

Optimization of the Process Parameters of Electro Discharge Machining Process for En8 Grade

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ABSTRACT: The Electro discharge machining process was carried out on EN8 grade tool steel and its performance characteristics has been studied for optimizing the machining parameters of EDM process. The experiments were carried out for different machining parameters such as pulse on time, pulse off time, gap voltage and peak current using Taguchi's L9 orthogonal array. The machining characteristics consisting of surface roughness, material removal rate (MRR) and electrode wear ratio (EWR) has been studied for optimizing the machining parameters.

KEYWORDS: EDM; MRR; EWR; surface roughness; Taguchi's L9 orthogonal array; pulse duration; peak current

I. INTRODUCTION

Electro discharge machining is a non-conventional machining process which uses high frequency electric sparks for causing erosion in the work piece and thereby removes the work piece material. The fields like space research, nuclear industry, missile technologies requires machining of newly developed advanced materials like super alloys, ceramics and composites which are difficult to machine economically with the conventional machining techniques. But, non-conventional techniques like EDM can be used to machine those advanced materials more economically and effectively [1]. The EDM process is also being widely used for manufacturing dies and moulds in manufacturing industries and also for manufacturing various components in automobile and aerospace industries [4]. High pulse time and high current density should be applied to have a minimum electrode wear [2]. The pulse duration and discharge currents are the main factors that has a greater influence on the machining time and surface quality of the work pieces produced [3]. The material removal rate (MRR) and surface roughness are being influenced by pulse on time and discharge currents [4]. The performance characteristics such as material removal rate, electrode wear ratio and surface roughness can all together be improved by using modified taguchi method [7].

II. RELATED WORK

The Electro discharge machining process using copper as electrode can be optimized for EN8 to enhance its machining characteristics. The steps involved are summarized as follows.

1. EN8 is chosen as the work-piece to be machined in EDM process. All the work-piece should be of same dimensions as in figure1. The cutting of work-piece is done by using wire cut EDM machine.
2. Copper is chosen as the electrode material. All the copper electrode should be of same dimension as in figure 2. The cutting of electrode is done using lathe machine
3. The parameters that are considered in this study are pulse on time, pulse off time, gap voltage and peak current.
4. Their experimental layout is created by using Taguchi's L9 orthogonal array.
5. The experiment is carried out in EDM machine. The metal removal rate (MRR), electrode wear ratio (EWR) and surface roughness are found and the values are tabulated.

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III. EXPERIMENT

SELECTION OF WORKPIECE:

The work piece used in this study is EN8 which is also known as 080M40. It is an unalloyed medium carbon steel with the composition as shown in the table below.

C %	Si %	Mn %	Ni %	Cr %	Mo %	S %	P %	Fe %
0.35 - 0.45	0.05 - 0.35	0.60 - 1.00	-	-	-	0.06Max	0.06Max	Balance

Table 1-Composition of EN8 (Work-piece)

The maximum stress of this material is 700-850 N/mm², minimum yield stress is 465 N/mm², minimum elongation is 16% and hardness is 201-255 BHN. It is widely used for hydraulic rams (chromed), key steel, medium torqued shafts, medium bending and compression loading applications. It also has a good corrosion resistance.

SELECTION OF ELECTRODE:

Copper is the electrode used in this study. The important properties of copper are high strength-to-weight ratio, resistance to corrosion by many chemicals, high thermal and electrical conductivity, non-toxicity, reflectivity, appearance, non-magnetic and ease of formability and of machinability.

Electrical resistivity ($\mu\Omega/\text{cm}$)	Electrical conductivity compared with silver (%)	Thermal conductivity (W/mK)	Melting point ($^{\circ}\text{C}$)	Specific heat (cal/g $^{\circ}\text{C}$)	Specific gravity at 20 $^{\circ}\text{C}$ (g/cm ³)	Coefficient of thermal expansion ($\times 10^{-6} \text{ }^{\circ}\text{C}^{-1}$)
1.96	92	268 – 389	1083	0.092	8.9	6.6

Table 2-Physical properties of Copper electrode

EXPERIMENTAL PLAN:

First of all, the electrode and the work-piece are cut according to the required dimension. The dimensions of electrode and work-piece should be same for all the experiments. The lathe machine is used to cut the electrode. For the work piece, the wire cut EDM machine is used for cutting all specimens in same dimension. The figure below shows the sample of work-piece and electrode used. The diameter of electrode is 10mm and the work-piece has a length of 110mm, breadth of 50mm and height of 65mm.



