ISSN 2229-5518

Investigation of Machining Parameters for EDM Using Different Types of Electrodes by Taguchi Method

Bhavya K (E-mail: bhavya.3k2u@gmail.com), M. Indira Rani, Prof., JNTUHCEH (E-mail: marpuindira@gmail.com)

Abstract— The most important aspects to take into consideration in the majority of manufacturing processes is the correct selection of manufacturing condition. Electro Discharge Machining (EDM) is a capable of machining geometrically complex or hard material components, that are precise and difficult-to-machine such as heat treated tool steels, composites, super alloys, ceramics, carbides, heat resistant steels etc. Stainless steel is usually supplied in a hardened condition. These steels are categorized as difficult to machine materials; possess greater strength and toughness are usually known to create major challenges during conventional and non- conventional machining. The objective of the present paper is to study the effect of machining parameters such as discharge current, pulse on time on various machining responses like Metal Removal Rate (MRR), Tool Wear Rate (TWR) and Surface Roughness (SR) on Steel by using two different types of L-shapes electrodes i.e. beryllium copper and brass tools. The observed values in the experiments were determined by identifying the factor that is most affected by the Responses of Material Removal Rate (MRR), Tool Wear Rate (TWR) and Surface Roughness (SR).

Index Terms—EDM, Material Removal Rate, Tool Wear Rate, Surface Roughness.

.

1 INTRODUCTION

Non-conventional energy sources like sound, light, mechanical, chemical, electrical, electrons and ions are used in the new concept of manufacturing. The study of machining of such materials is due to development of harder and difficult to machine materials finding wide application in aerospace, nuclear engineering and other industries.Non-traditional machining has grown out of the need to machine these exotic materials. The machining processes are non-traditional in the sense that they do not employ traditional tools for metal removal and instead they directly use other forms of energy. The problems of high complexity in shape, size and higher demand for product accuracy and surface finish can be solved through non-traditional methods. Currently, non-traditional processes possess virtually unlimited capabilities except for volumetric material removal rates, for which great advances have been made in the past few years to increase the material removal rates. As removal rate increases, the cost effectiveness of operations also increase, stimulating ever greater operations and is now a well-established use of non-traditional process. The Electrical Discharge Machining process is employed widely for making tools, dies and other precision parts. The drilling, milling, grinding and other traditional machining option in many manufacturing industries throughout the world is replaced by EDM. It iscapable of machining geometrically complex or hard material components, that are precise and difficult-to-machine such as heat treated tool steels, composites, super alloys, ceramics, carbides, heat resistant steels etc. being widely used in die and mold making industries, aerospace, aeronautics and nuclear industries. Electric Discharge Machining has also made its presence felt in the new fields such as sports, medical and surgical instruments, optical, including automotive R&D areas.

2 PRINCIPLE OF EDM

In EDM process the metal is removed from the work piece due to erosion caused by rapidly recurring spark discharge taking place between the tool and work piece. Fig.1.1 shows the mechanical set up of EDM. A thin gap about 0.2mm is maintained between the tool and work piece by a servo system. 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.

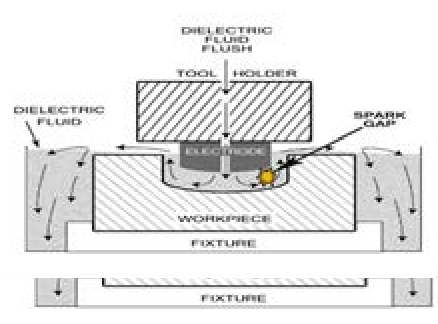


Fig.1.1 Electro Discharge Machining Set up.

2.1 Mechanism of MRR

The mechanism of material removal of EDM process is most widely established principle is the conversion of electrical energy it into thermal energy. During the process ofmachining the sparks are produced between work piece and tool. Thus each spark produces a tiny crater, and crater formation in the material along the cutting path by melting and vaporization, thus eroding the work piece to the shape of the

ISSN 2229-5518

tool. Material Removal Mechanism (MRM) is the process of transformation of material elements between the work-piece and electrode. The transformation are transported in solid, liquid or gaseous state, and then alloyed with the contacting surface by undergoing a solid, liquid or gaseous phase reaction.

