Optimization of MRR & TWR of Meso Holes on EN_31 Steel using Electrical Discharge Drilling

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Abstract

The current study focuses on the drilling of meso-holes in EN_31 steel using electrical discharge drilling (EDD). Experimental analyses were conducted using an EDD machine, with process parameters including depth of hole, current, T_ON (on-time), and T_OFF (off-time). To optimize machining characteristics, a Taguchi L-27 orthogonal array design of experiment was employed. The main response variables studied were material removal rate & Tool wear rate with the use of a 0.8mm diameter brass & Copper tubular electrode. Additionally, microstructure analysis was conducted using microscopic instruments to examine the results in detail.

Keywords— Electrical Discharge Drilling, EN_31 steel, Material removal rate, DOE, Taguchi_L27 OA.

1. Introduction

Recent years the growing demands for miniaturized components across various sectors, including automotive, aerospace, medical, and electronics manufacturing. To meet increasingly stringent design specifications and tight tolerances, micro-meso machining technologies have been established and are continuously evolving. Traditional machining methods using EN_31 Steel often fall short in terms of efficiency, quality, cost-effectiveness, and adaptability [1, 2]. Electric Discharge Machining (EDM) offers a solution to these manufacturing challenges, albeit with its own set of issues, particularly when attempting to machine high aspect ratios. To address this challenge, researchers have explored the use of rotating tube electrodes in EDM [3, 4]. However, there is a noticeable scarcity of studies discussing EDM with rotating tube electrodes. Among these, Nivin V and Arun. B. K utilized copper and brass rotating tubes with an inner diameter of 0.8 mm to perform EDM on EN41 steel, optimizing their techniques based on Grey and Taguchi methodologies [5, 6]. Following Taguchi's approach, Priyaranjan et al. conducted EDM on an AISI tool using a copper and brass rotating tube electrode [7]. This paper introduces a novel approach to

Electric Discharge Drilling (EDD), employing a high-quality rotary brass tube electrode with a 0.8mm diameter, facilitating the creation of meso- holes at both the entry and exit points within hard materials like EN_31 Steel. This innovative technique serves as a catalyst for advancing EDD in the context of high aspect ratio meso-hole drilling. Table 1 and Table 2 provide comprehensive data on the metallurgical properties of both the electrode (brass tube) and the workpiece (EN_31 Steel).

Table 1. Chemical Composition of Workpiece (EN_31 Steel)

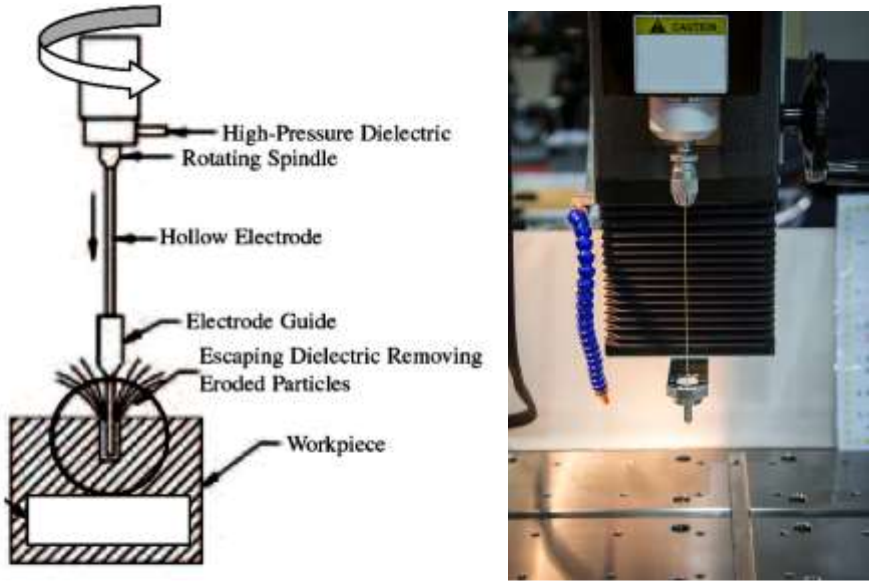
Element	C	Mn	Si	Cr	Mo	V	P	S
%	1.05	0.50	0.27	1.05	0.02	0.01	0.057	0.072

Table 2. Chemical Composition of Brass Tube Electrode

Element	Cu	Al	Tn	P	L	Fe	Z	Ni
%	56.7	0.03	0.02	0.02	3	0.1	39.85	0.08

2. Experimental Approach

In this research, we utilized EN_31 steel as the workpiece material, varying its thickness between 10, 15, and 20 mm. The tool was a commercially available 0.8mm brass rotary tube electrode. All experimental procedures were carried out using the Sparkonix EDM drill – speed II machine. Figure 1 provides a schematic illustration of the experimental setup, highlighting key components using color codes, including the workpiece, tube electrode, dielectric (deionized water), tank, and processing unit. The Processing unit played a crucial role in controlling essential parameters like RPM, current, Gap voltage, on-time, and off-time to regulate the machine's performance.



(a) (b)

Figure 1. Electrical Discharge Drilling (a) Schematic Diagram and (b) setup

The experiments were conducted following a Taguchi's orthogonal arrangement, specifically employing a 3-level, 4-factor L27 design. The process parameters considered for this design included the depth of the hole, current, time on, and time off. Table-4 displays the arrangement for this standard L27 Taguchi's experimental setup. Additionally, Table-3 presents the EDM settings alongside other consistent experimental parameters employed in this study.

