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EXPERIMENTAL INVESTIGATION OF PARAMETERS ON EDM FOR EN 31 STEEL USING A COPPER ELECTRODE

MD.Farid, UG students, Department of Mechanical Engineering, NRI Institute of Technology, Vijayawada, A.P, India-521212.
N. Harsha Vardhan, UG students, Department of Mechanical Engineering, NRI Institute of Technology, Vijayawada, A.P, India-521212.
P. Manikanta, UG students, Department of Mechanical Engineering, NRI Institute of Technology, Vijayawada, A.P, India-521212.
Ms. K. Bhargavi, Assistant Professor, Department of Mechanical Engineering, NRI Institute of Technology, Vijayawada, A.P, India-521212.

ABSTRACT:
The quality of machined components significantly influences their performance and durability. This study investigates the Experimental "Investigation of Parameters on EDM for EN 31 Steel Using A Copper Electrode" by analysing and adjusting machining parameters such as cutting speed, feed rate, and depth of cut, we aim to identify the optimal settings to achieve minimal surface roughness and maximum MRR. A Taguchi design of experiments approach is employed to ensure systematic evaluation. Results reveal that precise control of machining parameters leads to significant improvements in surface finish and productivity.
Keywords: Electrical Discharge Machining (EDM), EN 31 Steel, Copper Electrode, material removal rate (MRR), tool wear rate (TWR)

INTRODUCTION:
This Chapter Describes Electrical Discharge Machining (EDM) is a widely used non-traditional machining process that removes material through controlled electrical sparks. It is particularly beneficial for machining hard materials and complex geometries that are difficult to process using conventional methods. Among the various workpiece materials used in EDM, EN 31 steel is a high-carbon alloy steel known for its excellent wear resistance and high hardness, making it suitable for applications in bearings, dies, and automotive components. The performance of EDM is significantly influenced by various process parameters, including pulse current, pulse duration, voltage, and dielectric fluid. These parameters directly affect machining efficiency, material removal rate (MRR), tool wear rate (TWR),

LITERATURE REVIEWS:
This Chapter Here's a **literature review** section on the **Taguchi Method in Electrical Discharge**
Debasish Mohanty [1] Research on WEDM of EN-31 steel has focused on optimizing process parameters to improve material removal rate (MRR) and surface finish. Studies have investigated the effects of pulse-on time, pulse-off time, table feed, wire feed, and servo voltage on MRR and surface roughness. The optimal parameters for high MRR and good surface finish have been identified, with larger pulse-on time and wire feed, and smaller pulse-off time and servo voltage, resulting in higher MRR. Conversely, lower pulse-on time and wire feed, and higher pulse-off time and servo voltage, result in better surface finish. The findings of this study are consistent with previous research, highlighting the importance of careful parameter selection to achieve desired machining performance.
L. Feroz Ali [2] Research on EDM of EN 8 steel has focused on optimizing process parameters to improve material removal rate (MRR), reduce electrode wear rate (EWR), and enhance surface finish. Taguchi technique has been employed to determine the optimal parameters. Studies have shown that pulse-on time, pulse-off time, peak current, and voltage significantly affect MRR, EWR, and surface

roughness. Analysis of variance (ANOVA) has revealed that MRR and EWR can be improved by optimizing process parameters. Confirmation tests have validated the effectiveness of the optimized parameters, resulting in improved surface finish, reduced TWR, and increased MRR. The findings of this study are consistent with previous research, highlighting the importance of process parameter optimization in EDM.

PARTH KUMAR.S.PATEL [3] This study investigated the effects of process parameters on EDM of EN47 spring steel using Copper, Graphite, and Tungsten Carbide Coated Copper electrodes. The results showed that Copper electrode achieved the highest material removal rate (MRR) of 40.49 mm3/min, while Graphite electrode obtained the best surface roughness (Ra) of 2.25 µm. Graphite and Copper electrodes exhibited low tool wear rates (TWR) of 0.029 mm3/min. The study demonstrated that optimizing process parameters, such as pulse-on time, pulse-off time, current, and voltage, can significantly improve EDM performance. The findings provide valuable insights for selecting optimal electrodes and process parameters for EDM of EN47 spring steel, leading to improved machining efficiency and surface quality.

