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Optimization of EDM Parameters Using Taguchi Method For HDS11

M. Murugan
P.G Scholar M.E. (Manufacturing Engineering), Department of Mechanical Engineering, University college of Engineering, BIT Campus, Anna university, Trichy, Tamil Nadu, India.

T. Senthil Kumar
Professor, Department of Mechanical Engineering, University college of Engineering, BIT Campus, Anna University, Trichy, Tamil Nadu, India.

B.Kumaragurubaran
Assistant Professor, Department of Mechanical Engineering, University college of Engineering, BIT Campus, Anna university, Trichy, Tamil Nadu, India.

Abstract – Metal removal mechanism in Electrical Discharge Machining (EDM) is mainly a thermal phenomenon where thermal energy is produced in plasma channel, and is dissipated though work piece, tool and dielectric. The process is mostly used in situations where machining of very hard materials, intricate parts, complex shapes. The aim of this work is to pursue the influence of three design factors current (I), pulse (V), pulse on(Ton), and pulse off (Toff) which are the most connected parameters to be controlled by the EDM process over machining specifications such as material removal rate (MRR) and characteristics of surface integrity such as average surface roughness (Ra) and the hardness (HR) and also to quantify them. The experiments were carried out as per L9 orthogonal array. Each experiment were performed under different conditions such as Ampere rating, pulse on time and pulse off time. The optimal factor for Surface Roughness, Machining timing, Material Removal rate were obtained when Pulse on time is 2µs, Pulse Off time 6 µs and Amps-8. Particularly output response was mainly depending on the pulse on time for the output Response. Contribution was Surface Roughness-38%, Machining Timing was 52%, Material Removal Rate was 84%. Through the SEM analysis found the areas from where material is removed come up as craters. The depth of crater for small discharge current was less while for a large discharge current it was found to be more.

Index Terms – EDM, surface roughness (Ra); hardness (HR); material removal rate (MRR); current (I); voltage (V); pulse on(Ton).

1. INTRODUCTION

In recent years, the technology of electrical discharge machining (EDM) has been enhanced considerably to meet the requirements in various manufacturing fields, especially in the die manufacturing industry. Electrical discharge machining is widely used non-traditional machining method for removing material from the workpiece without applying any physical cutting force by the tool. EDM is a thermo-electrical process in which material is eroded from the work-piece by a series of successive electrical sparks between the work-piece and the electrode (tool) separated by a thin film of dielectric fluid (deionized water) that is continuously fed to the machining zone to flush away the eroded particles. Flushing is the most vital function in any electrical discharge machining operation. Flushing is the process of introducing clean filtered dielectric fluid into the spark gap. Incorrect flushing can result in inconsistent cutting and poor machining. Side flushing is one of the most common and preferred method for flushing in where the dielectric fluid is forced through the sides into the working gap. A comprehensive study of various parameters (current, pulse on time, pulse off time) on the surface roughness has been carried out. Taguchi Method using L9 orthogonal array has been used in carrying out experimentations for solving the optimization process.

2. EXPERIMENTAL DATA

Table 1: An Orthogonal Array L_9 Formation

Trial No.	Designation	T ON	T/OFF	AMPS
1	$A_1B_1C_1$	2	4	6
2	$A_1B_2C_2$	2	5	8
3	$A_1B_3C_3$	2	6	10
4	$A_2B_1C_2$	3	4	8
5	$A_2B_2C_3$	3	5	10
6	$A_2B_3C_1$	3	6	6
7	$A_3B_1C_3$	4	4	10
8	$A_3B_2C_1$	4	5	6
9	$A_3B_3C_2$	4	6	8

Design of experiment is an effective tool to design and conduct the experiments with minimum resources. Orthogonal Array is a statistical method of defining parameters that converts test areas into factors and levels. Test design using orthogonal array creates an efficient and concise test suite with fewer test cases without compromising test coverage. In this work, L9 Orthogonal Array design matrix is used to set the control parameters to evaluate the process performance. The Table 1 shows the design matrix used in this work.

Table 2: Experimental Data

Trial No.	Designation	Pulse on time µs	Pulse off time µs	Current Amps	RA Micron	MT min	MRR gm/min
1	$A_1B_1C_1$	2	4	6	2.003	25	0.444
2	$A_1B_2C_2$	2	5	8	3.568	21	0.476
3	$A_1B_3C_3$	2	6	10	2.189	16	0.625
4	$A_2B_1C_2$	3	4	8	2.303	15	0.600
5	$A_2B_2C_3$	3	5	10	2.345	13	0.769
6	$A_2B_3C_1$	3	6	6	2.342	19	0.789
7	$A_3B_1C_3$	4	4	10	2.494	11	1.454
8	$A_3B_2C_1$	4	5	6	3.533	16	1.000
9	$A_3B_3C_2$	4	6	8	5.719	14	1.142

