

An Experimental Investigation and Optimisation of EDM by Copper Electrode in OHNS Steel

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ABSTRACT: The Engine cylinder is one of the major automobile components, which is subjected to high temperature variations. The electric discharge machining is categorized as a thermoelectric process in which the 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 electric spark discharges between the tool and work piece separated by dielectric medium. The present work is aimed at characterizing the electric discharge machining of OHNS steels on EDM because the electrode with micro features is employed to cut its mirror image in the work piece on that it is necessary to investigate the machining efficiency of the electrodes used. With the consideration of influencing parameters, here a series of experiments were conducted with the copper electrode used as the tool and OHNS as the work piece in the machining process. The combination of the gap voltage, ampere setting were selected for maximum material removal rate (MRR), surface roughness (SR) and circularity cut and over cut thus finally the optimum cutting condition is said to be obtained.

KEYWORDS: EDM, MRR, OHNS steel, Optimization, 19 array, copper electrode

1. INTRODUCTION

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 piece-tool gap. Because of the material removal due to sparks, after some time a uniform gap distance is formed throughout the gap between the tool and the work piece. Thus, a replica of the tool surface shape is formed on the work piece as shown in Figure 1.1. The tool is fed until the required depth of cut is achieved. Finally, a cavity corresponding to replica of the tool shape is formed on the work piece.

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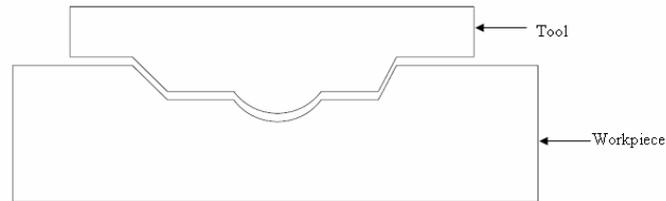


Figure 1.1: Schematic of tool and work piece in Electric Discharge Machining

The work piece form the two conductive electrodes in the electric circuit. Pulsed power is supplied to the electrodes from a separate power supply unit. The appropriate feed motion of the tool towards the work piece is generally provided for maintaining a constant gap distance between the tool and the work piece during machining. This is performed by either a servo motor control or stepper motor control of the tool holder. As material gets removed from the work piece, the tool is moved downward towards the work piece to maintain a constant inter-electrode gap. The tool and the work piece are plunged in a dielectric tank and flushing arrangements are made for the proper flow of dielectric in the inter-electrode gap.

Typically in oil die-sinking EDM, pulsed DC power supply is used where the tool is connected to the negative terminal and the work piece is connected to the positive terminal. The pulse frequency may vary from a few kHz to several MHz. The inter electrode gap is in the range of a few tens of micro meter to a few hundred micro meter. Material removal rates of up to 300 mm³/min can be achieved during EDM. The surface finish (Ra value) can be as high as 50 μm during rough machining and even less than 1 μm during finish machining.

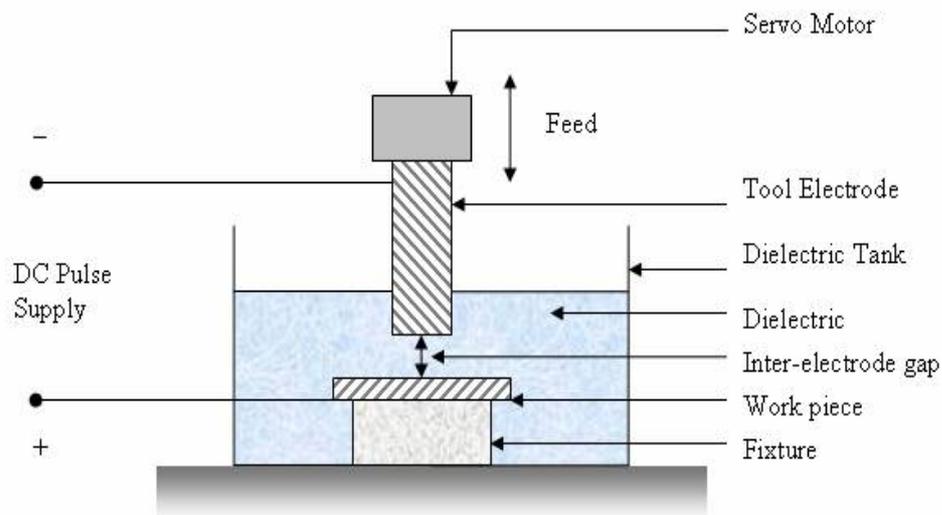


Figure 1.2: Schematic of an Electric Discharge Machining (EDM) machine tool

1.1 Effect of input parameters

Based on the discharge phenomena discussed above, the effect of various input parameters on material removal rate (MRR) and surface roughness (Ra) is discussed below.

