https://dx.doi.org/10.22161/ijaers.68.5 ISSN: 2349-6495(P) | 2456-1908(O)

EDM Process Parameter Analysis and Optimization using CD Function Multi Objective Optimization on EN-08 work Piece Material

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***Abstract*—*High precision machining is possible in present era because of non-conventional machining methods like EDM, WEDM, AJM, ECM and many more. In present research study, EDM method is applied to optimize the selective process parameters of EDM machine on high strength steel material EN-08. In present study, four process parameters are selected which are T-on, T-off, Current and Pressure. Each factor has four levels as per machine range. Pilot experiments are also performed to find the exact range of machining parameters. Pilot experiments are based on "One factor vary and others constant" concept. After pilot experiments, Design of experiment (DOE) method called Taguchi method is applied to find the minimum experiments for this research study. L-16 orthogonal array is selected for this research study.*
***Keywords*—Non conventional, EN-08 steel material, EDM, DOE, CD Function, ANOVA, S/N ratio analysis.**

I. INTRODUCTION

EDM is a machining innovation which is today one of the best in class machining process for metals. It has been supplanting traditional machining operations and is equipped for machining mind boggling on hard material segments, that are hard to machine. Machining of any electrically conductive material regardless of its hardness, by the use of warm energy is one of the prime points of interest of EDM process. It is an electro-warm non-customary machining process in which metal is expelled because of warm energy of the sparkle. EDM utilized electrical energy to produce electrical sparkle that happen between an electrode and a work piece within the sight of a dielectric liquid. EDM is primarily used to machine hard materials like hastalloy, nimonics, nitralloy, etc. The EDM methods were first found by Sir Joseph Priestley an English Scientist. He detected the erosive effect of electrical discharges on metals.

Current EDM created in late 1940 which have been acknowledged worldwide as a standard process in manufacturing.

1.1 Working Principle of EDM Process

EDM is a controlled metal expulsion process that is utilized to expel metal by methods for electric spark erosion. So, it is also called spark erosion machining process. The main aim of the process is controlled removal of material from the work piece. The tool is made cathode and work piece is anode. The tool and work and also the tool slide servo-mechanism, are connected into the circuit. The function of the servo-mechanism is to maintain a very small gap (approximately 0.025 to 0.075 mm) between the tool and the work piece. The spark is the transient electric discharge across the gap between work and tool. When the potential difference (voltage) across the gap (between the electrode and work piece) becomes sufficiently large, the dielectric fluid becomes ionized and breaks downs to produce an electrically conductive spark channel. Thus, thousands of spark-discharge occurs per second across the gap between tool and work, which creates high temperature of approximately 10,000˚C which causes erosion on the surface of work piece just as on the electrode. The temperature is constrained by managing the spark gap between the electrode and the work piece. Fig 1.1 shows the working principle of EDM process. The electrode and work piece ought to have great electrical conductivity to create the great spark. A necessary condition for producing a discharge is the ionization of the dielectric, i.e., splitting up of its molecules into ions and electrons. Both tool and work piece are submerged in a dielectric fluid having poor electrical conductivity. Distilled water, lamp fuel, transformer oil, paraffin oil, kerosene, lubricating oils, etc are normal sort of dielectric fluids utilized in EDM process.

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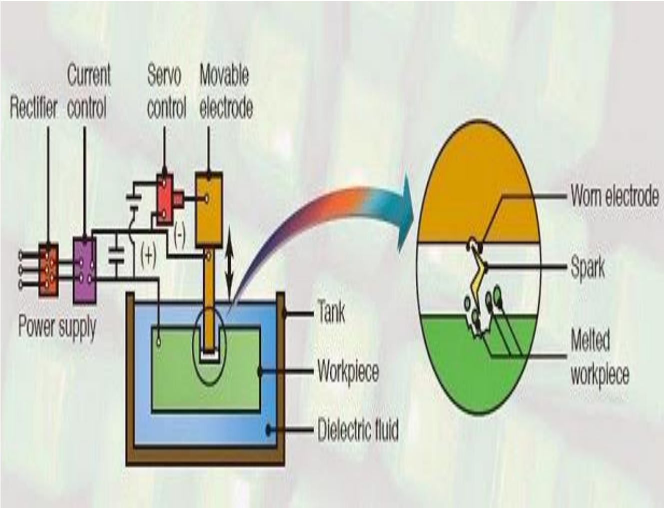

