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Experimental Investigation and Improvement of Surface Finish Analysis on HCHCR Steel Using EDM

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ABSTRACT

This experimental aims at achieving the integrated approach to solve the optimization problem of EDM process. At any stage, the dominance factor of the input variables and output variables contained in the constraints and objective functions can be computed.

Electric discharge machining is categorized as a thermoelectric process in which heat energy of spark is used to remove material from the work piece. The machining process involves controlled erosion of electrically conducting material by the initiation of rapid and repetitive electrical spark discharges between the tool and work piece separated by the dielectric medium. The present work is aimed at characterizing the electric discharge machining of HCHCR steels on EDM. Since an electrode with micro features is employed to cut its mirror image in the work piece, it is necessary to investigate the machining efficiency of the electrodes used. Furthermore, to improve the machining efficiency, it is momentous to consider the effect of various influencing input and output parameters. In this project, a series of experiments has to be conducted with copper electrode as a tool and HCHCR steel as work piece to machine small depth on the work piece.. The combination of Pulse on time, pulse off time and Gap current is new line considered for maximum Material Removal Rate (MRR), Surface Roughness (SR), machining timing. The main aim has to be identifying the electrode which could enhance the production of quality of impression and to have a significant contribution for modern industrial requirements. . The experiments has to be carried out as per L9 orthogonal array with each experiment performed under different conditions of such as Ampere rating, sparking voltage while machining.

***Keywords:** EDM, Material removal Rate, HCHCR, Optimization*

INTRODUCTION

Electric Discharge Machining

Electric discharge machining is a thermo-electric non-traditional 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 a 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 electrode 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. To prevent excessive heating, electric power is supplied in the form of short pulses. Spark occurs wherever the gap between the tool and the work piece surface is smallest. After material is removed due to a spark, this gap increases and the location of the next spark shifts to a different point on the work piece surface. In this way several sparks occur at various locations over the entire surface of the work piece corresponding to the work.

Figure 1.1: Tool shape and corresponding cavity formed on work piece

After EDM Operation

THEORETICAL BACKGROUND

Discharge Phenomena

Phases of discharge

The discharge process during EDM can be separated into three main phases .They are preparation phase, discharge phase and interval phase. Details of each phase are discussed below.

Discharge phase

EDM PROCESS

ELECTRO-MECHANICAL THEORY

This theory suggests that abrasion of material particles takes place as a result of the concentrated electric field. The theory proposes that the electric field separates the material particles of the work piece as it exceeds the forces of cohesion in the lattice of the material. This theory neglects any thermal effects. Experimental evidence lacks supports for this theory.

ILLUSTRATION – 1

A charged electrode is brought near the workplace. Between them is insulating oil, known in EDM as dielectric fluid. Even though a dielectric fluid is a good insulator, a large enough electrical potential can cause the fluid to break down into ionic (charged) fragments, allowing an electrical current to pass from electrode to work piece.

The presence of graphite and metallic particles suspended in the fluid can aid this electrical transfer in two ways: the particles(electrical conductors) aid in ionizing the dielectric oil and can carry the charge directly; and the particles can catalyze the electrical breakdown of the fluid.

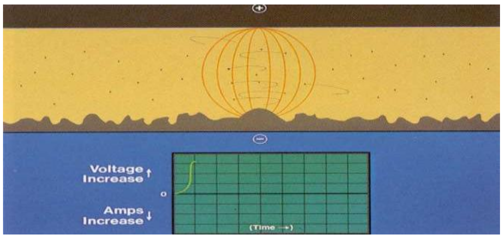

Figure 3.1: Illustration – 1

ILLUSTRATION – 2

As the number of ionic (charged) particles increases, the insulating properties of the dielectric fluid begin to decrease along a narrow channel centered in the strongest part of the field. Voltage has reached its peak, but current is still zero.