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1.1.1 Discharge Current

The discharge current (I_d) is a measure of the power supplied to the discharge gap. A higher current leads to a higher pulse energy and formation of deeper discharge craters. This increases the material removal rate (MRR) and the surface roughness (Ra) value. Similar effect on MRR and Ra is produced when the gap voltage (V_g) is increased.

1.1.2 Pulse-on time

Machining takes place only during the pulse-on time (T_{on}). When the tool electrode is at negative potential, material removal from the anode (work piece) takes place by bombardment of high energy electrons ejected from the tool surface. At the same time positive ions move towards the cathode. When pulses with small on times are used, material removal by electron bombardment is predominant due to the higher response rate of the less massive electrons. However, when longer pulses are used, energy sharing by the positive ions is predominant and the material removal rate decreases. When the electrode polarities are reversed, longer pulses are found to produce higher MRR.

1.1.3 Pulse-off time

A non-zero pulse off time is a necessary requirement for EDM operation. Discharge between the electrodes leads to ionization of the spark gap. Before another spark can take place, the medium must de-ionize and regain its dielectric strength. This takes some finite time and power must be switched off during this time. Too low values of pulse-off time may lead to short-circuits and arcing. A large value on the other hand increases the overall machining time since no machining can take place during the off-time. The surface roughness is found to depend strongly on the spark frequency. When high frequency sparks are used lower values of Ra are observed. It is so because the energy available in a given amount of time is shared by a larger number of sparks leading to shallower discharge craters.

1.1.4 Flushing Pressure

Apart from the electrical parameters, pressure of the dielectric media may have an effect on the process performance during die sinking EDM. Velocity of the dielectric media jet is directly proportional to the inlet flushing pressure. A high velocity flushing jet would lead to better flushing of debris from the discharge gap thus improving the MRR and Ra values. Forced flow of media also helps in reducing the time required for recovery of dielectric strength of the medium since fresh and previously non-ionized medium is continuously supplied to the gap. This leads to higher process stability. Also, it is found that the dielectric strength of air is dependent on the pressure and increases with an increase in the pressure. This favors an increase in the MRR of the process.

1.1.5 Tool rotation

Tool electrode rotation is commonly used in small-hole EDM drilling operations. Tool rotation improves flushing and leads to a more uniform electrode wear. The effects of improved flushing are an increased MRR and lower Ra value. At the same time, process stability increases because tool rotation makes it easier to introduce fresh dielectric into discharge gap as the used up dielectric is thrown out due to the centrifugal force. Thus, even with low pulse off times and poor flushing conditions good machining performance is obtained.

II. EXPERIMENTAL SETUP

Two electrodes were machined to a cylindrical shape of 14 mm diameter and 50mm length. A plate of 200 mm \times 60 mm size and thickness 18 mm of OHNS die steel was taken. It was subjected to a standard hardening cycle and it has a hardened at the range of 40 to 45 HRC.

One surface of the work piece was then ground on a surface grinder to remove surface irregularities and minor scaling. The hardness of this surface was measured on Rockwell Hardness Tester C scale using a diamond cone. After mounting the work piece and one of the electrodes on the machine, the depth of machining was set at 25mm. The work piece was machined with 15 A discharges current and other standard machine settings. The time of machining was recorded in minutes and final weights of the work piece were taken. The machining cycle was repeated for the next value of discharge current. Similarly, the observations were made for the other two electrodes.

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For each electrode material, the effect of variation in discharge current was studied on output parameters, namely, material removal rate (MRR), machined surface roughness. Surface roughness readings were taken on the bottom surface of the machined cavity. Surface roughness was measured on Surf test equipment giving Ra value in microns.



Figure 1.3 General Experimental Setup

2.1 Electrode Materials

Electrode material has a significant influence on important output parameters, such as, material removal rate, surface roughness and dimensional accuracy. Copper and brass are two commonly used EDM electrode materials in the industry because these materials have high melting temperature and excellent electrical and thermal conductivity. Copper can be easily machined to any shape, suffers less wear, has good thermal conductivity, and is economical.