Table 3. EDD parameters for Meso hole drilling of EN_31

Parameters	**Range**
Dielectric type	Deionised water
Work piece	EN_31
Work piece dimension	100 mm *50mm*10 mm
Electrode Material	Brass tube
Electrode dimensions	0.8mm diameter 400 mm Length
Depth of hole	10 15 20 mm
Current	3 6 9 Amps
ON_Time	6 8 10 µs
OFF_Time	2 3 4 µs

Figure 2. Meso holes Produced on EN_31 Steel by Electrical Discharge Drilling with 10mm, 15mm, 20mm thickness

3. Results and Discussion

- **Analysis of Material Removal Rate in Meso Holes by EDD With Brass and copper Tube electrode**

The Experimental results of material removal rate in meso holes by EDD with Brass Tube electrode are list table 4.

Table 4. Experimental Results of MRR on EN-31 of Meso holes by EDD with Brass tube electrode

Expt. No	Depth	Current	T_ON	T_OFF	MRR with Brass Electrode	MRR Copper Electrode
1	10	3	6	2	12.78	8.648
2	10	3	6	2	12.50	8.681
3	10	3	6	2	12.91	8.830
4	10	6	8	3	12.83	8.542
5	10	6	8	3	12.24	8.547
6	10	6	8	3	13.46	9.649
7	10	9	10	4	12.98	9.656
8	10	9	10	4	12.10	8.169
9	10	9	10	4	12.17	8.428
10	15	3	8	4	12.37	8.808
11	15	3	8	4	12.44	8.570
12	15	3	8	4	12.29	8.412
13	15	6	10	2	13.41	9.279
14	15	6	10	2	13.61	9.362
15	15	6	10	2	12.75	9.972
16	15	9	6	3	12.78	10.597
17	15	9	6	3	12.80	10.333
18	15	9	6	3	12.43	9.857
19	20	3	10	3	13.87	8.692
20	20	3	10	3	14.35	8.529
21	20	3	10	3	13.40	9.197
22	20	6	6	4	12.18	8.614
23	20	6	6	4	12.71	8.255
24	20	6	6	4	12.22	8.529
25	20	9	8	2	13.34	9.695
26	20	9	8	2	12.32	9.131
27	20	9	8	2	12.71	9.127

With Brass Tube electrode the MRR values vary between the experiments. For each drilling depth, as the current increases (3A → 6A → 9A), the MRR generally shows an increasing and Variation in T_ON and T_OFF also affects MRR. For example, Experiment 13 with 6A current, 10 T_ON, and 2 T_OFF has a higher MRR (13.41) compared to Experiments 14 and 15 with similar parameters but different T_ON and T_OFF. The relationship between the pulse on-time and pulse off-time and MRR isn't direct, and there seems to be some interaction with other factors. In case of Copper tube electrode, Higher Depth and Current values tend to result in higher Material Removal Rates (MRR), suggesting that increasing depth and current could lead to faster material removal. Shorter Turn-On and Turn-Off times are associated with higher MRR values, indicating that more continuous operation of the process might be more efficient for material removal Experiment 16 with 15mm depth, 9A current, 6 T_ON, and 63T_OFF has a higher MRR (10.597)

Table: 5. Response Table for Signal to Noise Ratios for Brass Tube Electrode

Level	Depth	Current	T_ON	T_OFF
1	22.04	22.26	22	22.22
2	22.11	22.14	22.04	22.35
3	22.27	22.01	22.38	21.85
Delta	0.23	0.24	0.38	0.5
Rank	4	3	2	1

Table.5. shows the response table outlines Signal-to-Noise Ratios (SNRs) analysis for optimizing Brass Tube Electrode performance. SNRs are used to assess the quality of performance, with lower values indicating better results. Parameters like "Depth," "Current," "T_ON" (Turn-On Time), and "T_OFF" (Turn-Off Time) are studied across different levels. The table provides insights into parameter effects and rankings for achieving improved Brass Tube Electrode performance.

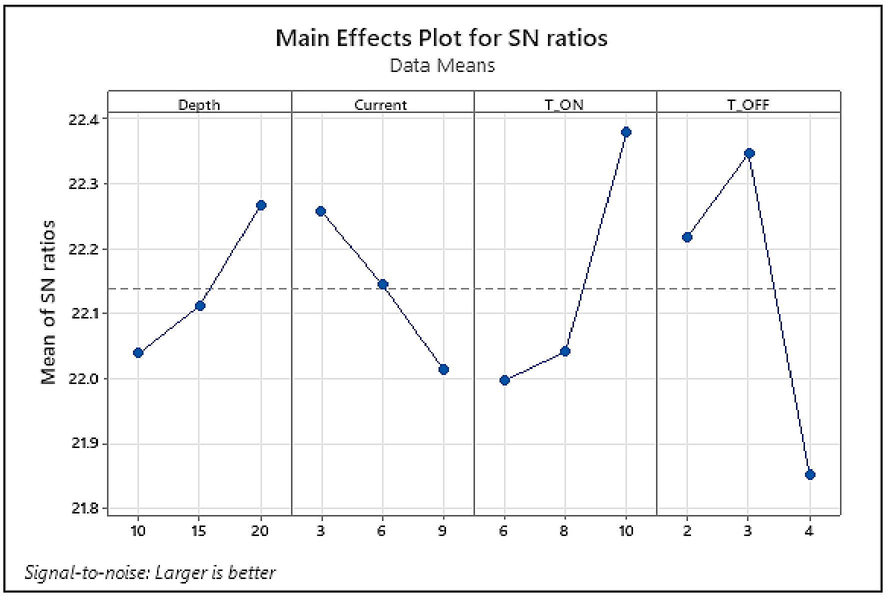


Figure 3 . S/N ratio MRR of EN_31 by Brass tube electrode

From Fig .3, S/N Graph the combination is A3-B1-C3-D2 i.e (Depth of hole 20mm, Current 3 Amps, T_ON 10 µs, T_OFF 3 µs.) the combination matches with Taguchi L 27 OA ie Trail 20 with maximum Material Removal rate 14.35 mm3/min

Regression Analysis of MRR on Meso holes drilling in EN_31 steel by EDD using Brass electrode

Regression Analysis is carried by regression mathematical equation in which predicted valves are compared with experimental values table 6. In Fig 3 its clears show that Experiment values are closely correlating with predicated values of material removal rate of meso holes .