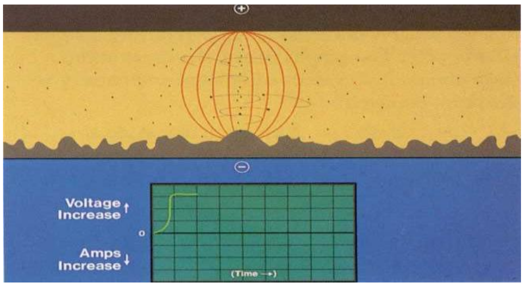

Figure 3.2: Illustration – 2

ILLUSTRATION – 3

A current is established as the fluid becomes less of an insulator. Voltage begins to decrease.

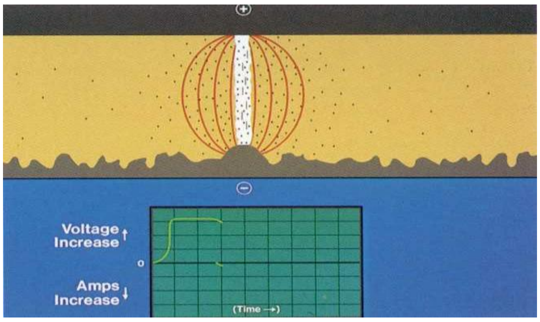

Figure 3.3: Illustration – 3

ILLUSTRATION – 4

Heat builds up rapidly as current increases, and the voltage continues to drop. The heat vaporizes some of the fluid, work piece, and electrode, and a discharge channel begins to form between the electrode and work piece.

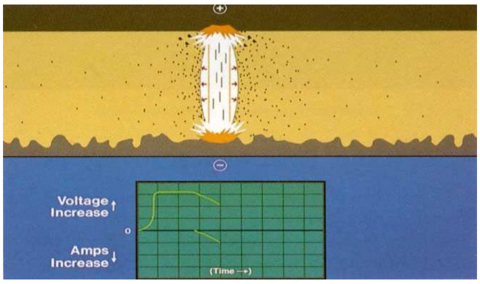

Figure 3.4: Illustration – 4

ILLUSTRATION – 5

A vapour bubble tries to expand outward, but its expansion is limited by a rush of ions towards the discharge channel. These ions are attracted by the extremely intense electro-magnetic field that has built up. Current continues to rise, voltage drops.

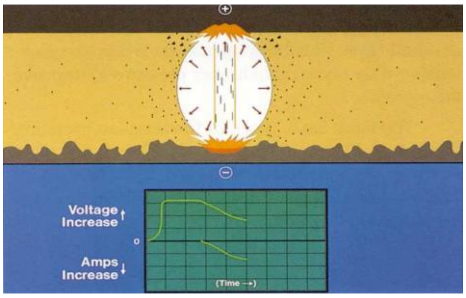

Figure 3.5: Illustration – 5

ILLUSTRATION - 6

Near the end of the on-time, current and voltage have stabilized, heat and pressure within the vapour bubble have reached their maximum, and some metal is being removed.

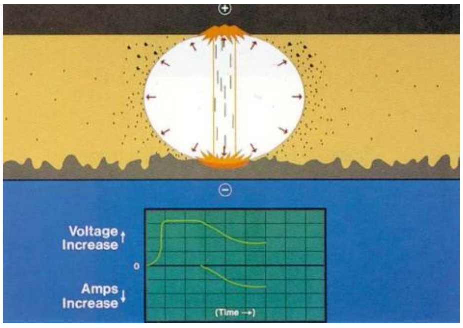

Figure 3.6: Illustration – 6

ILLUSTRATION – 7

At the beginning of the off-time, current and voltage drop to zero. The temperature decreases rapidly, collapsing the vapor bubble and causing the molten metal to be expelled from the work piece.

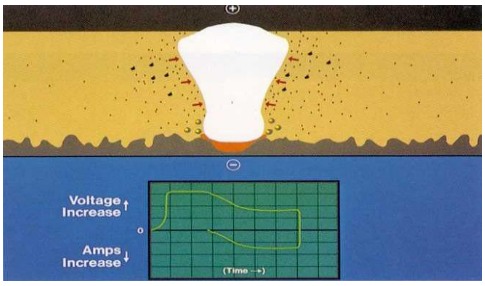

Figure 3.7: Illustration – 7

ILLUSTRATION – 8

Fresh dielectric fluid rushes in, flushing the debris away and quenching the surface of the work piece. Unexpelled molten metal solidifies to form what is known as the recast layer.

