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PROCESS PARAMETERS OPTIMIZATION OF EDM FOR MACHINING ON HCHCR D3 STEEL USING ANOVA

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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, pulse on time (T_{on}), and pulse off time (T_{off}) which are the most connected parameters to be controlled by the EDM process over HCHCR machining specifications such as material removal rate (MRR) and characteristics of surface integrity such as average surface roughness (R_a) 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.

Keywords: ANOVA, EDM, material removal rate (MRR), Surface roughness.

I. Introduction

The need to machine newly developed metals and non-metals for unusual complex part geometries that cannot easily be accomplished by normal machining methods. It is impossible to find sufficiently strong and hard tools to machine aforesaid materials at economic cutting speeds with good surface finish and dimensional tolerance. Hence, there is great demand for new machining technologies to cut these ‘difficult-to-machine’ materials with ease and precision. Joseph Priestley, The English physicist, first noted the erosion of metals by electric sparks in 1770. Russian scientists B. R. Lazarenko and N. I. Lazarenko first introduced controlled machining by electric discharges in 1943 among modern machining processes, electric discharge machining (EDM) has become highly popular in manufacturing industries due to its capability to machine any electrically conductive material into desired shape with required dimensional accuracy irrespective of its mechanical strength. The metal removal takes place due to erosion caused by rapidly occurring discharge between tool and work. This process may be used for machining any material irrespective of hardness. Figure 1 shows a representative diagram of a typical EDM setup. When a suitable voltage is built up across tool and the workpiece, an electrostatic field of sufficient strength is established, causing cold emission of electron from the cathode .These liberated electrons accelerate towards the anode and after gaining sufficient velocity electrons collide with the molecules of dielectric fluid, breaking them into electrons and positive ions. A narrow column of ionized dielectric fluid molecules is established connecting the two electrodes and spark generates due to the avalanche of electrons. This results in a compression shock wave. Very high temperature (10000 to 12,000 °C) is developed which induces melting and evaporation of both the electrode and work piece. The machining process successively removes minute quantities of work piece material, in the form of molten metal, during discharges. The removed material solidifies to form debris. Dielectric fluid drives away the debris and thus preventing them from sticking to surface of tool.

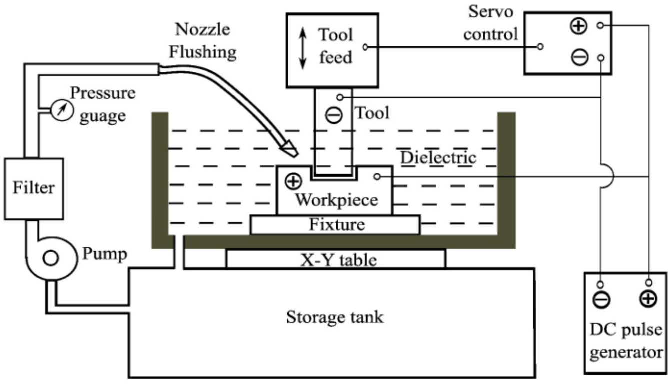

Fig. 1 A Typical EDM Setup

Selection of orthogonal array

Table 1: Control Parameters and their levels

PARAMETERS AND LEVELS	LEVEL 1	LEVEL 2	LEVEL 3
Pulse on time	4	6	8
Pulse off time	8	9	10
Gap current	6	8	10

Three process parameters are considered as controlling factors. They are pulse on time, pulse off time, gap current. Each parameter has 3 levels. Table 1 shows the parameters and their levels considered for the experimentation.
Nine experimental combination values are shown in table 2

Table 2: Taguchi L_9 orthogonal Array Combination

S.NO	COMBINATION	PULSE ON TIME(µs)	PULSE OFF TIME(µs)	GAP CURRENT(A)
1	$A_1B_1C_1$	4	8	6
2	$A_1B_2C_2$	4	9	8
3	$A_1B_3C_3$	4	10	10
4	$A_2B_1C_2$	6	8	8
5	$A_2B_2C_3$	6	9	10
6	$A_2B_3C_1$	6	10	6
7	$A_3B_1C_3$	8	8	10
8	$A_3B_2C_1$	8	9	6
9	$A_3B_3C_2$	8	10	8

II. EXPERIMENTAL SETUP

Work piece material: HCHCR D3 steel is an air hardening, high-carbon, high-chromium tool steel. It has high wear and abrasion resistant properties. It is heat treatable and will offer hardness in the range 55-62 HRC, and is machinable in the annealed condition. HCHCR D3 steel shows little distortion on correct hardening. HCHCR D3 steel's high chromium content gives it mild corrosion resisting properties in the hardened condition.

Methodology: The experiments have been carried using electric discharge machine with HCHCR D3 STEEL as work piece and copper as electrode and uses direct current straight polarity where electrode acts as anode and workpiece acts as cathode. The dielectric fluid used as IPOL and has servo control mechanism. The HCHCR D3 steel of 32 mm diameter is cut using Band saw in to circular pieces of 9 numbers. The tool material used for the experimentation is electrolytic copper tool (99.9%). The diameter of the tool electrode is 20mm and its total length is 25 mm. Three .process parameters pulse on time, pulse off time, gap current and their levels are selected.