3 Experimental Details and Results

The present paper discusses the experimental results after selecting the work piece and tool electrode material. SS 321 is the work piece selected and Brass and Copper L type electrodes are used.

Table 1: Work piece: SS-321, Electrode: Brass, Gap: 0.2mm, Depth: 1mm

Amps	T_{on} Ms	T_{off} µs	Initial wt. Kg	Final wt. Kg	Diff gm	M/c. time Min	MRR mg/min	SR µm
4	100	98.71	4.229	4.228	1	78	1.60	2.26
4	105	103.61	4.231	4.229	2	76	3.28	2.43
6	100	98.80	4.235	4.231	4	84	5.95	2.75
6	105	103.68	4.240	4.235	5	80	7.81	2.96

3.1 Confirmation test for Material Removal Rate

Table 2: Process Parameters of MRR

Parameters	Low	High
Current A	4	6
T_{on} B	100	105
T_{Off} C	98.72	103.68

Table 3: Experimental Calculation of MRR

Expt	A	B	C	MRR	S/N	
1	4	100	98.71	1.60	10.103	$A_2B_2C_1$
2	4	105	103.68	3.28	16.338	
3	6	100	103.68	5.95	21.510	
4	6	105	98.71	7.81	23.875	

Table 4: Theoretical Calculation of MRR

	Level 1	Level 2	
A	2.44	6.88	$A_2B_2C_1$
B	3.775	5.545	
C	4.705	4.615	

Estimated value of the material removal rate at optimum condition is using the following equation.

$y_{opt}= m + (m_{Aopt}-m) + (m_{Bopt}-m) + (m_{Copt}-m)$
$=4.66 + (6.88-4.66) + (5.545-4.66) + (4.705-4.66)$
$= 4.66 +2.22\ 0.885+ 0.045 = 7.810$

Table 10: Work piece: SS-321, Electrode: Brass, Gap: 0.2mm, Depth: 1mm

Amps	T_{on} µs	T_{off} µs	Initial wt.gm	Final wt. gm	Diff gm	M/c. time Min	TWR mg/min
4	100	98.71	21.50	21.40	0.10	78	1.28
4	105	103.61	22.20	21.90	0.30	76	3.90
6	100	98.80	21.80	21.30	0.50	84	5.95
6	105	103.68	21.70	21.10	0.60	80	7.50

3.2 Confirmation test for Tool Wear Rate

Table 11: Process Parameters of TWR

Parameters	Low	High
Current A	4	6
T_{on} B	100	105
T_{off} C	98.71	103.68

Table 12: Experimental Calculation of TWR

Expt.	A	B	C	MRR	S/N	
1	4	100	998.71	1.28	3.876	$A_1B_1C_1$
2	4	105	103.68	3.90	-5.800	
3	6	100	103.68	5.95	-9.469	
4	6	105	98.71	7.50	-11.480	

Table 13: Theoretical Calculation of TWR

	Level 1	Level 2	
A	2.590	6.725	$A_1B_1C_1$
B	3.615	5.700	
C	4.390	4.925	

Once the optimal combination of process parameters and their levels was obtained, the final step is to verify the estimated result against experimental value. Estimated value of the tool ware rate is

$y_{opt}= m + (m_{Aopt}-m) + (m_{Bopt}-m) + (m_{Copt}-m)$
$=4.658 + (2.59-4.658) + (3.615-4.658) + (4.39-4.658)$
$= 4.658 – 2.068 – 1.043 - 0.268 = 1.28$

3.3 Results of confirmation test for Tool Wear Rate

Table 14: Confirmation test for TWR

	Estimation	Experiment	Difference (%)
TWR	1.28	1.28	0.0
S/N	3.876		

It can be seen that there is no difference between experimental result and the estimated result.