Somnath M. [4] This study investigated the effects of machining parameters on material removal rate (MRR) in EDM of Inconel 718. The results showed that current is the most significant parameter affecting MRR, with a maximum MRR obtained at 50 A. Voltage and pulse-on time had less significant effects on MRR, with initial increases followed by decreases. Response surface methodology (RSM) and Minitab software were used to model and optimize the process. The study demonstrates the importance of careful parameter selection to achieve optimal MRR in EDM of Inconel 718. The findings provide valuable insights for improving EDM efficiency and surface quality in machining of this challenging alloy..

Ashok Kumar [5] This study investigated the feasibility of machining EN-19 tool steel using a U-shaped tubular copper electrode and internal flushing by electric discharge machine. The effects of current, pulse-on time, and electrode diameter on material removal rate (MRR), tool wear rate (TWR), and overcut (OC) were examined. The results showed that current has a significant impact on MRR, while pulse-on time has a negative effect. The optimal MRR of 4.634 mm3/min was achieved at a pulse-on time of 50 µs. The study demonstrates the potential of using U-shaped electrodes in EDM for machining complex geometries in hard-to-machine materials like EN-19 tool steel.

Komal K [6] This study reviews the effects of machining parameters on EDM performance measures such as material removal rate (MRR), radial overcut (ROC), electrode wear rate (EWR), and surface roughness (SR). The results show that peak current, pulse-on time, and gap voltage significantly affect MRR, while peak current and pulse-on time influence EWR. Radial overcut is mainly affected by peak current, duty cycle, and pulse-on time. Surface roughness increases with discharge current and pulseoff time, but decreases with pulse-on time. The study highlights the importance of optimizing machining parameters to improve EDM efficiency and performance. The findings provide valuable insights for controlling EDM process parameters to achieve desired outcomes.

Prem Prakash [7] This review paper examines the optimization of Electrical Discharge Machining (EDM) process parameters, focusing on Material Removal Rate (MRR), Tool Wear Rate (TWR), Relative Wear Ratio (RWR), and Surface Roughness (SR). EDM performance is influenced by parameters such as discharge current, pulse on/off time, arc gap, duty cycle, and wire feed. Various optimization techniques, including traditional and non-traditional methods, have been employed to improve EDM efficiency. The review highlights the importance of identifying optimal process parameters and suitable optimization techniques for specific EDM applications. The findings provide valuable insights for researchers and practitioners seeking to enhance EDM performance and productivity. The review also identifies areas for future research, including the development of hybrid optimization techniques.

Jithin ambarayil joy [8] This study investigates the optimization of process parameters in Electrical Discharge Machining (EDM) of En31 tool steel to improve material removal rate (MRR) and surface roughness (SR). The results show that pulse-on time, current, and voltage are significant factors affecting MRR and SR. The optimum values of MRR and SR were found to be 0.252 g/min and 5.02 µm, respectively. The study highlights the importance of interaction effects between process parameters, particularly between current and pulse-on time, and pulse-on time and spark gap. The findings provide valuable insights for optimizing EDM process parameters to achieve desired performance characteristics in machining En31 tool steel.

K.S Morankar [9] This study investigates the optimization of electrical discharge machining (EDM) process parameters for SCM420 low alloy steel using response surface methodology. The effects of peak current, pulse-on time, and gap voltage on material removal rate (MRR) and surface roughness (Ra) were examined. The results show that pulse-on time has significant effects on MRR and Ra, while peak current is the most significant parameter for Ra. The optimal process parameters were found to be 22 A peak current, 460 µs pulse-on time, and 25 V gap voltage. The study demonstrates the effectiveness of response surface methodology in optimizing EDM process parameters for improved machining performance. The findings provide valuable insights for manufacturers seeking to optimize EDM processes for SCM420 low alloy steel.

Gill Road [10] This study investigates the optimization of machining parameters in dry electric discharge machining (Dry EDM) of EN31 steel using oxygen gas as a dielectric medium. The effects of polarity, discharge current, gas flow pressure, pulse-on time, RPM, and gap voltage on material removal rate (MRR), tool wear rate (TWR), and surface roughness (Ra) were examined. The results show that discharge current and pulse-on time significantly affect MRR, while gas flow pressure, pulse-on time, and RPM significantly affect TWR. The study demonstrates the potential of dry EDM for achieving lower TWR and better surface roughness. The findings provide valuable insights for optimizing machining parameters in dry EDM of EN31 steel.