Fig.1.1. Working principle of EDM process

II. LITERATURE REVIEW

Nagahanumaiah et al. [1] have displayed the spectroscopic measurement of temperature and electron thickness in the miniaturized scale EDM process. A precise report utilizing L18 OA tests dependent on the Taguchi technique is directed to comprehend the impact of shifting process parameters including voltage, current, spark gap and electrode measure on the plasma attributes. The line pair technique and the Stark widening of the ghostly line are utilized to figure plasma temperature and electron thickness, individually. The spark gap and electrode measure are found to impact the plasma qualities. The plasma delivered by low energy discharge in smaller scale EDM is more non-perfect, denser, and colder than the high-energy discharge plasma created in the regular EDM process. The bury molecule separate is generally equivalent to the Debye length, bringing about increasingly electrostatic associations between particles.

Jaswin et al. [2] have examined the improvement of the profound cryogenic treatment for En 52 valve steel utilizing the Taguchi strategy in mix with the GRA. The elements considered for the streamlining are the cooling rate, dousing temperature, splashing period, and hardening temperature, each at three distinct dimensions. The mechanical properties, for example, the rigidity, hardness, and wear opposition are chosen as the quality targets. Nine test runs dependent on L9 OA of the Taguchi technique are performed. An ideal parameter blend of the profound cryogenic treatment is gotten by means of the GRA. The ANOVA is connected to recognize the most persuasive factor and it is discovered that the splashing period is the most compelling variable for the profound cryogenic treatment of En 52 valve steel. The consequences of the affirmation tests demonstrate that the rigidity, hardness, and wear obstruction of the profound cryotreatedEn 52 valve steel tests have improved all the while through the ideal blend of the profound cryogenic treatment parameters got from the proposed technique. The improvement in the rigidity, hardness, and wear opposition of the profound cryotreated tests at the enhanced treatment condition on the examples without profound cryogenic treatment is 7.84%, 11.16%, and 46.51%, individually. Through the profound cryogenic treatment, the wear opposition of the En 52 valve steel has improved more contrasted with different reactions.

Aghdeab and Ahmed [3] have studied machining responses such as material removal rate (MRR) and electrode wear ratio (EWR) under the effect of different machining conditions in EDM process. The process parameters taken by them were pulse on time (Ton), pulse off time (Toff) and electrical current (Ip). This work was carried out in order to achieve best MRR and least EWR using copper electrode with fixed diameter (10 mm) for the machining of stainless steel AISI 316L with a constant thickness (0.8 mm). They used different values for the Ton (25, 50 and 75) µs, Toff (9, 18 and 25) µs and Ip (16, 30 and 50). The results of experiments showed the main effects of machining conditions on MRR and EWR. Where, the MRR increased with increasing the Ton, MRR decreased with increasing the Toff and MRR increased with increasing Ip. While, the EWR decreased with increasing the Ton, EWR decreased with increasing Toff until access to a specific Toff then EWR increased with longer Toff and EWR increased with increasing Ip. The maximum MRR is (48.16 mm3/min) at Ton (75 µs), Toff (9 µs) and Ip (50 A) and minimum EWR is (0.179 %) at Ton (75 µs), Toff (9 µs) and Ip (16 A).

Ali et al. [4] have examined the portrayal of type of micro holes delivered by miniaturized scale Electrical Discharge Drilling (small scale EDD) on beryllium copper amalgam utilizing tungsten carbide electrode of 300 m measurement. Utilizing a fixed arrangement of miniaturized scale EDD parameters, smaller scale openings of various angle proportions are bored. They chose structure attributes width, roundness, and decrease points are researched. The gap measurement and roundness are assessed by utilizing SEM and graphical estimation. The smaller scale gap is segmented to measure the depth and decrease edge. The varieties of these structure qualities are plotted against perspective proportion. This test consider demonstrates that measurement, roundness mistake, and decrease point of the small-scale gap increment with the expansion of angle proportion nearly at a similar rate. The electrode wear proportion is not irrelevant for low angle proportion micro hole. Be that as it may, it increments strongly with the expansion of angle proportion.