Fig.1-Workpiece



Fig.2-Electrode Material

The machining parameters that are considered in this study are pulse on time, pulse off time, gap voltage and discharge current. The machining parameters and their levels of values are shown in the table below.

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Symbols	Parameters	Units	Level 1	Level 2	Level 3
A	PULSE ON TIME (Ton)	μs	50	100	200
B	PULSE OFF TIME (Toff)	μs	4	8	12
C	GAP VOLTAGE (Vg)	V	100	120	130
D	PEAK CURRENT (Ip)	A	35	37	40

Table 3-Machining parameters and their levels

L9 orthogonal array:

The Taguchi's L9 orthogonal array is employed for doing experimentation. This L9 orthogonal array can be used to analyse the effect of four independent variable with each variable having three set values (level values). The experimental layout for the four machining parameters using the L9 orthogonal array is shown in Table 4. Experimental design using L9 orthogonal array is shown in table 5.

S.NO	PULSE ON TIME	PULSEOFF TIME	GAP VOLTAGE	PEAK CURRENT
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

Table 4-Layout of L9 orthogonal array

S.NO	PULSE ON TIME μs	PULSEOFF TIME μs	GAP VOLTAGE V	PEAK CURRENT A
1	50	4	100	35
2	50	8	120	37
3	50	12	130	40
4	100	4	120	40
5	100	8	130	35
6	100	12	100	37
7	200	4	130	37
8	200	8	100	40
9	200	12	120	35

Table 5-Experimental design using L9 orthogonal array

ELECTRO DISCHARGE MACHINING PROCESS:

The work-piece is given a positive polarity and the copper is given a negative polarity with kerosene acting as the dielectric fluid. The EDM process is carried out in a Sodick CNC EDM die sink machine of model AQ55L. After completion of each machining process, the work piece was blown by compressed air using air gun to ensure no debris and dielectrics were present. The mass of the work-piece and electrode is measured before and after machining process for each of the nine experiments using Precisa balance machine of model 92SM – 202A DR. The machining parameters

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are set according to the Table 5 and the machining time for all the nine experiments is 3 minutes. Then machining process is carried out on the work-piece and the values are tabulated.



Fig.3-Sodick CNC EDM of model AQ55L



Fig.4-Precisa balance machine(92SM – 202A DR)

The figure 3&4 shows the machines that has been used for conducting the experiments.

IV. RESULTS

The experiments were carried out according to the table 5 and the data that had been collected for each experiments includes mass of the work-piece before and after machining, mass of the electrode before and after machining, and surface roughness. These data are tabulated and are used to find the material removal rate (MRR) and electrode wear ratio (EWR).

MATERIAL REMOVAL RATE (MRR):

The MRR is an important machining characteristics that determines the productivity in an industry. The MRR should be high to have better machining performance and to have high production rate. The MRR is calculated by using the following formulae,

$$MRR = (MRW/T) \text{ in g/min;}$$

WRR = Work-piece removal rate in g;

T = Machining time in minute;

The WRR is the difference between the mass of the work-piece before and after machining.

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S.NO	Mass of the workpiece before machining g	Mass of the workpiece after machining g	Work-piece removal rate WRR g	Machining time T minutes	Material removal rate MRR g/minute
1	67.24	66.01	1.23	3	0.41
2	68.29	66.74	1.55	3	0.516667
3	64.33	62.57	1.76	3	0.586667
4	64.6	63.6	1	3	0.333333
5	70.91	69.3	1.61	3	0.536667
6	76.75	74.58	2.17	3	0.723333
7	67.02	65.97	1.05	3	0.35
8	69.4	67.59	1.81	3	0.603333
9	65.52	63.7	1.82	3	0.606667

Table 6-Material removal rate (MRR)

The table 6 shows the MRR value for all the nine experiments. And the graphical representation of the MRR is shown in the figure 5.