Table: 6. Comparison of Experiment and predicted Material removal rate of EN_31 Meso Holes with Brass Tube electrode

Expt. No	Experiment MRR	Predicted MRR	% Error
1	12.78	12.80	-0.02
2	12.50	12.80	-0.30
3	12.91	12.80	0.11
4	12.83	12.64	0.19
5	12.24	12.64	-0.40
6	13.46	12.64	0.82
7	12.98	12.48	0.50
8	12.10	12.48	-0.38
9	12.17	12.48	-0.31
10	12.37	12.72	-0.35
11	12.44	12.72	-0.28
12	12.29	12.72	-0.43
13	13.41	13.38	0.03
14	13.61	13.38	0.23
15	12.75	13.38	-0.63
16	12.78	12.33	0.45
17	12.80	12.33	0.47
18	12.43	12.33	0.10
19	13.87	13.46	0.41
20	14.35	13.46	0.89
21	13.40	13.46	-0.06
22	12.18	12.42	-0.24
23	12.71	12.42	0.29
24	12.22	12.42	-0.20
25	13.34	13.08	0.26
26	12.32	13.08	-0.76
27	12.71	13.08	-0.37

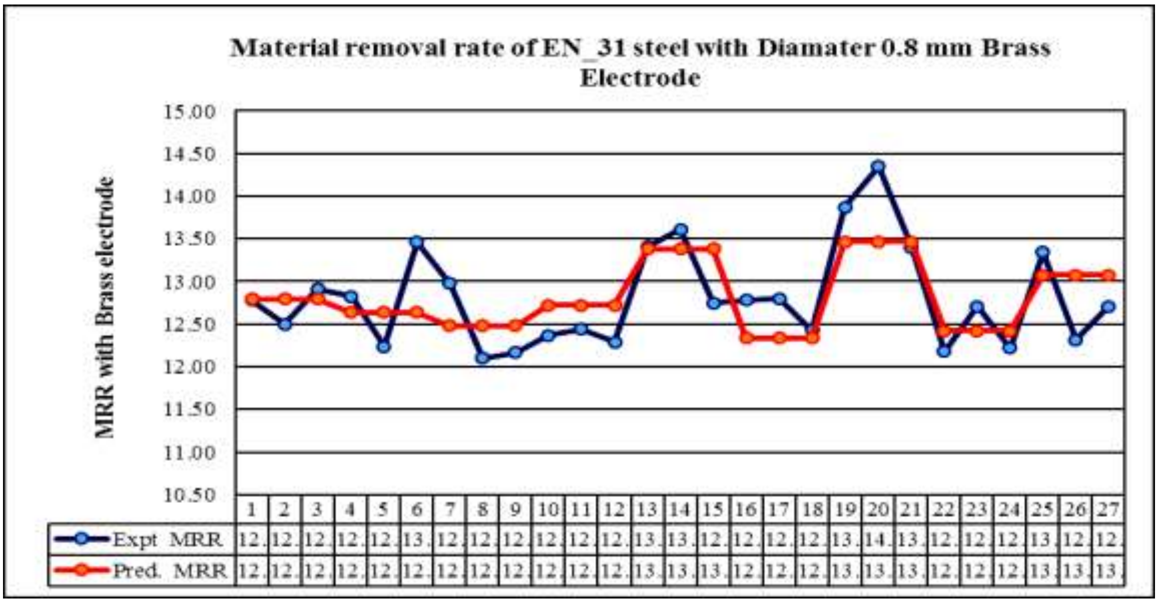


Figure 4. Comparison of Experiment and Predicted Material Removal Rate of EN_31 by Brass tube electrode

Table: 7 Analysis of Variance of Material removal rate of EN_31 Meso holes

Source	DF	Adj SS	Adj MS	% Contribution
Depth	2	0.5761	0.2880	6.64
Current	2	0.5991	0.2996	6.90
T_ON	2	1.8672	0.9336	21.52
T_OFF	2	2.6650	1.3325	30.72
Error	18	2.9689	0.1649	34.22
Total	26	8.6764	******	100.00

From Table: 7. Anova analysis is carried out with most influence factors on process parameter of Machining of meso holes on EN31 steelT_OFF" has the highest contribution, explaining 30.72% of the variance. This suggests that T_OFF plays a significant role in influencing Material Removal Rate. "T_ON" follows closely, contributing 21.52% to the total variance. "Depth" and "Current" have comparatively lower contributions, accounting for 6.64% and 6.90%, respectively. "Error" reflects unexplained variability or experimental error, contributing 34.22% to the total variance.

S/N ratio of material removal rate in meso holes by EDD with Copper Tube electrode

Table.8. shows the response of Signal-to-Noise Ratios (SNRs) analysis conducted with a copper tube electrode. The analysis involves varying parameters such as "Depth," "Current," "T_ON", and "T_OFF across different levels. The SNR values are utilized to gauge the quality for higher the MRR with electrode performance, with lower values indicating preferable outcomes. The ranking system, denoted by the "Rank" row, further emphasizes the parameter's impact on performance improvement. Contextual understanding is crucial for a comprehensive interpretation of these results in the context of electrode optimization.

