5.887

The optimal values of process variables at their selected levels are as follows:

$\overline{A_1}$: 3 machine units

$\overline{B_3}$: 7 machine units

IV. CONCLUSION

The following conclusions have been drawn from the present research:

- AA7075 has been successfully processed using EDDM.
- Pulse off time has the maximum contribution while evaluating surface quality of AA7075.
- Pulse on-time and off time has the significant effect on the processing of aluminum alloy while flushing pressure has the non-significant contribution.
- The minimum value of surface roughness is 5.85 at lower value of pulse on-time and higher value of pulse-off time.

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