Abhishek Thakura [11] This study investigates the optimization of machining parameters in Electric Discharge Machining (EDM) of stainless steel 316. The effects of discharge current, pulse-on time, pulse-off time, and dielectric pressure on material removal rate (MRR) and surface roughness (SR) were examined. The results show that discharge current and pulse-on time have significant effects on MRR, while pulse-off time has a minimal effect. Analysis of variance (ANOVA) and signal-to-noise ratio (S/N ratio) were used to optimize the process parameters. The study demonstrates the importance of optimizing machining parameters to achieve improved MRR and SR in EDM of stainless steel 316. The findings provide valuable insights for manufacturers seeking to optimize EDM processes for stainless steel 316

Nadeem Faisal [12] This study investigates the optimization of machine process parameters in Electrical Discharge Machining (EDM) for EN 31 steel using evolutionary optimization techniques. The study employs Particle Swarm Optimization (PSO) and Biogeography-Based Optimization (BBO) techniques to optimize material removal rate (MRR) and surface roughness (Ra). The results show that BBO outperforms PSO in terms of computational time, percentage error, and optimized values. The study demonstrates the effectiveness of evolutionary optimization techniques in optimizing EDM process parameters for improved machining performance. The findings provide valuable insights for manufacturers seeking to optimize EDM processes for EN 31 steel. The study highlights the potential of BBO as a cost-effective solution for establishing optimum process parameters.

Anand R. Patel [13] This review paper discusses the optimization of process parameters in Wire Electric Discharge Machining (WEDM) for machining special steel. The study investigates the effects of pulse-on time, pulse-off time, and voltage on performance measures such as cutting rate and gap current. The Taguchi method and Genetic Algorithm are employed to optimize the output parameters.

The results show that optimal sets of process parameters can be obtained for various performance measures using Taguchi's design of experiment methodology. The study highlights the importance of optimizing WEDM process parameters to achieve improved machining performance and productivity. The findings provide valuable insights for manufacturers seeking to optimize WEDM processes for special steel machining.

Anand R. Patel [14] This study investigates the effects of machining parameters on material removal rate (MRR) and tool wear rate (TWR) in electrical discharge machining (EDM) of En 31 steel using a rectangular-shaped copper tool. The parameters examined include discharge current, pulse-on time, and voltage. The results show that discharge current is the most significant factor affecting MRR and TWR, followed by pulse-on time and tool diameter. The study demonstrates the importance of optimizing machining parameters to achieve improved EDM performance. The findings provide valuable insights for manufacturers seeking to optimize EDM processes for En 31 steel machining

Goutam Dubey [15] This study investigates the optimization of process parameters for rotary Electro Discharge Machining (EDM) of EN31 tool steel using a copper electrode. The effects of peak current, voltage, duty cycle, and electrode rotation on material removal rate (MRR), tool wear rate (TWR), and machining rate (MR) were examined. The results show that peak current and voltage have significant effects on MRR and TWR. The study demonstrates the importance of optimizing process parameters to achieve improved rotary EDM performance. The findings provide valuable insights for manufacturers seeking to optimize rotary EDM processes for EN31 tool steel machining. The study highlights the potential of rotary EDM for machining hard-to-machine materials like EN31 tool steel.

S. Suthan [16] This study investigates the optimization of process parameters in wire electrical discharge machining (WEDM) of stainless steel 316L using a copper wire electrode. The effects of pulse-on time, pulse-off time, and gap current on surface roughness and material removal rate were examined. The results show that pulse-off time has the most significant effect on surface roughness, while pulse-on time has a significant effect on material removal rate. The study employs the Taguchi technique and ANOVA to optimize the WEDM process parameters. The findings provide valuable insights for manufacturers seeking to optimize WEDM processes for stainless steel 316L machining.

Ms. Pallavi [17] This study investigates the effect of Electrical Discharge Machining (EDM) process parameters on tool wear using EN 31 tool steel. The parameters examined include discharge current, pulse-on time, and pulse-off time. The results show that discharge current has the most significant effect on tool wear, followed by pulse-on time and pulse-off time. The study employs the Taguchi method using an L9 orthogonal array to analyze the effects of the process parameters on tool wear. The findings provide valuable insights for manufacturers seeking to minimize tool wear and optimize EDM processes for EN 31 tool steel machining..