Table 8. Response Table for Signal to Noise Ratios with copper tube electrode

Level	Depth	Current	T_ON	T_OFF
1	18.85	18.79	19.19	19.25
2	19.49	19.03	19.01	19.35
3	18.94	19.45	19.08	18.67
Delta	0.64	0.66	0.19	0.68
Rank	3	2	4	1

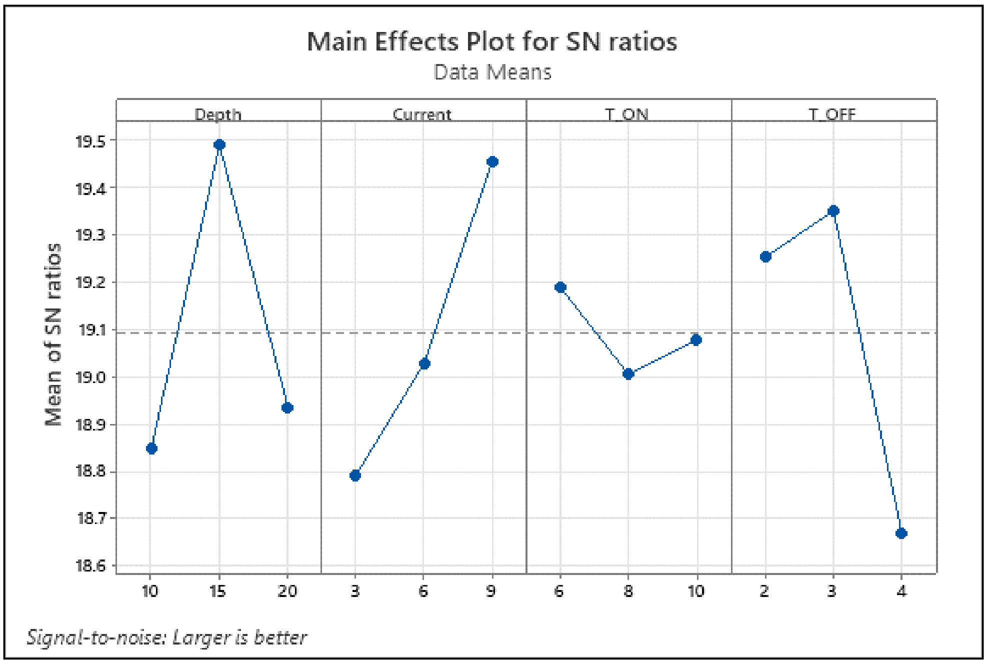


Figure.5. S/N ratio Material Removal Rate of EN_31 meso holes by Copper tube electrode

From Fig .5, S/N Graph the combination is A2-B3-C1-D2 i.e (Depth of hole 15mm, Current 9 Amps, T_ON 6 µs, T_OFF 3 µs.) the combination matches with Taguchi L 27 OA ie Trail 16 with maximum Material Removal rate 10.597 mm3/min

Regression Analysis of MRR on Meso holes drilling in EN_31 steel by EDD using Copper electrode

Table 9. Experimental Results of Material removal rate on EN-31 of Meso holes by EDD with Copper tube electrode

Expt. No	Experiment MRR	Predicted MRR	% Error
1	8.65	8.99	-3.95
2	8.68	8.99	-3.55
3	8.83	8.99	-1.81
4	8.54	9.01	-5.42
5	8.55	9.01	-5.36
6	9.65	9.01	6.68
7	9.66	9.02	6.59

Expt. No	Experiment MRR	Predicted MRR	% Error
8	8.17	9.02	-10.42
9	8.43	9.02	-7.03
10	8.81	8.38	4.90
11	8.57	8.38	2.25
12	8.41	8.38	0.41
13	9.28	9.27	0.06
14	9.36	9.27	0.93
15	9.97	9.27	7.00
16	10.60	9.47	10.68
17	10.33	9.47	8.39
18	9.86	9.47	3.97
19	8.69	8.65	0.53
20	8.53	8.65	-1.37
21	9.20	8.65	5.99
22	8.61	8.84	-2.60
23	8.25	8.84	-7.06
24	8.53	8.84	-3.62
25	9.70	9.74	-0.41
26	9.13	9.74	-6.62
27	9.13	9.74	-6.67

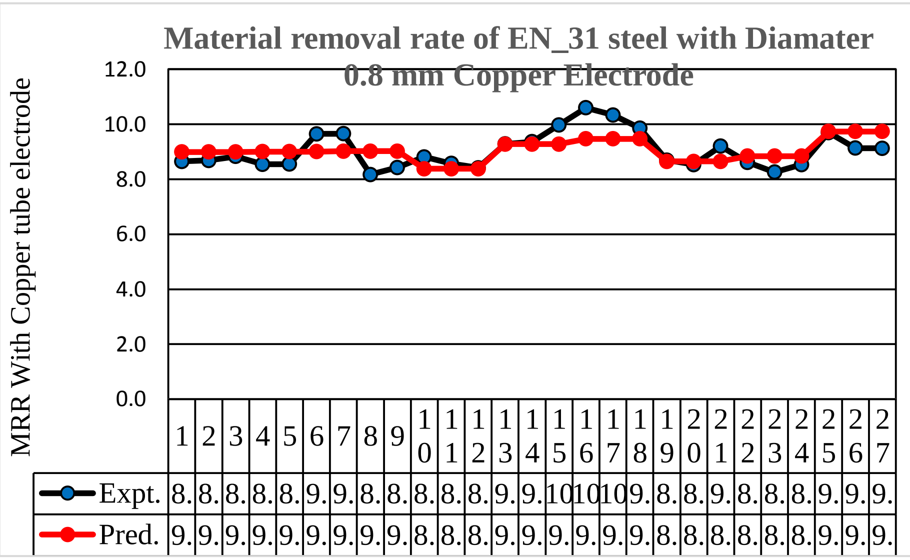


Figure 6. Comparison of Experiment and Predicted Material Removal Rate of EN_31 by Copper electrode

Regression Analysis is carried by regression mathematical equation in which predicted valves are compared with experimental values table 9. In Fig 6 its clears show that Experiment values are closely correlating with predicated values of material removal rate of meso holes with copper tube electrode

Table 10. Analysis of Variance of Material removal rate of EN_31 Meso holes

Source	DF	Adj SS	Adj MS	% Contribution
Depth	2	2.4536	1.22682	0.2215
Current	2	2.5030	1.25152	0.2260
T_ON	2	0.1942	0.09708	0.0175
T_OFF	2	2.6553	1.32766	0.2398
Error	18	3.2690	0.18161	0.2952
Total	26	11.0752		100

From table 10 Anova of MRR with copper electrode on meos holes shows the Depth, Current, and T_OFF show relatively higher adjusted mean squares, suggesting that they contribute more to the variability in the material removal rate compared to T_ON. The Error term also has a significant adjusted mean square, indicating the experimental error.