Prabhu et al. [5] have examined whether smooth surface completion could be acheived by utilizing multiwalled carbon nanotubes (external diameter=10 – 20 nm, length is upto 30μm) in the dielectric. For this, graphite was utilized as an electrode. They detailed that the most predominant factor for SR was current trailed by pulse on time.

Tsai et al. [6] had developed the surface alloying of the composite electrode to improve the surface properties of the work piece. Ball shining EDM was proposed to improve SR. It utilizes hard smooth balls joined to the electrode to frame a plastic mis happening layer on the work piece surface amid sparking, yielding a solidified surface microstructure.

III. MACHINE SPECIFICATIONS

The experiments were carried out on a EDM machine {AGIE CHARMILLES (China), Model SP-1, ACT SPARK} of AGIE Machine Tools Ltd., China installed at Advanced Manufacturing Laboratory of Mechanical Engineering Department, CIPET, Jaipur (Rajasthan), India. The pictorial view of EDM machine tool (Figure 3.1) has the following specifications:

Descriptions	Unit	Value
Machine Dimensions (D, W, H)	mm	1200, 1500, 2200
Machine Weight	Ton	1.720
Tool Travel Length X, Y, Z	mm	320, 250, 250
Work Piece	mm	790, 480, 235
Work Piece Weight	kg	400
Max Electrode	kg	60
Head to Table Distance (Min/Max)	mm	250/500
Dielectric Fluid (Capacity)	L	290
Generator Type		ISOPULSE/R
Machining Current	A	50
Max MRR	mm^3/mi	330
Best Surface Finish	Micro-	0.4
Power Supply Consumption	kVA	10
CNC Type		PC controlled (disk
Monitor		Color
Controlled Axis		3(X, Y-step motor,
Machining Current	A	100
Diagnostic		Embedded

Fig.3.1 : Experimental Setup

IV. PROCESS PARAMETER SELECTION

In the present work, the Taguchi's strategy-based S/N extent, and the reaction surface logic have been used to design the preliminaries and coming about examination of the data assembled.

4.1 Factor's and machine range

In present research work two different DOE methods were adopted for experimental work, so factors were decided for Taguchi method and RSM methodology.

4.2 Pilot Experiments

The purpose of the pilot experiments is to study the variations of the EDM process parameters on performance measures such as cutting rate, MRR and TWR. Also, it is intended to ascertain the range of different parameters required for the two types of experimental design methodology used in this work.

The pilot experiments were performed on EDM {AGIE CHARMILLES (China), Model SP-1, ACT SPARK} (Figure 4.3). Various input parameters varied during the experiments are pulse on time (Ton), pulse off time (Toff), peak current (IP), pressure. The effects of these input parameters are studied on CT,MRR and TWR using one factor at a time approach.

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Fig.4.1. Machine Pictorial View

Following parameters are kept constant at a fixed value during the experiments:
Work Material: Industrial Steel (Grade EN-08)
Cutting Tool: Cu Electrode of diameter 3 mm
Servo Feed: 2010 unit
Flushing Pressure: 1 unit (15 kg/cm2)
Peak Voltage: 2 unit (110-volt DC)
Conductivity of Dielectric: 20 mhos
Work Piece Height: 24 mm
Cutting rate in mm/min and gap current in ampere were directly noted from machine's control panel.

4.2.1 Effect of Input Parameters on Performance Measure Cutting Time

Table 4.1

PILOT EXPERIMENT (ONE FACTOR VARIABLE &VARIABLE & ANOTHER CONSTANT) FOR CT

Ton	CT	Toff	CT	Current	CT	Pressure	CT
50	480	20	465	3	472	0.5	476
75	469	21	393	4	432	0.6	405
100	351	22	412	5	402	0.7	390
125	270	23	430	6	398	0.8	378

4.2.2 Effect of Input Parameters on Performance Measure MRR

Table 4.2

PILOT EXPERIMENT (ONE FACTOR VARIABLE &VARIABLE & ANOTHER CONSTANT) FOR MRR

Ton	MRR	Toff	MRR	Current	MRR	Pressure	MRR
50	16.3	20	16.1	3	16.2	0.5	16.4
75	15.1	21	12.6	4	14.1	0.6	13.1
100	11.3	22	13.3	5	13.6	0.7	12.5
125	8.7	23	13.5	6	12.8	0.8	12.2