Table 1.1 Properties of OHNS work material and cooper electrode.

PROPERTY	UNIT	MATERIAL
		COPPER
Thermal conductivity	W/m-K	391
Electrical resistivity	Ohm-cm	1.67
Specific heat capacity	J/g-deg C	0.385
Melting point	Deg C	1083

2.2 Work Material

Work material –OHNS steel

Work material size–32mm dia 10mm thickness

2.2.1 CHEMICAL PROPERTIES

Table 1.2 Chemical properties

C	Mn	Si	S	P	Cr
0.90	0.30	0.10	0.40	0.40	1.00
1.20	0.75	0.35	-		1.60

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2.2.2 PHYSICAL PROPERTIES

Table 1.3 Physical properties

SL.NO	PROPERTIES	VALUE
1.	Ultimate Tensile strength (Mpa)	224.07
2.	Yield Stress (Mpa)	2033.95
3.	Elongation (%)	5
4.	Density(Kg/m ³)	7833.413
5.	Hardness(HRC)	62

2.3. Machining Parameters

Table 1.4 Machining Parameters

Sparking Voltage (V)	V80±5%
Discharge Current (A)	15,11,10,8,7,6,5,4
Servo Control	Electro Mechanical
Polarity	Normal (Electrode – Positive)
Dielectric fluid	Commercial Grade Kerosene
Flushing side	Flushing with Pressure
Work piece Material	OHNS Die Steel (Hardened and Tempered)
Electrode Material	Copper and Brass

III. DESIGN OF ORTHOGONAL ARRAY

First Taguchi Orthogonal array is designed in minitab-16 to calculate S/N ratio and means which steps is given below. Create Taguchi Design is selected as shown in figure. Then a window of Taguchi design is opened. To start Minitab, click shortcut of Minitab on Desktop of computer. A window is opened in computer as shown in Figure 1.4 & 1.5

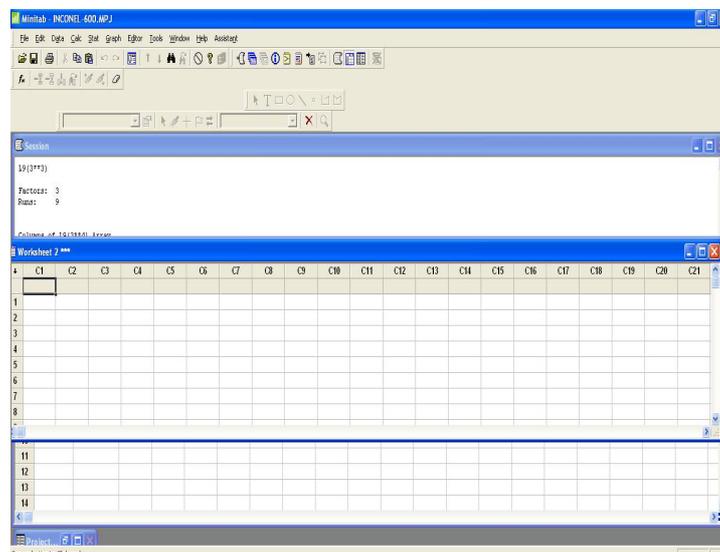


Fig: 1.4 design of orthogonal array

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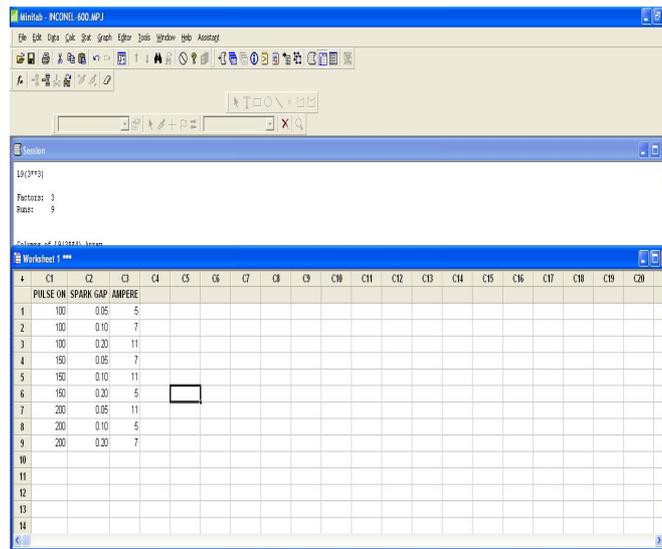