Analysis of Tool Wear rate in Meso hole by EDD

Analysis of Tool wear Rate on Meso hole by electrical discharge drilling in EN_31 with Brass & Copper tube electrode with diameter 0.8mm in Table .The experimental results present a comparison of TWR values in EN-31 Meso holes using Electro-Discharge Drilling (EDD) with Brass and Copper tube electrodes. The TWR measurements for both types of electrodes exhibit variability across experiments. The Brass electrode yields TWR values ranging from approximately 5.41 to 8.56, while the Copper electrode produces values ranging from about 2.188 to 8.304. Notably, the Copper electrode generally results in lower TWR values compared to Brass, suggesting its potential efficacy in achieving the desired tapering effect during the drilling process. Further statistical analysis, the significance of these differences between the two electrode types. Overall, a deeper understanding of the EDD process, the significance of taper wire resistance, and the specific characteristics of EN-31 Meso holes would provide a more comprehensive interpretation of these results in table 11.

Table 11. Experimental Results of TWR on EN-31 of Meso holes by EDD with Brass & Copper tube electrode

S.No	TWR With Brass electrode	TWR With Coper electrode
1	7.98	5.141
2	8.01	5.475
3	8.32	4.529
4	7.84	4.190
5	6.51	3.920
6	6.59	4.668
7	7.63	5.809

S.No	TWR With Brass electrode	TWR With Coper electrode
8	6.78	8.304
9	7.07	6.936
10	7.55	7.948
11	8.56	2.414
12	5.54	3.182
13	7.88	3.170
14	7.04	3.309
15	7.09	6.655
16	7.12	6.637
17	6.17	7.131
18	8.41	6.233
19	5.43	2.188
20	7.50	4.739
21	5.41	3.894
22	6.75	3.616
23	6.20	3.055
24	6.83	4.447
25	7.17	2.932
26	6.65	6.923
27	8.49	6.673

Table 12. Response Table for Signal to Noise Ratios Smaller is better for TWR

Level	Depth	Current	T_ON	T_OFF
1	-17.40	-17.10	-17.27	-17.66
2	-17.29	-16.87	-17.23	-16.67
3	-16.57	-17.28	-16.76	-16.93
Delta	0.83	0.40	0.52	0.99
Rank	2	4	3	1

The response table.12, displays Signal-to-Noise Ratios (SNRs) for optimizing Taper Wire Resistance (TWR), where lower values indicate better performance. Different parameter levels, including Depth, Current, T_ON (Turn-On Time), and T_OFF (Turn-Off Time), are evaluated. Lower SNRs reflect more consistent and preferable TWR results. The table ranks parameters by the magnitude of their impact on TWR optimization. Overall, the table provides insight into parameter effects on achieving desirable TWR outcomes through SNR analysis.

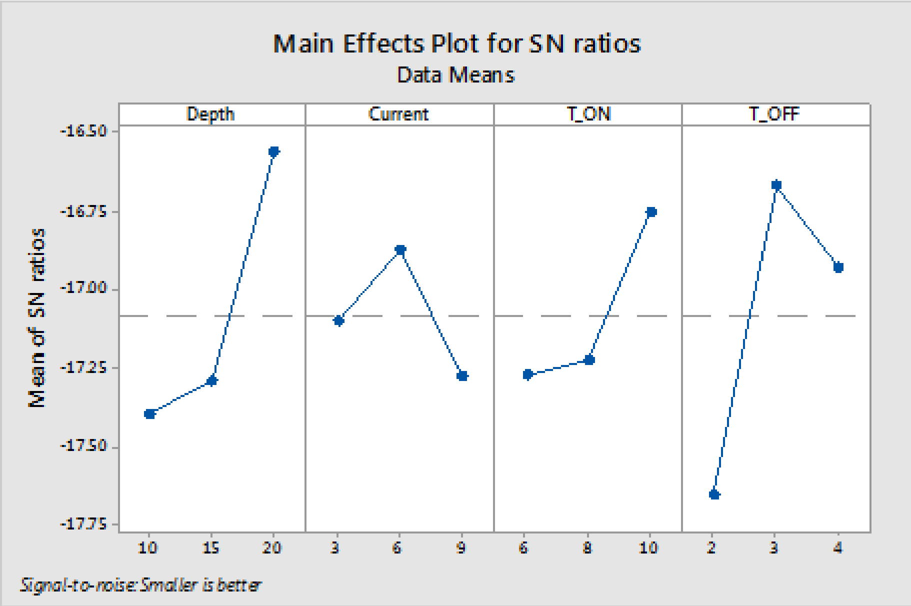


Figure 7. S/N ratio TWR of EN_31 by Brass tube electrode

From Fig .7, S/N Graph the combination is A3-B2-C3-D2 i.e (Depth of hole 20mm, Current 6 Amps, T_ON 10 µs, T_OFF 3 µs.) the combination does not matches with Taguchi L 27 OA ie so confirmation test is required for the combination

Regression Analysis of TWR on Meso holes drilling in EN_31 steel by EDD using Brass electrode

The presented Regression Analysis examines the congruence between predicted and observed Tool wear rate (TWR) values for EN_31 Meso Holes. Each data point is assigned a sequential experiment number and includes experimentally derived TWR values ("Expt.TWR"), as well as TWR values predicted through regression modeling ("Pred. TWR"). The accompanying "% Error" metric quantifies the percentage deviation between predicted and observed TWR values. The analysis emphasizes the predictive accuracy of the regression model through instances of low percentage errors, indicative of close alignment between predictions and observations. Conversely, higher percentage errors reveal disparities requiring model refinement or further experimental exploration.