Prof. M. S. Shinge1 [18] This study investigates the optimization of process parameters in wire electrical discharge machining (WEDM) of EN31 steel. The effects of pulse-on time, pulse-off time, peak current, and wire tension on machining time and surface roughness were examined. The Taguchi method was used to determine the optimal parametric combinations. The results show that the optimal parameters for minimizing machining time and surface roughness are different. The study provides valuable insights for manufacturers seeking to optimize WEDM processes for EN31 steel machining. The findings can be used to improve the efficiency and accuracy of WEDM processes, leading to enhanced product quality and reduced production costs.

Ashwani Kharol [19] This study investigates the effects of discharge current on machining parameters in electrical discharge machining (EDM) of hard steels using copper and aluminium electrodes. The parameters examined include metal removal rate (MRR), tool removal rate (TRR), and surface roughness. The results show that discharge current significantly affects MRR, TRR, and surface roughness. The study demonstrates the importance of optimizing EDM process parameters to achieve improved machining performance. The findings provide valuable insights for manufacturers seeking

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to optimize EDM processes for hard steel machining. The study highlights the potential of EDM for machining difficult-to-machine materials and suggests avenues for future research, including the use of alternative electrode materials and workpiece materials.
R. Shanmugar Pragash [20] This study investigates the optimization of machining parameters in Electrical Discharge Machining (EDM) of SS 317 steel using copper and brass electrodes. The effects of pulse-on time, pulse-off time, and current on material removal rate (MRR) and electrode wear rate (EWR) were examined using a full factorial design. The results show that higher MRR is achieved with higher current and pulse-on time, while lower EWR is achieved with lower current and pulse-off time. The study demonstrates the effectiveness of factorial design in optimizing EDM process parameters. The findings provide valuable insights for manufacturers seeking to optimize EDM processes for SS 317 steel machining

EXPERIMENTAL DETAILS :
This Method experimental setup for EDM machining process is designed to systematically examine and optimize machining performance, particularly focusing on parameters such as surface roughness and material removal rate (MRR). A detailed arrangement of equipment, tools, and processes ensures precise and reliable machining of materials like EN 31 steel.
SELECTION OF PROCESS VARIABLES
A total of three process variables and three levels are selected for the experimental procedure.
The deciding process variables are
Voltage (V) is the electromotive force that drives electric current through a circuit**.**
pulse On Time (Ton) is the duration for which the electrical discharge is active, typically measured in microseconds (μs).
Discharge On Time (Ton) is the time duration during which the electrical discharge

DESIGN OF EXPERIMENT:
By using minitab-16 software insert the 3 factors and 3 levels in Taguchi design of experiment method I got the following array and design of steps to perform experiment. Taguchi Orthogonal Array Design L9(3**3)

- Factors: 3
- Runs: 9

Table 1 : Selection of process variables

Ma c h in in g p a r a me t e r s	Symbol	Unit	Level		
			Level 1	Level 2	Level 3
Voltage	V	V	1	2	3
Pulse on time	Ton	μs	5	7	9
Discharge current	Ip	A	4	6	8

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Fig 1: Maching process Fig 2: After machining material

Table 2: observation table

Exp. no	Current (Ip)	Voltage(v)	T-on	Weight of workpiece (Wjb-Wja)	Weight of tool (Wjb-Wja)	Time (min)
1	4	1	5	5.115	0.0682	19:45
2	4	1	5	4.575	0.0610	16:52
3	4	1	5	4.61	0.064	20:02
4	4	2	7	4.65	0.082	15:11
5	4	2	7	6.915	0.083	12:32
6	4	2	7	6.24	0.162	13:55
7	4	3	9	8.715	0.128	12:32
8	4	3	9	8.215	0.134	11:44
9	4	3	9	6.96	0.074	9:01
10	6	1	5	9.33	0.072	11:37
11	6	1	5	8.31	0.064	14:02
12	6	1	5	8.715	0.0812	12:32
13	6	2	7	6.145	0.0991	6:45
14	6	2	7	4.65	0.124	6:36
15	6	2	7	5.125	0.0724	5:31
16	6	3	9	6.125	0.0841	8:42
17	6	3	9	5.565	0.0621	9:32
18	6	3	9	4.985	0.0661	9:21
19	8	1	5	4.65	0.0661	5:31
20	8	1	5	4.325	0.0721	5:44
21	8	1	5	4.815	0.0841	5:21
22	8	2	7	5.115	0.0921	9:47
23	8	2	7	8.19	0.121	9:02
24	8	2	7	8.4	0.107	8:39
25	8	3	9	7.415	0.0734	7:27
26	8	3	9	6.15	0.0621	7:47
27	8	3	9	5.246	0.0624	7:37