Fig: 1.5 Taguchi design

3.1 ORTHOGONAL ARRAY L₉ FORMATION

Table 1.5 Input parameters

TRIALNO.	DESIGNATION	GAP CURRENT	PULSE ON TIME	PULSE OFF TIME
1	A ₁ B ₁ C ₁	6	2	4
2	A ₁ B ₂ C ₂	8	2	5
3	A ₁ B ₃ C ₃	10	2	6
4	A ₂ B ₁ C ₂	8	3	4
5	A ₂ B ₂ C ₃	10	3	5
6	A ₂ B ₃ C ₁	6	3	6
7	A ₃ B ₁ C ₃	10	4	4
8	A ₃ B ₂ C ₁	6	4	5
9	A ₃ B ₃ C ₂	8	4	6

3.2 PROCESS PARAMETERS AND THEIR LEVELS

Table 1.6 Process parameters and their levels

S.NO	GAP CURRENT	PULSE ON TIME	PULSE OFF TIME
1	6	2	4
2	8	3	5
3	10	4	6

IV. RESULT & DISCUSSION

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 Taguchi Method.

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The steps used are as follows

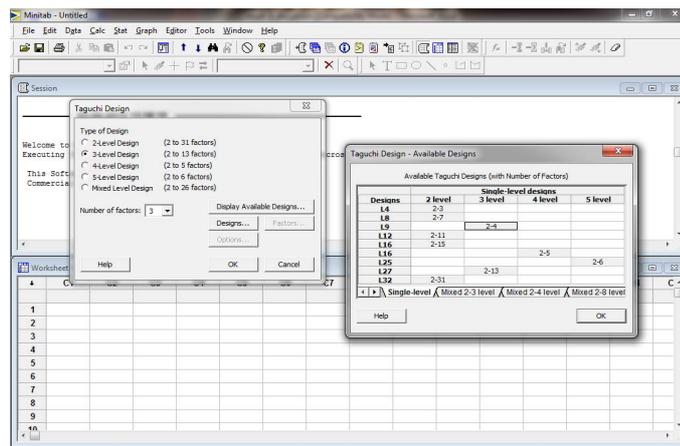


Fig :1.6 Selection of Available Design

Click on Design and Select L₂₇. Then click on ok as shown below.

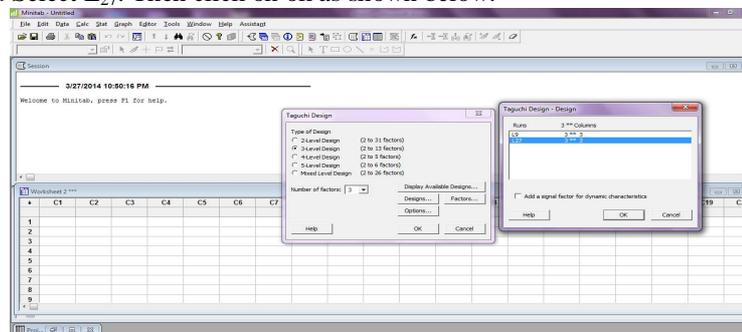


Fig1.7 Selection of Taugchi Design

Click on Factor and write name of factor and levels of factor at desired place. Then press ok as shown in

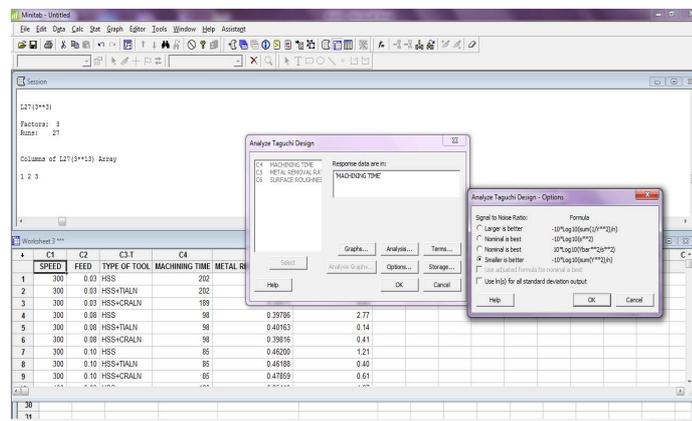


Fig: 1.8 Analysis Taugchi Design Option

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Given the input response in the given column in the Taguchi design factor dialog box