In essence, this Regression Analysis affords a comprehensive evaluation of the model's efficacy in predicting TWR values for EN_31 Meso Holes, informing potential enhancements and advancing predictive capabilities for future experiments in Table 13.

Table: 13. Comparison of Experiment and predicted TWR of EN_31 Meso Holes

S.No	Expt.TWR	Pred. TWR	% Error
1	7.98	7.96	0.30
2	8.01	7.96	0.70
3	8.32	7.96	4.42
4	7.84	7.48	4.59
5	6.51	7.48	-14.84
6	6.59	7.48	-13.45

7	7.63	7.01	8.14
8	6.78	7.01	-3.40
9	7.07	7.01	0.85
10	7.55	6.75	10.60
11	8.56	6.75	21.18
12	5.54	6.75	-21.67
13	7.88	7.23	8.26
14	7.04	7.23	-2.62
15	7.09	7.23	-1.98
16	7.12	7.42	-4.10
17	6.17	7.42	-20.27
18	8.41	7.42	11.87
19	5.43	6.49	-19.50
20	7.50	6.49	13.40
21	5.41	6.49	-20.08
22	6.75	6.68	1.01
23	6.20	6.68	-7.77
24	6.83	6.68	2.13
25	7.17	7.16	0.03
26	6.65	7.16	-7.78
27	8.49	7.16	15.64

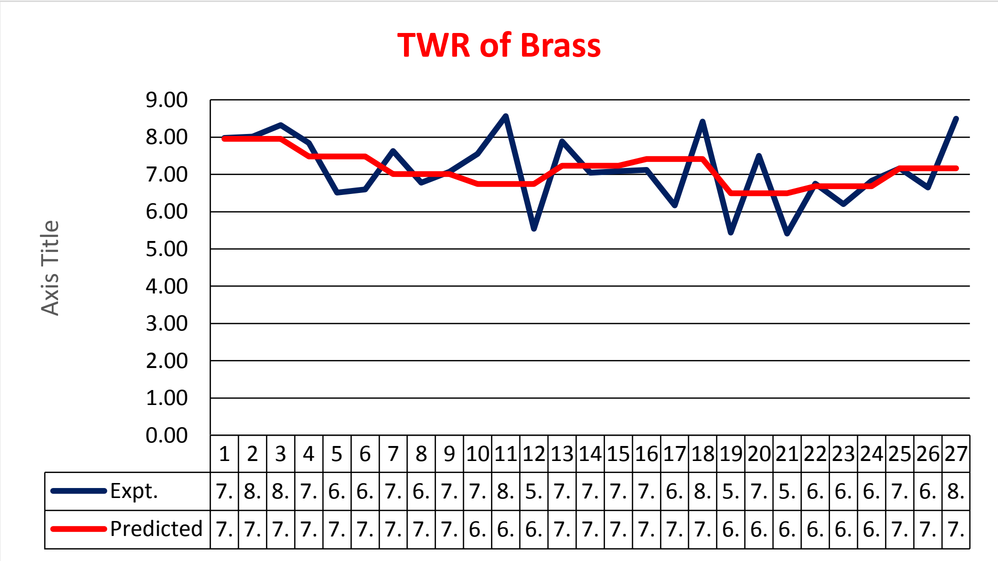


Figure 8. Comparison of Experiment and Predicted Tool wear rate in meso holes of EN_31 by Brass tube electrode

Table 14.ANOVA Analysis of Variance of Tool wear rate with Brass electrode

Source	DOF	Adj SS	Adj MS	% Contribution
Depth	2	2.4558	1.2279	11.4
Current	2	14.1716	0.2103	65.9
T_ON	2	0.9602	0.4801	4.5
T_OFF	2	3.5108	1.7554	16.3
Error	18	0.4207	0.7873	2.0
Total	26	21.5191		100

From Table.14, ANOVA Analysis of Variance of Tool wear rate with Brass electrode, Current has the most significant impact, contributing 65.9% to the total variance in Tool Wear Rate. This indicates that Current plays a substantial role in influencing wear rate when using a Brass electrode."T_OFF" also contributes significantly, explaining 16.3% of the variance. "Depth" and "T_ON" have comparatively lower contributions, explaining 11.4% and 4.5% of the variance, respectively. “Error" represents unexplained variability or experimental error, contributing 2.0% to the total variance.

Analysis of Tool wear Rate on Meso hole by electrical discharge drilling in EN_31 with Copper tube electrode with diameter 0.8mm

Table 15. Response Table for Signal to Noise Ratios Smaller is better for TWR of Copper

Level	Depth	Current	T_ON	T_OFF
1	-14.57	-13.27	-14.02	-14.25
2	-14.69	-12.49	-14.03	-13.53
3	-12.75	-16.26	-13.96	-14.23
Delta	1.94	3.77	0.07	0.71
Rank	2	1	4	3

From The response table .15, summarizes Signal-to-Noise Ratios (SNRs) analysis for optimizing Copper TWR values. Smaller SNR values indicate better TWR performance. Parameters "Depth," "Current," "T_ON" (Turn-On Time), and "T_OFF" (Turn-Off Time) are examined across different levels. SNR trends and parameter rankings are highlighted. The table aids in understanding how parameter adjustments impact TWR optimization for Copper tube electrode.