Table 3: Machine specifications

Voltage (V)	V80±5%
Discharge Current (A)	8, 10,12
Servo Control	Electro Mechanical
Polarity	Normal (Electrode – Positive
Dielectric fluid	IPOL
Flushing side	Flushing with Pressure
Work piece Material	HCHCR D3
Electrode Material	Copper

Fig. 2 Experimental setup

Fig. 3 Machined work pieces

Machining time: The time during which the work piece gets machined to change the dimension is called machining time. By using stop watch machining time is noted.

Surface roughness: Central line average method (Ra) is used to calculate surface roughness. It is the average absolute deviation of the roughness irregularities from the mean line over one sampling length. Talyor Hobson Talysurf device is used to measure surface roughness

Fig.4 Talyor Hobson Talysurf device

Material removal rate:

It is calculated by the formula

$$MRR = \frac{W_i - W_f}{\rho_w T}$$

Where W_i = initial weight of work piece before machining
W_f = final weight of work piece after machining
ρ_w = density of the work piece
T = machining time

Table 4: Experimental results for Machining time, Surface roughness and MRR

S.NO	COMBINATION	TIME ON (μs)	TIME OFF(μs)	GAP CURRENT (A)	MACHINING TIME (min)	SURFACE ROUGHNESS R$_a$(μm)	MRR(gm /min)
1	$A_1B_1C_1$	4	8	6	20.80	3.277	0.026
2	$A_1B_2C_2$	4	9	8	25.00	5.269	0.021
3	$A_1B_3C_3$	4	10	10	30.12	3.561	0.015
4	$A_2B_1C_2$	6	8	8	22.40	4.045	0.021
5	$A_2B_2C_3$	6	9	10	27.00	4.293	0.017
6	$A_2B_3C_1$	6	10	6	26.50	8.296	0.018
7	$A_3B_1C_3$	8	8	10	26.04	7.370	0.022
8	$A_3B_2C_1$	8	9	6	24.68	7.406	0.024
9	$A_3B_3C_2$	8	10	8	26.24	8.463	0.017

III. RESULTS AND DISCUSSIONS

After conducting the experiments based on the combinations obtained from the design of experiments from the Mini tab software results were generated

Table 5: Response table for S/N ratios for machining time

LEVEL	TIME ON	TIME OFF	GAP CURRENT
1	-27.97	-27.23	-27.56
2	-28.03	-28.14	-27.78
3	-28.18	-28.81	-28.84
Delta	0.21	1.58	1.28
Rank	3	1	2

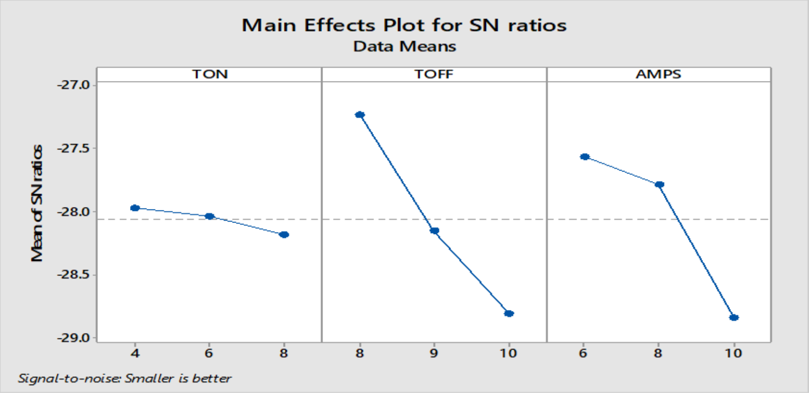

Fig. 5 Main effect plot for machining time

From table 5, figure 5 it is observed that for minimum machining time the optimal parameter value obtained from S/N ratios at pulse on time-8,pulse off time -10 and gap current-10.

Table 6: S/N Response table for Surface roughness

LEVEL	TIME ON	TIME OFF	GAP CURRENT
1	4.036	4.897	6.326
2	5.545	5.656	5.926
3	7.746	6.773	5.075
Delta	3.711	1.876	1.252
Rank	1	2	3

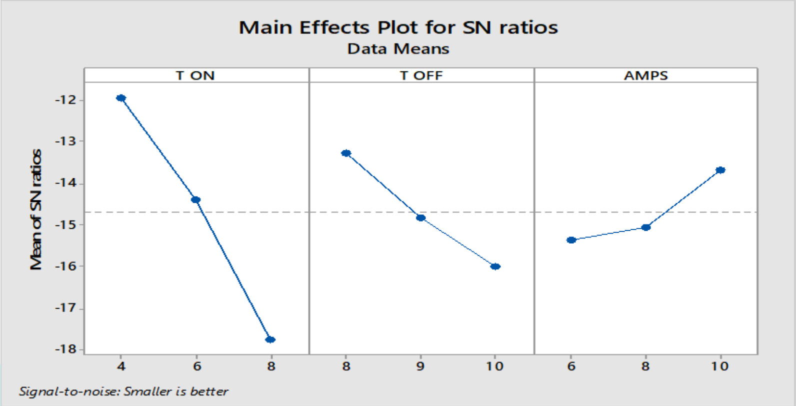

Fig. 6 Main effect plot for surface roughness

From table 6, figure 6 it is observed that for minimum surface roughness the optimal parameter value obtained from S/N ratios at pulse on time-8, pulse off time -10 and gap current-6