ISSN 2229-5518

Table 15: Work piece: SS-321, Electrode: Copper, Gap: 0.2mm Depth: 1mm

Amps	T_{on}	T_{off}	Initial Wt. gm	Final Wt. gm	Diff gm	M/c Time Min	MRR mg/min	SR µm
4	100	99.06	4.241	4.240	1	106	1.17	3.47
4	105	104.0	4.242	4.241	1	105	1.19	3.86
6	100	98.97	4.243	4.242	1	98	1.27	4.54
6	105	103.92	4.244	4.243	1	97	1.28	4.68

3.4 Confirmation test for Material Removal Rate

Table 16: Process Parameters of MRR

Parameters	Low	High
Current A	4	6
T_{on} B	100	105
T_{Off} C	99.06	103.92

Table 17: Experimental Calculation of MRR

Expt	A	B	C	SR	S/N	
1	4	100	99.06	1.17	7.384	$A_2B_2C_1$
2	4	105	103.92	1.19	7.531	
3	6	100	103.92	1.27	8.096	
4	6	105	99.06	1.28	8.165	

Table 18: Theoretical Calculation of MRR

	Level 1	Level 2	
A	1.18	1.275	A_2B_2 C_2
B	1.22	1.235	
C	1.225	1.230	

Estimated value of the material removal rate at optimum condition is

$$y_{opt} = m + (m_{Aopt}-m) + (m_{Bopt}-m) + (m_{Copt}-m)$$
$$=1.228 + (1.275-1.228) + (1.235-1.228) + (1.230-1.228)$$
$$= 1.228 +0.0475+0.0075+0.0025 = 1.285$$

Table 19: Confirmation test for MRR

	Estimation	Experiment	Difference (%)
MRR	1.285	1.28	0.5
S/N	8.165		

It can be seen that the difference between experimental result and the estimated result is only 0.005 mg/min.

3.5 Confirmation Test for surface Roughness

Table 20: Process parameters of SR

Parameters	Low	High
Current A	4	6
T_{on} B	100	105
T_{off} C	99.06	103.92

Table 21: Experimental Calculation of SR

Expt.	A	B	C	SR	S/N	
1	4	100	99.06	3.47	-4.785	$A_1B_1C_1$
2	4	105	103.92	3.86	-5.711	
3	6	100	103.92	4.54	-7.120	
4	6	105	98.06	4.68	-7.384	

Table 22: Theoretical Calculation of SR

	Level 1	Level 2	
A	3.665	4.61	$A_1B_1C_1$
B	4.005	4.27	
C	4.075	4.20	

Estimated value of the surface roughness at optimum condition is calculated by adding the average performance to the contribution of each parameter at the optimum level using the following equation.

$$y_{opt} = m + (m_{Aopt}-m) + (m_{Bopt}-m) + (m_{Copt}-m)$$
$$= 4.138+ (3.665-4.138) + (4.005-4.138) + (4.075-4.138)$$
$$= 4.138 – 0.473 - 0.133 - 0.063 = 3.469$$

3.6 Results of confirmation test for Surface Roughness

Table 23: Confirmation test for SR

	Estimation	Experiment	Difference (%)
SR	3.469	3.47	-0.1
S/N	-4.785		

It can be seen that the difference between experimental result and the estimated result is only -0.001µm.

Table 24: Work piece SS-321, Electrode: Copper Gap: 0.2mm Depth: 1mm

Amps	T_{on}	T_{off}	Initial Wt.gm	Final Wt. gm	Diff gm	M/c. Time Min	TWR mg/min
4	100	99.06	23.112	23.101	0.01	106	0.094
4	105	104.0	23.135	23.112	0.023	105	0.219
6	100	98.97	24.126	24.078	0.048	98	0.489
6	105	103.92	23.156	23.220	0.064	97	0.659

The confirmation experiment is the final step in the first iteration of the design of the experiment process.

ISSN 2229-5518

3.7 Confirmation Test for Tool Wear Rate

Table 25: Process Parameters of TWR

Parameters	Low	High
Current A	4	6
T_{on} B	100	105
T_{off} C	99.06	103.92

Table 26: Experimental Calculation of TWR

Expt	A	B	C	TWR	S/N	
1	4	100	99.06	0.094	26.558	
2	4	105	103.92	0.219	19.211	$A_1B_1C_1$
3	6	100	103.92	0.489	12.234	
4	6	105	99.06	0.659	9.642	

Table 27: Theoretical Calculation of TWR

	Level – 1	Level – 2	
A	0.15	0.574	
B	0.292	0.439	$A_1B_1C_2$
C	0.377	0.354	

Estimated value of the tool ware rate at optimum condition is 0.0581 which is obtained by using the following equation.