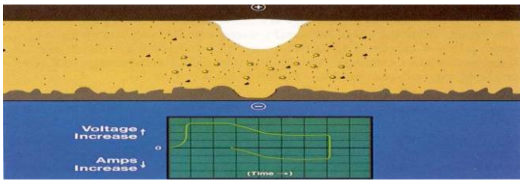

Figure 3.8: Illustration – 8

ILLUSTRATION – 9

The expelled metal solidifies into tiny spheres dispersed in the dielectric oil along with bits of carbon from the electrode. The remaining vapor rises to the surface. Without a sufficient off-time, debris would collect making the spark unstable. This situation could create a DC arc which can damage the electrode and the work piece.

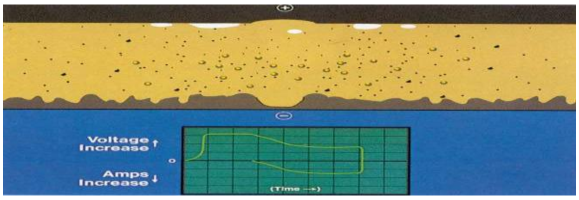

Figure 3.9: Illustration – 9

This on/off sequence represents one EDM cycle that can repeat up to 250,000 times per second. There can be only one cycle occurring at any given time. Once this cycle is understood we can start to control the duration and intensity of the on/off pulses to make EDM work for us.

AN ORTHOGONAL ARRAY L9 FORMATION

TRIALNO.	**DESIGNATION**	Pulse on time	Pulse off time	AMPS
1	$A_1B_1C_1$	4	5	8
2	$A_1B_2C_2$	4	6	10
3	$A_1B_3C_3$	4	7	12
4	$A_2B_1C_2$	5	5	10
5	$A_2B_2C_3$	5	6	12
6	$A_2B_3C_1$	5	7	8
7	$A_3B_1C_3$	6	5	12
8	$A_3B_2C_1$	6	6	8
9	$A_3B_3C_2$	6	7	10

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PROCESS PARAMETERS AND THEIR LEVELS

Process parameters and their levels

s.no	Pulse on time	Pulse off time	Pulse off time
1	4	5	8
2	5	6	10
3	6	7	12

RESULT &DISCUSSION

CALCULATION

After finding all the observation as given in table (3.2) & (6), and S/N ratio and means are calculated and various graph for analysis is drawn by using Minitab-15. The S/N ratio for Ra, Machining time and MRR is calculated on Minitab -15 Software using Taugchi Method.

EXPERIMENTAL DATA

MRR=BW-AW/DENSITY*TIME TAKEN)

TRIAL NO.	DESIGNATION	T ON	T/OFF	AMPS	RA µS	**MT Min**	MRR Kg/m³
1	$A_1B_1C_1$	4	5	8	1.263	**28**	0.111999489
2	$A_1B_2C_2$	4	6	10	1.520	**23**	0.11199384
3	$A_1B_3C_3$	4	7	12	2.801	**18**	0.111999206
4	$A_2B_1C_2$	5	5	10	3.913	**19**	0.111999248
5	$A_2B_2C_3$	5	6	12	3.174	**15**	0.111999056
6	$A_2B_3C_1$	5	7	8	3.145	**20**	0.111999285
7	$A_3B_1C_3$	6	5	12	4.558	**13**	0.111998901
8	$A_3B_2C_1$	6	6	8	4.620	**16**	0.111999107
9	$A_3B_3C_2$	6	7	10	5.167	**18**	0.111999213

SURFACE ROUGHNESSES (ANALYSIS OF RESULT)