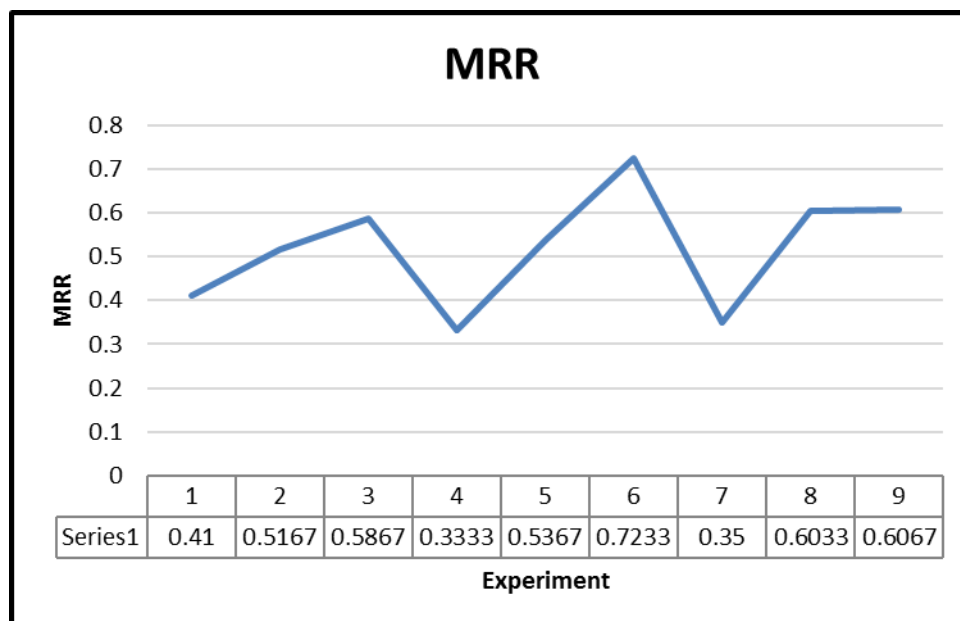


Fig.5-Material removal rate (MRR)

ELECTRODE WEAR RATIO:

Electrode wear imposes high costs on manufacturers to substitute the eroded complicated electrodes by new ones. In order to increase the machining efficiency, erosion of the electrode must be minimized in EDM process. Therefore, studying the electrode wear and related significant factors would be effective to enhance the machining productivity and process reliability. The electrode wear ratio (EWR) is defined by the ratio of the electrode wear weight (EWW) to the work piece removal weight (WRW) and usually expressed in percentage, that is

$$EWR (\%) = [EWW/WRW] \times 100$$

Where;

EWW = Electrode Wear Weight

WRW = Work Piece Removal Weight

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S.NO	Mass of the electrode before machining g	Mass of the electrode after machining g	Electrode Wear weight EWW g	Work-piece removal weight WRW g	Electrode wear ratio EWR %
1	14.48	13.96	0.52	1.23	42.27642
2	14.73	14.32	0.41	1.55	26.45161
3	14.61	14.43	0.18	1.76	10.22727
4	14.71	14.41	0.3	1	30
5	14.48	14.31	0.17	1.61	10.55901
6	14.77	14.68	0.09	2.17	4.147465
7	14.6	14.47	0.13	1.05	12.38095
8	14.51	14.45	0.06	1.81	3.314917
9	14.56	14.52	0.04	1.82	2.197802

Table 7-Electrode wear ratio (EWR)

The table 7 shows the EWR value for all the nine experiments. And the graphical representation of the EWR is shown in the figure 6.

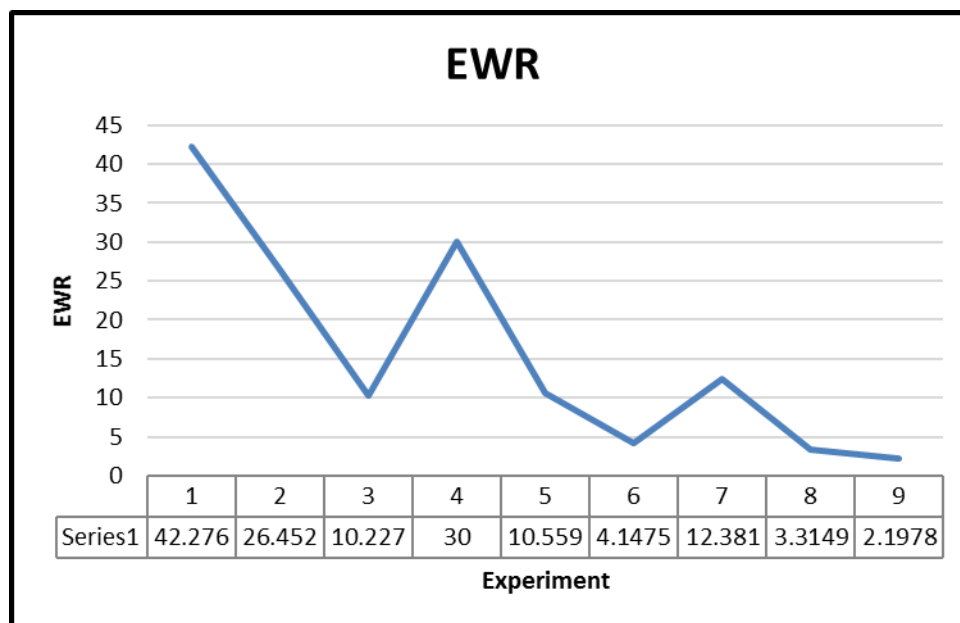


Fig.6-Electrode wear ratio (EWR)