$y_{opt} = m + (m_{Aopt}-m) + (m_{Bopt}-m) + (m_{Copt}-m)$

$= 0.3652 + (0.157-0.3652) + (0.292-0.3652) + (0.354-0.3652) = 0.3652 – 0.209 - 0.0737 - 0.0112 = 0.0581$

3.8 Results of Confirmation test for Tool Wear Rate

Table 28: Confirmation test for TWR

	Estimation	Experiment	Difference %
TWR	0.0581	0.094	-3.59
S/N	26.558		

Results of confirmation test for Material Removal Rate

Table 5: Confirmation test for MRR

	Estimation	Experiment	Difference (%)
MRR	7.810	7.810	0.0
S/N	23.873		

The difference between experimental result and the estimated result is nil as mentioned in Table 5 which indicates that they are very close.

3.9 Confirmation test for Surface Roughness

Table 6: Process Parameters of Surface Roughness

Parameters	Low	High
Current A	4	6
T_{on} B	100	105
T_{off} C	98.71	103.68

Table 7: Experimental Calculation of SR

Expt.	A	B	C	SR	S/N	
1	4	100	98.71	2.26	-1.061	
2	4	105	103.68	2.43	-1.691	A_1 B_1
3	6	100	103.68	2.75	-2.766	C_1
4	6	105	98.71	2.96	-3.405	

Table 8: Theoretical Calculation of SR

	Level - 1	Level - 2	
A	2.345	2.855	A_1 B_1 C_2
B	2.505	2.695	
C	2.610	2.585	

Estimated value of the surface roughness at optimum condition is obtained using the following equation.

$y_{opt} = m + (m_{Aopt}-m) + (m_{Bopt}-m) + (m_{Copt}-m)$

$= 2.60 + (2.345-2.60) + (2.505-2.60) + (2.585-2.60)$

$= 2.60 – 0.255 – 0.095 - 0.015 = 2.235$

3.10 Results of confirmation test for Surface Roughness

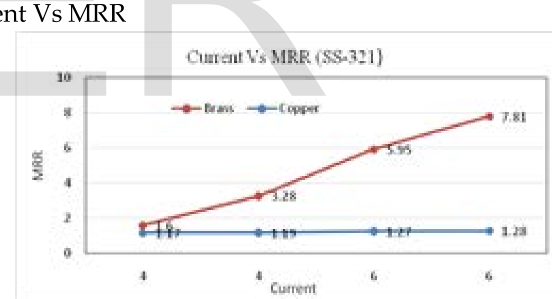
Table 9: Confirmation test for SR

	Estimation	Experiment	Difference (%)
SR	2.235	2.26	2.5
S/N	-1.061		

It can be seen that the difference between experimental result and the estimated result is strongly correlated with the estimated result, as the error is only 2.5%.

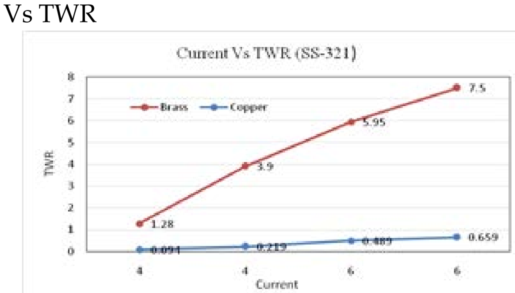
4 Results & Discussions

Current Vs MRR



MRR increases with increase of discharge current. Higher is the discharge current, more energy enters into the specimen and hence the MRR increases.

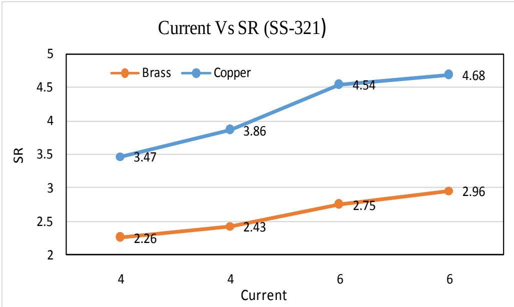
Current Vs TWR



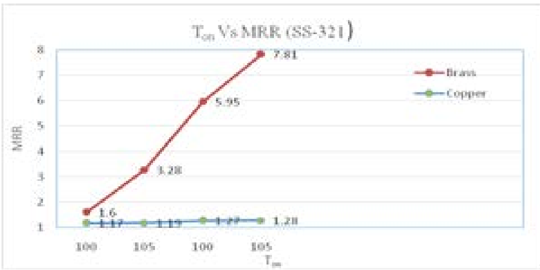
TWR increases with increase of discharge current.