2.1. Surface Roughnesses (Analysis of Result)

Table 3: Surface Roughness and S/N Ratios Values for the experiments

Trial No.	Designation	T ON µs	T OFF µs	Current Amps	RA Micron	S/N Response valve (db) for Ra
1	$A_1B_1C_1$	2	4	6	2.003	-6.0336
2	$A_1B_2C_2$	2	5	8	3.568	-11.0485
3	$A_1B_3C_3$	2	6	10	2.189	-6.8049
4	$A_2B_1C_2$	3	4	8	2.303	-7.2459
5	$A_2B_2C_3$	3	5	10	2.345	-7.4029
6	$A_2B_3C_1$	3	6	6	2.342	-7.3917
7	$A_3B_1C_3$	4	4	10	2.494	-7.9379
8	$A_3B_2C_1$	4	5	6	3.533	-10.9629
9	$A_3B_3C_2$	4	6	8	5.719	-15.1464

2.2. Roughness Response for Each Level of the Process Parameter

Table 4: Response Table for Signal to Noise Ratios (Smaller is better)

Level	T ON	T OFF	AMPS
1	-7.962	-7.072	-8.129
2	-7.347	-9.805	-11.148
3	-11.349	-9.781	-7382
Delta	4.002	2.732	3.765
Rank	1	3	2

Table 5: Response Table for Means

Level	T ON	T OFF	AMPS
1	2.587	2.267	2.626
2	2.330	3.149	3.863
3	3.915	3.417	2.343
Delta	1.585	1.150	1.521
Rank	1	3	2

2.3. Analysis Of Variance (ANOVA)

Table 6: Analysis of Variance (ANOVA) results for the Roughness

Source	DF	SEQ SS	ADJ SS	ADJ SS	F	P	% of contribution
T ON	2	4.3445	4.3445	2.1723	5.52	0.153	38
T OFF	2	2.1722	2.1722	1.0861	2.76	0.266	19
AMPS	2	3.9237	3.9237	1.9618	4.99	0.167	35
ERROR	2	0.7866	0.7866	0.3933			
TOTAL	8	11.2270					

S = 1.52753 R-Sq = 96.89% R-Sq(adj) = 87.56%

2.4. MRR (Analysis of Result)

Table 7: MRR and S/N Ratios Values for the experiments

Trial No.	Designation	T ON µs	T OFF µs	Current Amps	MRR gm/min	S/N Response valve (db) for mc
1	$A_1B_1C_1$	2	4	6	0.444	-7.05234
2	$A_1B_2C_2$	2	5	8	0.476	-6.44786
3	$A_1B_3C_3$	2	6	10	0.625	-4.08240
4	$A_2B_1C_2$	3	4	8	0.600	-4.43697
5	$A_2B_2C_3$	3	5	10	0.769	-2.28147
6	$A_2B_3C_1$	3	6	6	0.789	-2.05846
7	$A_3B_1C_3$	4	4	10	1.454	3.25129
8	$A_3B_2C_1$	4	5	6	1.000	0.00000
9	$A_3B_3C_2$	4	6	8	1.142	1.15332

2.5. MRR for Each Level of the process parameter

Table 8: Response Table for Signal to Noise Ratios (Larger is better)

Level	T ON	T/OFF	AMPS
1	-5.861	-2.746	-3.037
2	-2.926	-2.910	-3.247
3	1.468	-1.663	-1.038
Delta	7.329	1.2473	2.206
Rank	1	3	2

Table 9: Response Table for Means

Level	T ON	T/OFF	AMPS
1	0.5150	0.8327	0.7443
2	0.7193	0.7483	0.7393
3	1.1987	0.8520	0.9493
Delta	0.6837	0.1037	0.2100
Rank	1	3	2

2.6. Analysis Of Variance (ANOVA)

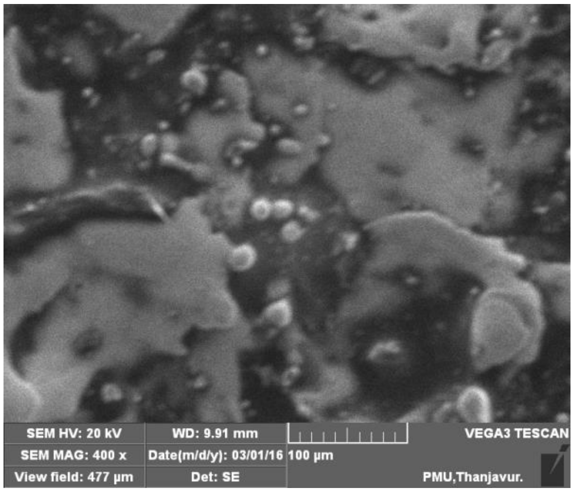
Table 10: Analysis of Variance (ANOVA) results for the MRR