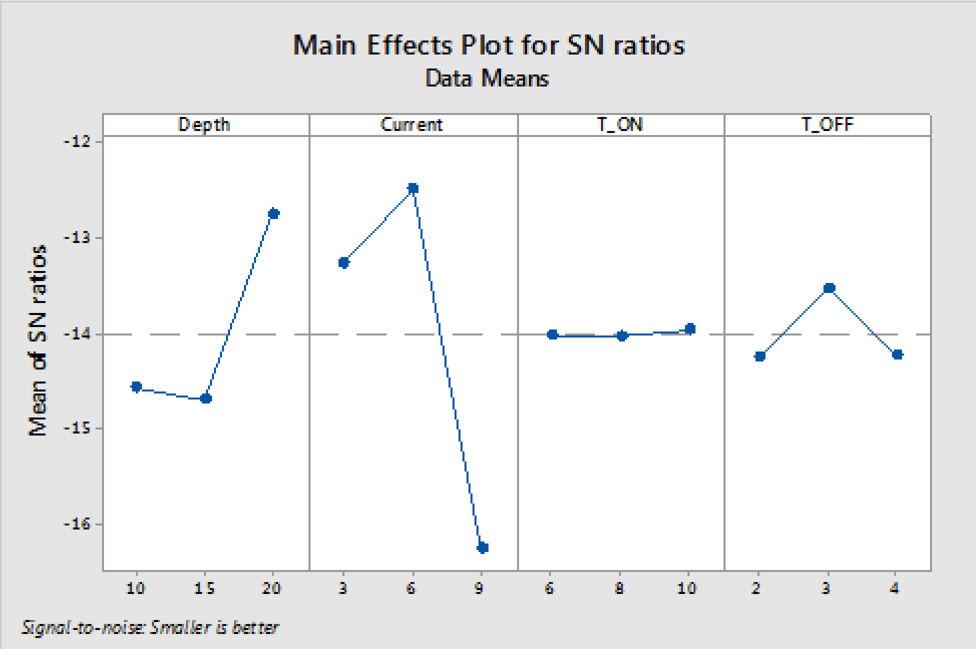


Figure 9. S/N graph of Tool wear rate in meso holes of EN_31 by EDD with Copper tube electrode

From Fig .9, S/N Graph the combination is A3-B2-C3-D2 i.e (Depth of hole 20mm, Current 6 Amps, T_ON 10 µs, T_OFF 3 µs.) the combination does not matches with Taguchi L 27 OA ie so confirmation test is required for the combination

Regression Analysis of TWR on Meso holes drilling in EN_31 steel by EDD using Copper electrode

This regression analysis aims to predict the wear rate of a copper tool. Observed Tool wear rate (TWR) values for copper tool wear are compared with predicted values from the regression model. The analysis highlights instances of both accurate predictions and discrepancies. Some cases exhibit a close match between predicted and observed TWR values, while others show significant differences, quantified by percentage errors. Positive and negative values indicate overestimation and underestimation, respectively. This analysis provides insights into the model's effectiveness in predicting copper tool wear rates and identifies areas for improvement.in table.16.

Table 16. Comparison of Experiment and predicted TWR of EN_31 Meso Holes with copper tube electrode

Expt.No	EXPt. TWR_Copper	Predicted TWR of copper	% Error
1	5.1	4.6	11.14
2	5.5	4.6	16.56
3	4.5	4.6	-0.87
4	4.2	5.6	-32.54
5	3.9	5.6	-41.66
6	4.7	5.6	-18.97
7	5.8	6.5	-12.54

8	8.3	6.5	21.26
9	6.9	6.5	5.74
10	7.9	4.0	49.49
11	2.4	4.0	-66.29
12	3.2	4.0	-26.18
13	3.2	4.8	-52.97
14	3.3	4.8	-46.57
15	6.7	4.8	27.13
16	6.6	6.0	8.92
17	7.1	6.0	15.24
18	6.2	6.0	3.02
19	2.2	3.3	-51.29
20	4.7	3.3	30.14
21	3.9	3.3	14.97
22	3.6	4.5	-24.63
23	3.1	4.5	-47.49
24	4.4	4.5	-1.32
25	2.9	5.3	-82.14
26	6.9	5.3	22.85
27	6.7	5.3	19.96

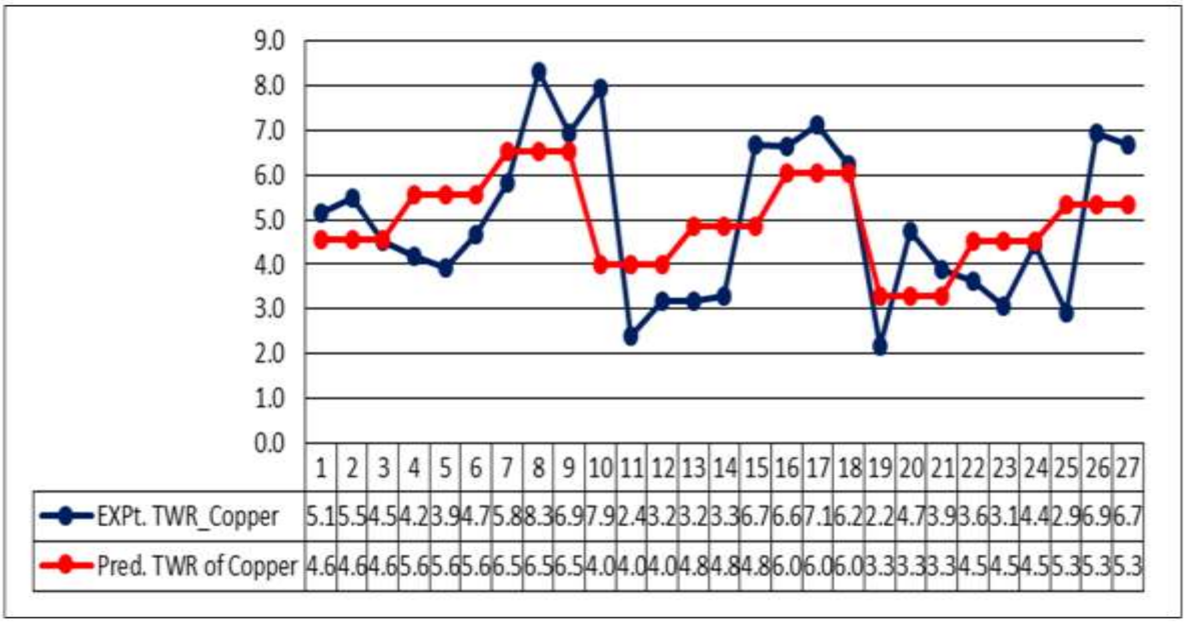


Figure 10. Comparison of Experiment and Predicted Tool wear rate in meso holes of EN_31 by EDD with Copper tube electrode