4.2.3 Effect of Input Parameters on Performance Measure TWR

Table 4.3

PILOT EXPERIMENT (ONE FACTOR VARIABLE & VARIABLE & ANOTHER CONSTANT) FOR TWR

Ton	TWR	Toff	TWR	Current	TWR	Pressure	TWR
50	44.36	20	44.68	3	45.12	0.5	44.61
75	45.36	21	44.42	4	46.35	0.6	46.25
100	46.35	22	43.25	5	46.14	0.7	46.92
125	46.81	23	42.83	6	45.39	0.8	47.21

4.2.4 Parameter classification and selection of optimal levels

When the ANOVA on the raw data (identifies control parameters which affect average) and S/N data (identifies control parameters which affect variation) are completed, the control parameters may be put into four classes (Ross1988):

Class I: Parameters which affect both average and variation
(Significant in both i.e. raw data ANOVA and S/N ANOVA)

Class II: Parameters which affect variation only
(Significant in S/N ANOVA only)

Class III: Parameters which affect average only
(Significant in raw data ANOVA only)

Class IV: Parameters which affect nothing.
(Not significant in both ANOVAs)

The parameters design strategy is to select the proper levels of class I and class II parameters to reduce variation and class III parameters to adjust the average to the target

4.2.5 Orthogonal Array for current study

Table 4.3

L16 ORTHOGONAL ARRAY FOR PRESENT RESEARCH WORK

S.N.	Ton	Toff	Current	Pressure
1	50	20	3	0.5
2	50	21	4	0.6
3	50	22	5	0.7
4	50	23	6	0.8
5	75	20	4	0.7
6	75	21	3	0.8
7	75	22	6	0.5
8	75	23	5	0.6
9	100	20	5	0.8

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S.N.	Ton	Toff	Current	Pressure
10	100	21	6	0.7
11	100	22	3	0.6
12	100	23	4	0.5
13	125	20	6	0.6
14	125	21	5	0.5
15	125	22	4	0.8
16	125	23	3	0.7

V. RESULTS AND DISCUSSION

The present research study is present the role of EDM process parameters for creating the hole in sheet of thickness of 5 mm made of EN-08 steel material. The selection of process parameters is done using literature review and local industrial survey among operator of EDM machine installed in Jaipur industrial regions. The process parameters which are selected for the present research work are Ton, Toff, current and pressure. Design of experiment method is used to develop the experiment table. Taguchi method is applied for these factors and each have four levels and the developed table is present in table 5.1. All experiments are conduct at CIPET, central tool room where this EDM machine is installed.

Table 5.1

L-16 ORTHOGONAL ARRAY FOR EDM RESEARCH STUDY FOR EN-08 MATERIAL

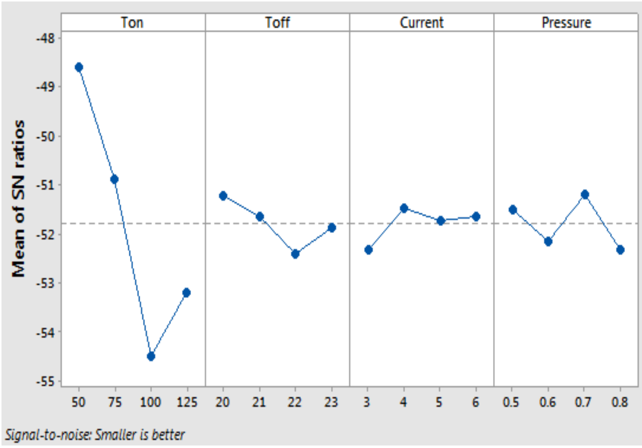
Run	Ton	Toff	Current	Pressure
1	50	20	3	0.5
2	50	21	4	0.6
3	50	22	5	0.7
4	50	23	6	0.8
5	75	20	4	0.7
6	75	21	3	0.8
7	75	22	6	0.5
8	75	23	5	0.6
9	100	20	5	0.8
10	100	21	6	0.7
11	100	22	3	0.6
12	100	23	4	0.5
13	125	20	6	0.6
14	125	21	5	0.5
15	125	22	4	0.8
16	125	23	3	0.7

Each experiment is conduct three times to get more accurate results from EDM machine.