SURFACE ROUGHNESS:

The surface roughness of a machined material is also an important machining characteristics. The surface roughness is quantified by the deviations in the direction of the normal vector of a real surface from its ideal form. The surface is said to be rough for larger deviations and the surface is said to be smooth for smaller deviations. For better machining performance, the surface roughness value should be as low as possible.

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S.NO	PULSE ON TIME μs	PULSE OFF TIME μs	GAP VOLTAGE V	PEAK CURRENT A	ROUGHNESS VALUE μm
1	50	4	100	35	10.048
2	50	8	120	37	9.436
3	50	12	130	40	8.700
4	100	4	120	40	10.842
5	100	8	130	35	8.147
6	100	12	100	37	12.882
7	200	4	130	37	15.381
8	200	8	100	40	20.663
9	200	12	120	35	21.228

Table 8-Surface roughness

The surface roughness value is found for all the experiments and the values are tabulated as in the table 8. The graphical representation of surface roughness is shown in the figure 7.

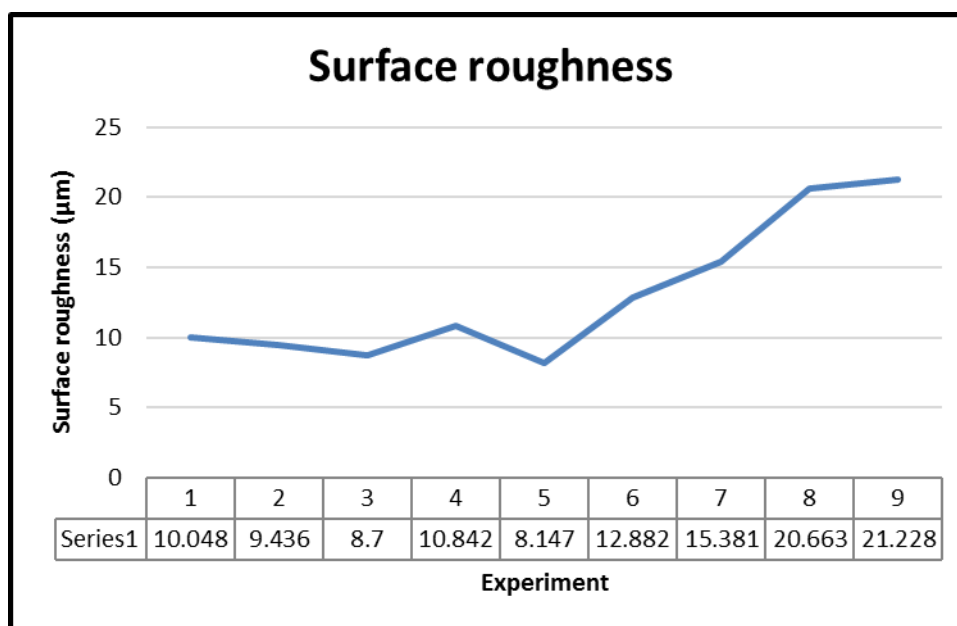


Fig.7-Surface roughness

V. CONCLUSION

This study was carried out to optimize the EDM process on EN8 using copper as electrode. The conclusion of this study is summarized as follows,

- 1) The experiment 6 gives the most optimum machining characteristics with the MRR value of 0.72333 g/min, EWR value of 4.14747% and surface roughness value of 12.882 μm .
- 2) The optimum machining parameters (experiment 6) are pulse on time is 100 μs , pulse off time is 12 μs , gap voltage is 100V and peak current is 37A.
- 3) MRR increases with the increase in pulse on time and pulse off time. So, for higher MRR, the duration of pulse on time and pulse off time should be high.
- 4) EWR decreases with the increase in pulse on time and pulse off time. So, for lower EWR, the duration of pulse on time and pulse off time should be high.

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- 5) Surface roughness increases with the increase in pulse on time and peak current. And surface roughness decreases with the increase in gap voltage. So, for lower surface roughness, gap voltage should be as high as possible and both pulse on time and peak current should be as low as possible.

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