Calculations for M.R.R, T.W.R

1. Evaluation of MRR-

The material MRR is expressed as the ratio of the difference of weight of the workpiece before and after machining to the machining time and density of the material.
$MRR = Wjb - Wja / t \times p$

Where as

Wjb = Weight of workpiece before machining.
Wja = Weight of workpiece after machining.
t = Machining time = 1.00 hr.
p = Density of EN-19 steel material $=7.9 gm/cm^3$

2. Evaluation of tool wear rate

TWR is expressed as the ratio of the difference of weight of the tool before and after machining to the machining time. That can be explain these equations
$TWR = Wjb - Wja / t$

Where as

Wtb = Weight of the tool before machining.
Wta = Weight of the tool after machining.
t = Machining time (In this experiment the machining time is one hour).

RESULTS AND DISCUSSIONS:

The experimental data have been optimized with Taguchi's design of experiment. For the analysis of these data Minitab 16 software has been used. The results obtained by the above software.

TAGUCHI METHOD:

Step 1: Define the Problem and Objectives

1. Problem statement: Optimize cutting parameters to minimize surface roughness and maximize material removal rate during turning of stainless steel on a CNC lathe machine.
2. Objectives: Minimize surface roughness (Ra) and maximize material removal rate (MRR).
3. Constraints: Cutting tool life, machine limitations, and workpiece material properties.

Step 2: Select the Control Factors

1. Control factors: voltage (V), pulse on time (Ton), discharge current (IP),
2. Levels for each control factor: Typically 2-5 levels, e.g., voltage (1, 2, 3,).
3. Selection of control factors: Based on literature review, expert opinion, and preliminary experiments.

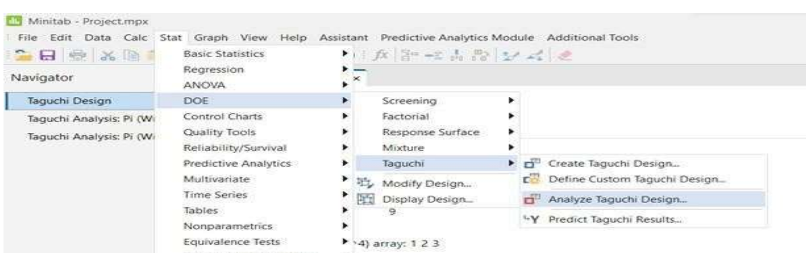

Fig 3: Taguchi Design Process.

Step 3: Choose an Orthogonal Array

1. Orthogonal array (OA): Select an OA based on the number of control factors and levels, e.g., L9,.
2. OA selection criteria: Ensure the OA can accommodate the number of experiments required and provides adequate resolution.

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Table 3: Parameters, codes, levels used for orthogonal array.

Ma c h in in g p a r a me t e r s	Symbol	Unit	Level		
			Level 1	Level 2	Level 3
Voltage	V	V	1	2	3
Pulse on time	Ton	µs	5	7	9
Discharge current	Ip	A	4	6	8

Table 4: response sheet

Exp No.	Ip (A)	V (v)	Ton (µs)	MRR (mm3/min)	TWR (gm/min)
1	4	1	5	12.59	0.00541
2	4	1	5	9.93	0.0036
3	4	1	5	11.68	0.0037
4	4	2	7	8.89	0.0041
5	4	2	7	10.78	0.0066
6	4	2	7	10.70	1.127
7	4	3	9	13.58	0.0131
8	4	3	9	11.68	0.011
9	4	3	9	7.93	0.014
10	6	1	5	13.42	0.0065
11	6	1	5	14.74	0.005
12	6	1	5	13.59	0.0051
13	6	2	7	5.017	0.0125
14	6	2	7	3.74	0.0155
15	6	2	7	3.44	0.023
16	6	3	9	6.68	0.008
17	6	3	9	6.56	0.009
18	6	3	9	5.851	0.006
19	8	1	5	3.019	0.0128
20	8	1	5	2.97	0.013
21	8	1	5	3.17	0.0161
22	8	2	7	6.131	0.0027
23	8	2	7	9.35	0.013

24	8	2	7	8.92	0.012
25	8	3	9	6.82	0.0107
26	8	3	9	5.81	0.0081
27	8	3	9	4.89	0.0078

The experimental data have been optimized with Taguchi's design of experiment. For the analysis of these data Minitab 16 software has been used. The results obtained by the above software.