Current Vs SR

ISSN 2229-5518

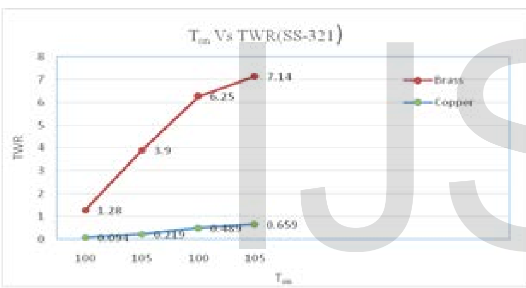


T_{on} Vs MRR



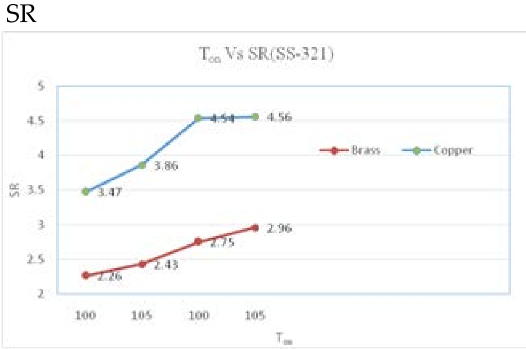
MRR increases with T_{on} as the energy supplied for long period of time.

T_{on} Vs TWR



TWR is directly proportional to the T_{on} i.e. TWR increases with T_{on}.

T_{on} Vs SR



5 Conclusions

In the present study the effect of various Electro Discharge Machining parameter such as discharge current (I_P), pulse on time (T_{on}) and pulse off time (T_{off}) on various machining responses like Metal Removal Rate (MRR) and Surface Roughness (SR) of SS 321 work piece material by using two different types of L-shaped electrodes i.e. beryllium copper and brass tool have been investigated. The experiments were conducted under various parameters setting of discharge current (I_P), pulse on time (T_{on}) and pulse off time (T_{off}) using L-4 Orthogonal Array based on Taguchi design was performed and following conclusions are made.

1. Brass electrode is not preferable to mass production as tool wear rate is high when compared to Beryllium Copper electrode.
2. The T_{off}has insignificant effect on MRR. The MRR increases with increase of discharge current. Higher is the discharge current, more energy enters into the specimen and hence the MRR increases. MRR increases with T_{on} as the energy supplied for long period of time.
3. The most important factor is discharge current then pulse on time and after that pulse off time in the case of Tool Wear Rate (TWR).
4. Optimum machining parameters for machining response SR by using Brass/ Beryllium Copper are $A_1B_1C_1$ i.e. 4 Amps ,T_{on}100 µs, T_{off}98.71 µs/99.06 µs. For MRR $A_2B_2C_1$ i.e.6 Amps, T_{on} 105 µs, T_{off}98.71 µs/99.06 µs.

References

[1] Yan-Cherng Lin, Yuan-fengchen, Ching-tien Lin, and Hsinn-jyhTzeng Feasibility study of rotary electrical discharge machining with ball burnishing for Al2O3/6061Al composite 2008, vol.23: 391–399.

[2] Tsai, H.C., Yan, B.H. and Huang, F.Y., 2003. EDM performance of Cr/Cu-based composite electrodes. International Journal of Machine Tools and Manufacture, 43(3), 245-252.

[3] Saha, S.K. and Choudhury, S.K., 2009. Experimental investigation and empirical modeling of the dry electric discharge machining process. International Journal of Machine Tools and Manufacture, 49(3-4), 297-308.

[4] Sohani, M.S., Gaitonde, V.N, Siddeswarappa, B. And Deshpande, A.S., 2009. Investigation sin to the effect of tool shapes with size factor consideration in sink electrical discharge machining (EDM) process. International Journal of Advanced Manufacturing Technology, 1-15.

[5] Zhou, M. And Han, F., 2009. Adaptive control for EDM process with a self-tuning regulator. International Journal of Machine Tools and Manufacture, 49(6), 462-469.