Table 17. Analysis of Variance in meso holes of EN_31 by EDD with Copper tube electrode

Source	DF	Adj SS	Adj MS	Contribution
Depth	2	6.7758	3.3879	8.466
Current	2	27.9601	13.9800	55.458
T_ON	2	0.6624	0.3312	34.936
T_OFF	2	0.2492	0.1246	0.828
Error	18	44.3841	2.4658	0.311
Total	26	80.0316		100

From Table.17, ANOVA Analysis of Variance of Tool wear rate with coper electrode Current plays the most substantial role, contributing 55.458% to the total variance in Tool Wear Rate. This suggests that current significantly influences wear rate with a Copper electrode. T_ON also holds notable importance, explaining 34.936% of the variance. Depth accounts for 8.466% of the variance. T_OFF has a minimal effect, contributing only 0.828%. "Error" reflects unexplained variability or experimental error, contributing 0.311% to the total variance.

Micro-Structure analysis of meso holes drilled on EN_31 Steel

Microstructure analysis was performed on the meso holes in EN_31 Steel, and SEM images were captured for the 27th run, both at the entry and exit points of the machined holes. Figure 11 illustrates the SEM image of the meso hole at the entrance. This image reveals a well-rounded top surface and minor burring along the sidewalls.

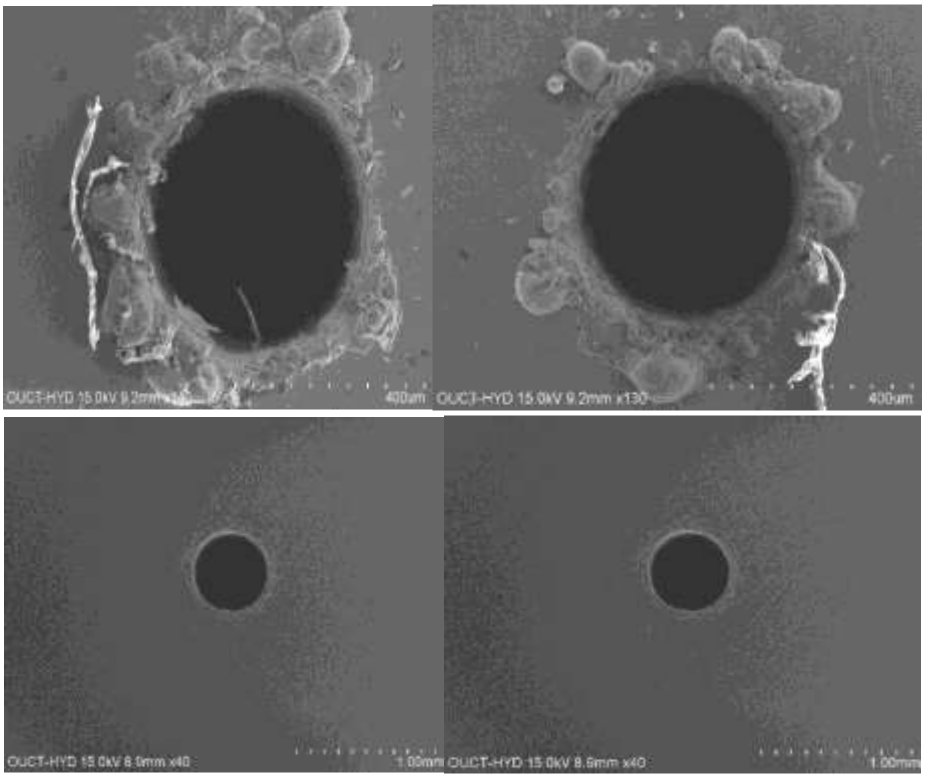


Figure 11. Machined hole entry & hole exit of Trail 20 Experiment of meso hole on EN_31 Steel

4. Conclusion

The paper has presented the optimization of the L27 Taguchi's experiment analysis for maximum material removal rate by Electrical discharge drilling machine of meso holes on EN_31 Steel using brass rotary tube electrode. The main conclusions are as follows:

- From DOE Taguchi L-27 OA the combination is A3-B1-C3-D2 i.e (Depth of hole 20mm, Current 3 Amps, T_ON 10 µs, T_OFF 3 µs.) the combination matches with Taguchi L 27 OA ie Trail 20 with maximum Material Removal rate 14.35 mm3/min
- For Copper Tube electrode the combination is A2-B3-C1-D2 i.e (Depth of hole 15mm, Current 9 Amps, T_ON 6 µs, T_OFF 3 µs.) the combination matches with Taguchi L 27 OA ie Trail 16 with maximum Material Removal rate 10.597 mm3/min
- From Brass & Copper Electrode the Tool wear rate , combination is A3-B2-C3-D2 i.e (Depth of hole 20mm, Current 6 Amps, T_ON 10 µs, T_OFF 3 µs.) the combination does not matches with Taguchi L 27 OA ie so confirmation test is required for the combination
- Regression Analysis is carried by regression mathematical equation in which predicted valves are compared with experimental values and closely correlating with predicated values of material removal rate of meso holes
- Micro-Structure analysis were investigation on meso holes of EN_31 Steel .It shows that the top has a good round look and the side walls have a small burr.

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