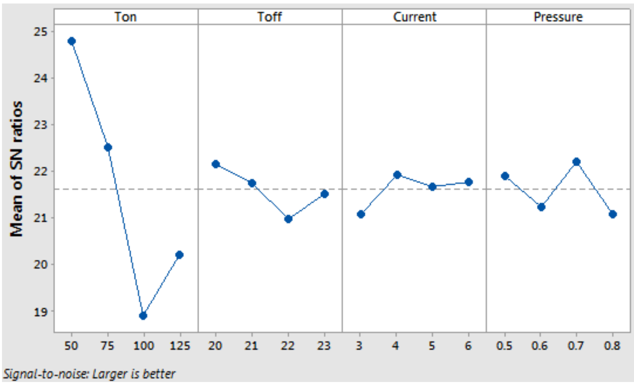
5.1 Signal to Noise ratio analysis

In present test, Signal to noise ratio-based log formula is used to find the rank among all factors for selective response. In present study three responses are selected for finding the rank using S/N ratio method. The theory part is discussed in previous section of this thesis chapters. Detailed analysis of S/N ratio for all response variables are present in following section.

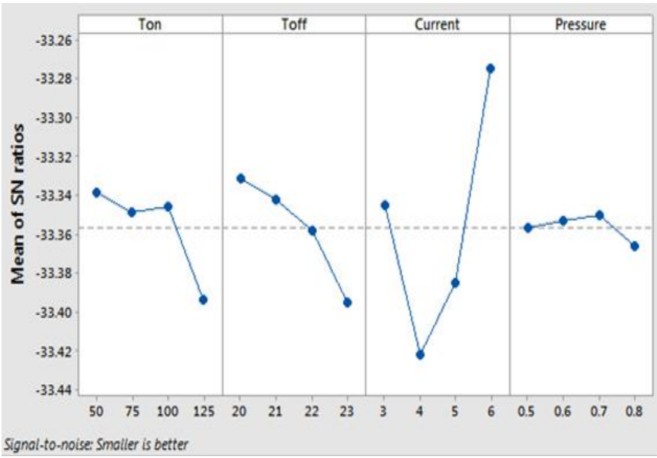
5.1.1 S/N ratio analysis for Cutting Time(CT)



5.1.2 S/N ratio analysis for Material Removal Rate (MRR)



5.1.3 S/N ratio analysis for Tool Wear Rate (TWR)



VI. CONCLUSION AND FUTURE SCOPE

In present experimental research work, effect of process parameters on EDM machine is studied on EN-08 steel base work piece. Experiments are designed as per Taguchi method and total 16 experiments are designed for selective factors and their levels which are present in table 6.1. The main conclusion of present research study is following:

Table 6.1
FACTOR AND LEVELS

Levels	TON (micro sec)	TOFF (micro sec)	CURRENT (Amp)	PRESSURE (kg/cm2)
I	50	20	3	0.5
II	75	21	4	0.6
III	100	22	5	0.7
IV	125	23	6	0.8

The Signal to noise ratio analysis is performed for all three response variables which are CT, MRR and TWR. The rank identification for these variables are present in following table 6.2.

Table 6.2
RANK IDENTIFICATION FOR ALL THREE RESPONSE VARIABLE

Response	First Rank	Second Rank	Third Rank	Fourth Rank
CT	Ton	Toff	Pressure	Current
MRR	Ton	Toff	Pressure	Current
TWR	Current	Toff	Ton	Pressure

Multi objective optimization is performed using CD function optimization for all three-response variables, CT, MRR and TWR and the optimum result for this optimization technique is present here:

Ton	Toff	C	P	TWR	MRR	CT	CD
75.75	20	3	0.569	46.0057	17.58	236.67	0.95

Future Scopes:
Although major outcomes are presented in this paper, but there is some scope of work, which may be analyzed in future study and which are following:
As the person place things, materials systems and machines are different in place to place, effect of different materials on same process parameters like high strength alloys, Role of FEM simulation modeling technique, Effect of different optimization techniques like ANN, Fuzzy Logic, MOGA etc can be taken up for more scientific research.

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