Source	DF	Seq SS	Adj SS	Adj MS	F	P	% of Contribution
T ON	2	0.73891	0.73891	0.36946	16.90	0.056	84
T/OFF	2	0.01823	0.01823	0.00912	0.42	0.706	2
AMPS	2	0.08615	0.08615	0.04307	1.97	0.337	10
Error	2	0.04371	0.04371	0.02186			4
Total	8	0.88701					100

S = 0.147842 R-Sq = 95.07% R-Sq(adj) = 80.29%

3. IMAGES OF SEM ANALYSIS

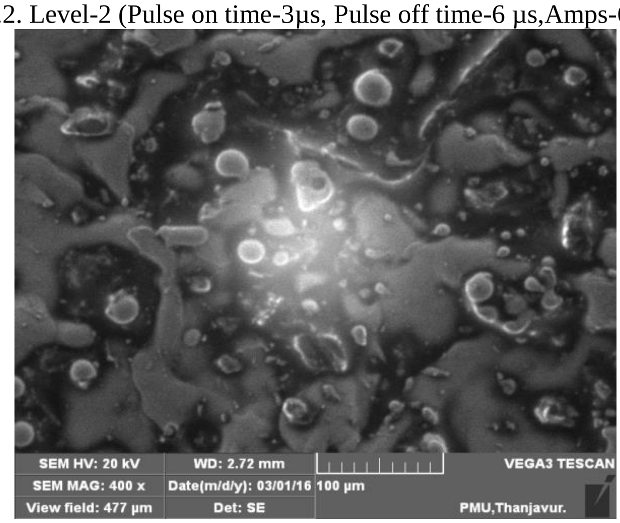
3.1. Level-1 (Pulse on time-2µs, Pulse off time-6 µs,Amps-10)



Observation

The loss of material is because of melting followed by its evaporation that can be observed from the features existing at the interface of the crack. The presence of grain boundary (top left side corner) indicates that the initiation of crack has not occurred from the grain boundary; instead it has started from the area where the resolidified layer exists. The compositional analysis was done from the dark phase (deep crater), the grey phase.

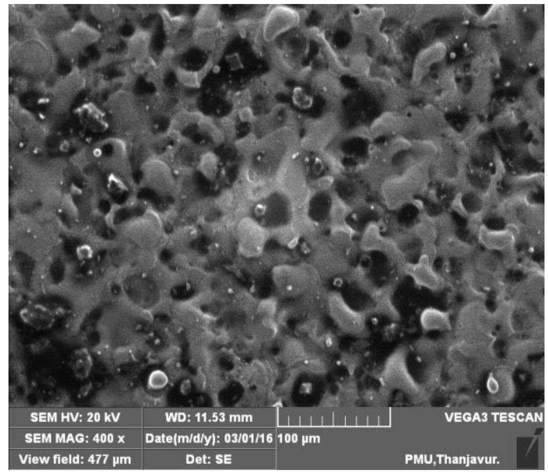
3.2. Level-2 (Pulse on time-3µs, Pulse off time-6 µs,Amps-6)



Observation

The dark area represents the existence of deep craters, the grey area represents the hallow craters with heat affected zone and the white phase represents a resolidified layer.

3.3. Level-3 (Pulse on time-4µs,Pulse off time-6 µs,Amps-8)



Observation

The network of the grey layer observed corresponds to the resolidified layer. The presence of cracks all along these networks indicates that the mechanism of crack formation is due to mechanical stresses which are evident more clearly in higher magnification micrograph. The presence of projected smooth, molten layer all along the crater, in which small size volcanic eruptions are, indicates that material beneath this white layer was still in the liquid state.

4. CONCLUSION AND RESULT

In this study, the Taugchi technique and ANOVA were used to obtain optimal machining parameters in the electrical discharge machining conditions. The experimental results were evaluated using Taguchi technique. The following conclusion can be drawn.

4.1. Optimal Control Factor

1. Surface Roughness-A1(Pulse on time -2µs)B3(Pulse on time -6 µs)C2(Amps-8)

2. Machining Timing-A1(Pulse on time -2µs)B3(Pulse on time -6 µs)C2(Amps-8)

3. Material Removal Rate- A1(Pulse on time -2µs)B3(Pulse on time -6 µs)C2(Amps-8)

4.1.2. Percentage contribution of Process parameter

1. Surface Roughness- Pulse on time 38%

2. Machining Timing -Pulse on time 52%

3. Material Removal – Pulse on time 84%

4.1.3. SEM Analysis Conclusion

The areas from where material is removed come up as craters. The depth of crater for small discharge current was less while for a large discharge current it was found to be more.

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