Table 7: S/N Response table for MRR

LEVEL	TIME ON	TIME OFF	GAP CURRENT
1	-33.91	-32.80	-33.00
2	-34.61	-33.78	-34.17
3	-33.65	-35.59	-35.01
Delta	0.97	2.79	2.01
Rank	3	1	2

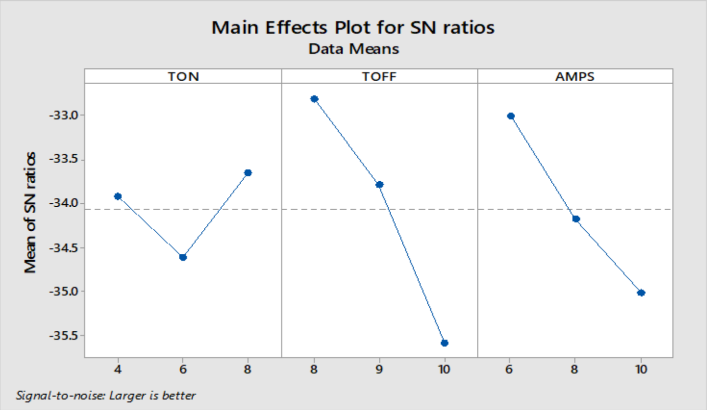

Fig. 7 Main effect plot for MRR

From table 7 and figure 7 it is observed that for minimum surface roughness the optimal parameter value obtained from S/N ratios at pulse on time-8, pulse off time -8 and gap current-6.

Table 8: ANOVA Results for Machining Time

Source	DF	Seq SS	Adj MS	F	P	% of contribution
Time On	2	0.2451	0.1225	0.10	0.910	1
Time Off	2	31.0056	15.5028	12.48	0.074	53
Gap Current	2	24.2643	12.1321	9.77	0.093	42
Error	2	2.4835	1.2417			4
Total	8	57.9984				100

From the table 8 it is observed that the percentage contribution of values for machining time at time on (1), time off (53) and gap current(42). It is observed that the time off have great influence on machining time. Since this analysis is a parameter based optimization design, from the above values it is clear that time off is the major factor to be selected effectively to get the minimum machining time.

Table 9: ANOVA Results for Surface Roughness

SOURCE	DF	SEQ SS	ADJ MS	F	P	% of contribution
Time- On	2	20.893	10.447	3.13	0.242	59
Time- Off	2	5.343	2.672	0.80	0.556	15
Gap Current	2	2.451	1.226	0.37	0.732	7
Error	2	6.684	3.342			19
Total	8	35.372				100

From the table 9 it is observed that the percentage contribution of values for surface roughness at pulse on time (59), pulse off time (15) and gap current (7). It is observed that the pulse on time have great influence on surface roughness. Since this analysis is a parameter based optimization design, from the above values it is clear that pulse on time is the major factor to be selected effectively to get the minimum surface roughness.

Table 10: ANOVA Results for MRR

Source	DF	Seq SS	Adj MS	F	P	% OF CONTRIBUTION
TIME ON	2	0.000010	0.000005	43.00	0.023	11
TIME OFF	2	0.000062	0.000031	277.00	0.004	59
GAP CURRENT	2	0.000034	0.000017	151.00	0.007	30
Error	2	0.000000	0.000000			0
Total	8	0.000105				100

From the table 10 it is observed that the percentage contribution of values for material removal rate at time on (11), time off (59) and gap current (30). It is observed that the time off have great influence on surface roughness. Since this analysis is a parameter based optimization design, from the above values it is clear that time off is the major factor to be selected effectively to get the maximum material removal rate.

IV. CONCLUSION

From the above analysis of various performances of parameters of EDM process following conclusions were drawn.

Optimal parameter combination for minimum machining time is obtained at pulse on time 8 µs, pulse off time 10 µ and gap current 10A.

Optimal parameter combination for minimum surface roughness is obtained at pulse on time 8 µs, pulse off time 10 µs and gap current 6A.

Optimal parameter combination for maximum material removal rate is obtained at pulse on time 8 µs, pulse off time 8 µs, and gap current 6A.

ANOVA results indicates that pulse off time is the significant parameter in determining machining time. The contribution of pulse off time, gap current, and pulse on time for minimum machining time is 53%, 42% and 1% respectively.

ANOVA results indicates that pulse on time is the significant parameter in determining surface roughness. The contribution of pulse on time, pulse off time, gap current, and for minimum surface roughness is 59%, 15% and 7% respectively.

ANOVA results indicates that pulse off time is the significant parameter in determining MRR. The contribution of pulse off time, gap current, and pulse on time for maximum MRR is 59%, 30% and 11% respectively.

V. ACKNOWLEDGEMENT

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