SURFACE ROUGHNESS AND S/N RATIOS VALUES FOR THE EXPERIMENTS

TRIAL NO.	**DESIGNATION**	**Pulse on time**	**Pulse off time**	**AMPS**	**RA**	**S/N Response valve (db) for mc**
1	$A_1B_1C_1$	4	5	8	1.263	-2.0281
2	$A_1B_2C_2$	4	6	10	1.520	-3.6369
3	$A_1B_3C_3$	4	7	12	2.801	-8.9463
4	$A_2B_1C_2$	5	5	10	3.913	-11.8502
5	$A_2B_2C_3$	5	6	12	3.174	-10.0321
6	$A_2B_3C_1$	5	7	8	3.145	-9.9524
7	$A_3B_1C_3$	6	5	12	4.558	-13.1755
8	$A_3B_2C_1$	6	6	8	4.620	-13.2928
9	$A_3B_3C_2$	6	7	10	5.167	-14.2648

ROUGHNESS RESPONSE FOR EACH LEVEL OF THE PROCESS PARAMETER

Response Table for Signal to Noise Ratios

Smaller is better

Level	A	B	C
T-ON	-11.40	-10.65	-10.04
T-AMPS	-11.58	-11.52	-11.58
AMPS	-10.18	-10.99	-11.53
Delta	1.40	0.88	1.54
Rank	2	3	1

Response Table for Means

Level	A	B	C
T-ON	3.763	3.448	3.182
T-AMPS	3.813	3.783	3.825
AMPS	3.229	3.574	3.798
Delta	0.584	0.335	0.643
Rank	2	3	1

General Linear Model: MT versus T-ON, T-OFF, AMPS

Factor	TYPE	LEVELS	VALUES
T ON	FIXED	3	4,5,6
T OFF	FIXED	3	5,6,7
AMPS	FIXED	3	8,10,12

ANALYSIS OF VARIANCE (ANOVA)

Analysis of Variance (ANOVA) results for the Roughness

Source	DF	SS	ADJ MS	MS	F	P	% of contribution
A	2	0.6286	0.6216	0.3143	1.19	0.458	30
B	2	0.1722	0.1722	0.0861	0.32	0.755	9
AMPS	2	0.7924	0.7924	0.3962	1.49	0.401	37
Error	2	0.5301	0.5301	0.2651			24
Total	8	2.1234					

MACHINING TIME (ANALYSIS OF RESULT)

MACHINING TIME AND S/N RATIOS VALUES FOR THE EXPERIMENTS

TRIAL NO.	**DESIGNATION**	**Pulse on time**	**Pulse off time**	**AMPS**	**MT Min**	**S/N Ratio**
1	$A_1B_1C_1$	4	5	8	28	-28.9432
2	$A_1B_2C_2$	4	6	10	23	-27.2346
3	$A_1B_3C_3$	4	7	12	18	-25.1055
4	$A_2B_1C_2$	5	5	10	19	-25.5751
5	$A_2B_2C_3$	5	6	12	15	-23.5218
6	$A_2B_3C_1$	5	7	8	20	-26.0206
7	$A_3B_1C_3$	6	5	12	13	-22.2789
8	$A_3B_2C_1$	6	6	8	16	-24.0824
9	$A_3B_3C_2$	6	7	10	18	-25.1055

MACHINING TIME FOR EACH LEVEL OF THE PROCESS PARAMETER

Response Table for Signal to Noise Ratios

Smaller is better

Level	Pulse on time	Pulse off time	AMPS
1	-27.09	-25.60	-26.35
2	-25.04	-24.95	-25.97
3	-23.82	-25.41	-23.64
Delta	3.27	0.65	2.71
Rank	1	3	2

Response Table for Means

Level	Pulse on time	Pulse off time	AMPS
1	23.00	20.00	21.33
2	18.00	18.00	20.00
3	15.67	18.67	15.33
Delta	7.33	2.00	6.00
Rank	1	3	2