ANALYSIS OF DATA AND DISCUSSION :

The data obtained from the experiments has been analyzed in a series of standard steps as discussed when they change from one level to another level are calculated and plotted as response curves. The response curves are the average value of the characteristic and average MRR values versus level of process parameters. The response curves are used as an aid to visualize the parametric effect on selected quality characteristics. The ANOVA identifies the significant parameters and quantifies their effect on the selected quality characteristics. Associated with each response curve is the MRR curve, which is used to keep in the selection

Table.5 Response for S/N Rations Larger is better (MRR)

Table.6 Response table for means Larger is better (MRR)

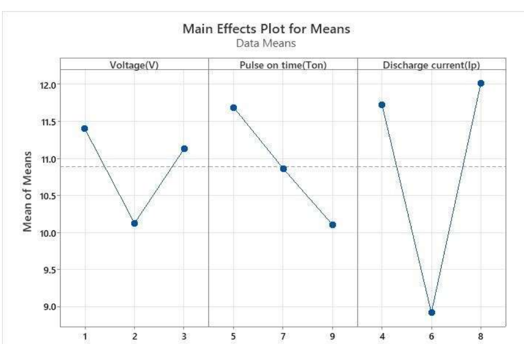
Response Table for Means

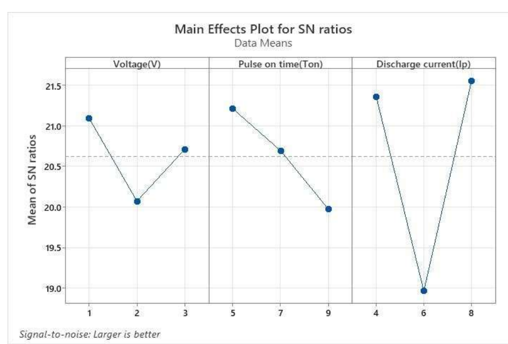
Level	Voltage(V)	Pulse on time(Ton)	Discharge current(Ip)
1	11.400	11.687	11.723
2	10.123	10.863	8.917
3	11.130	10.103	12.013
Delta	1.277	1.583	3.097
Rank	3	2	1

Response Table for Signal to Noise Ratios

Larger is better

Level	Voltage(V)	Pulse on time(Ton)	Discharge current(Ip)
1	21.10	21.21	21.36
2	20.07	20.70	18.97
3	20.71	19.97	21.55
Delta	1.02	1.24	2.59
Rank	3	2	1



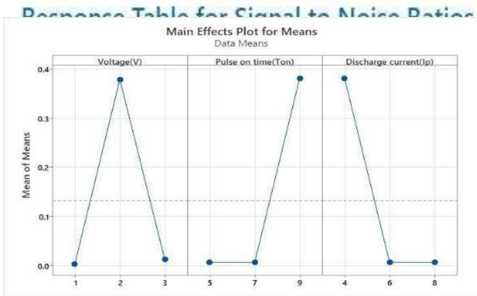


Graph 1 main effects plot for means

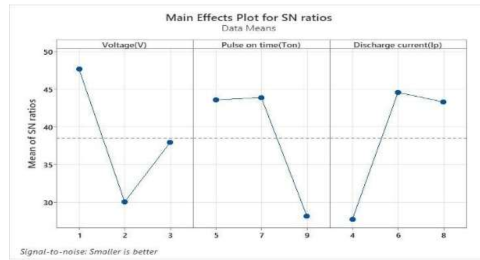
Graph 2 main effects plot for SN ratio

Table.7 Response for S/N Rations smaller is smaller is better (TWR)

Table.8 Response table for means better (TWR)



Graph 3 main effects plot for means



Graph 4 main effects plot for SN ratio

CONCLUSION:

In the present study on the effect of machining responses are MRR and TWR of the EN 31 steel component using the Rectangular-Shaped cu tool with Jet flushing system tool have been investigated for EDM process. The experiments were conducted under various parameters setting of Discharge Current (Ip), Pulse On-Time (Ton), and Voltage(v). L-18 OA based on Taguchi design was performed for Minitab software was used for analysis the result and theses responses were partially validated experimentally. Finding the result of MRR discharge current is most influencing factor and then pulse duration time and the last is diameter of the tool. MRR increased with the dis- charge current (Ip). As the pulse duration extended, the MRR decreases monotonically

In the case of Tool wear rate, the most important factor is discharge current then pulse on time and after that diameter of tool.

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