Main Effects Plot for Means

Main Effects Plot for SN ratios

General Linear Model: MT versus T-ON, T-OFF, AMPS

Factor	TYPE	LEVELS	VALUES
T ON	FIXED	3	4,5,6
T OFF	FIXED	3	5,6,7
AMPS	FIXED	3	8,10,12

ANALYSIS OF VARIANCE (ANOVA)

Analysis of Variance (ANOVA) results for the MACHINING TIME

Source	DF	SS	ADJ SS	ADJ MS	F	P	% of contribution
Pulse on time	2	84.222	84.222	42.111	7.73	0.114	52
Pulse off time	2	6.222	6.222	3.111	0.57	0.636	4
Amps	2	59.556	59.556	29.778	5.47	0.135	38
Error	2	10.889	10.889	5.444			6
Total	8	160.889					100

MRR (ANALYSIS OF RESULT)

MRR AND S/N RATIOS VALUES FOR THE EXPERIMENTS

(Before weight-0.106Kg-After weight-0.103Kg)

TRIAL NO.	DESIGNATION	Pulse on time	Pulse off time	AMPS	MRR Kg/min	S/N Response valve (db) for MRR
1	$A_1B_1C_1$	4	5	8	0.1023	-19.8025
2	$A_1B_2C_2$	4	6	10	0.1015	-19.8707
3	$A_1B_3C_3$	4	7	12	0.1002	-19.9826
4	$A_2B_1C_2$	5	5	10	0.1005	-19.9567
5	$A_2B_2C_3$	5	6	12	0.9910	-0.0785
6	$A_2B_3C_1$	5	7	8	0.1001	-19.9913
7	$A_3B_1C_3$	6	5	12	0.9800	-0.1755
8	$A_3B_2C_1$	6	6	8	0.9956	-0.0383
9	$A_3B_3C_2$	6	7	10	0.1002	-19.9826

MRR FOR EACH LEVEL OF THE PROCESS PARAMETER

Response Table for Signal to Noise Ratios

Larger is better

Level	Pulse on time	Pulse off time	Gap current
1	-19.885	-13.312	-13.77
2	-13.342	-6.663	-19.937
3	-6.732	-19.986	-6.746
Delta	13.153	13.323	13.191
Rank	3	1	2

Response Table for Means

Level	Pulse on time	Pulse off time	Gap current
1	0.1013	0.3943	0.3993
2	0.3972	0.6960	0.1007
3	0.6919	0.1002	0.6904
Delta	0.5903	0.5959	0.5897
Rank	2	1	3

Main Effects Plot for Means

Main Effects Plot for SN ratios

General Linear Model: MRR versus T-ON, T-OFF, AMPS

Factor	TYPE	LEVELS	VALUES
T ON	FIXED	3	4,5,6
T OFF	FIXED	3	5,6,7
AMPS	FIXED	3	8,10,12

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ANALYSIS OF VARIANCE (ANOVA)

Analysis of Variance (ANOVA) results for the MRR

Source	DF	SS	MS	F	P	% of contribution
Pulse on time	2	0.52321	0.26161	12882.09	0.000	**33**
Pulse off time	2	0.53262	0.26631	13113.57	0.000	34
Amps	2	0.52159	0.26076	12842.09	0.000	33
Error	2	0.00004	0.00002			0
Total	8	1.57746				100

CONCLUSION AND RESULT

In this study, the Taugchi technique and ANOVA were used to obtain optimal EDM parameters in the machining of HCHCR. with copper electrode . The experimental results were evaluated using Taguchi technique. The following conclusion can be drawn.

OPTIMAL CONTROL FACTOR

1.Surface Roughness-A2(T-ON – 5 µs)B3(T-OFF – 7 µs)C1(Amps-8)

2.Machining Timing- A1(T-ON – 4 µs)B3(T-OFF – 7 µs)C2(Amps-10)

3.Material Removal Rate- A3(T-ON – 6 µs)B1(T-OFF – 5 µs)C2(Amps-10)

Percentage of contribution of Process parameter

1. Surface Roughness- Amps- 37%
2. Machining Timing- Pulse off time-34%
3. Material Removal Rate-Pulse on time-51%

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