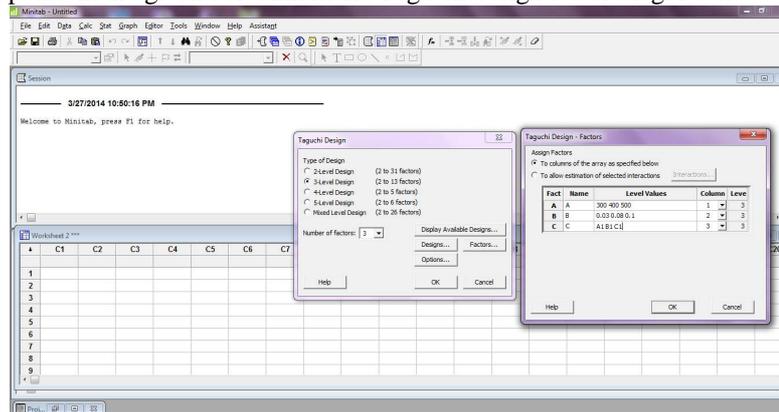


Fig: 1.9 Taguchi Design-Factor

Finally press ok in window analyses Taguchi design. Graph and S/N ratio is generated as shown

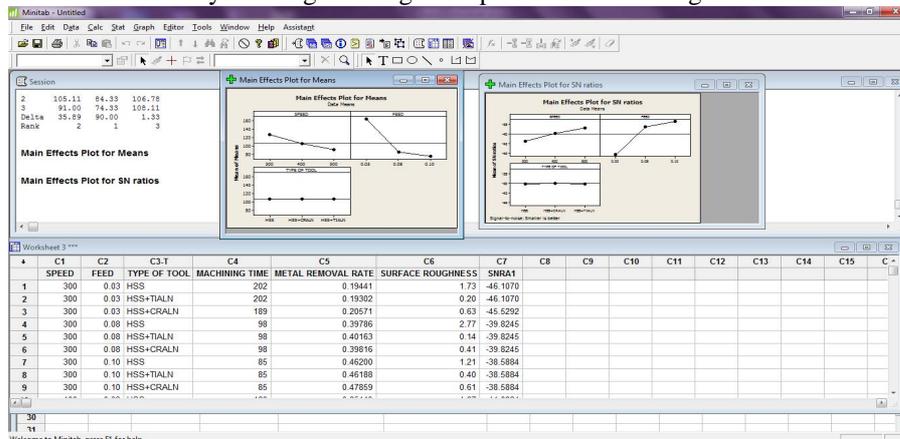


Fig: 1.10 S/N ratio for corresponding factors

4.1 Experimental Data and Analysis

Table 1.7 Process parameters and their levels

TRIAL NO.	DESIGNATION	T ON/OFF	AMPS	RA	MT	MRR
1	A ₁ B ₁ C ₁	4	6	2.003	19	0.315
2	A ₁ B ₂ C ₂	5	8	3.568	17	0.352
3	A ₁ B ₃ C ₃	6	10	2.189	13	0.538
4	A ₂ B ₁ C ₂	4	8	2.303	18	0.333
5	A ₂ B ₂ C ₃	5	10	2.345	15	0.400
6	A ₂ B ₃ C ₁	6	6	2.342	20	0.350
7	A ₃ B ₁ C ₃	4	10	2.494	16	0.375
8	A ₃ B ₂ C ₁	5	6	3.533	19	0.315
9	A ₃ B ₃ C ₂	6	8	5.719	21	0.333

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Table 1.8 surface roughness and s/n ratios values for the experiments

TRIAL NO.	DESIGNATION	Pulse on time	Pulse off time	AMPS	Mc	S/N Response valve (db) for mc
1	A ₁ B ₁ C ₁	2	4	6	2.003	-6.0336
2	A ₁ B ₂ C ₂	2	5	8	3.568	-11.0485
3	A ₁ B ₃ C ₃	2	6	10	2.189	-6.8049
4	A ₂ B ₁ C ₂	3	4	8	2.303	-7.2459
5	A ₂ B ₂ C ₃	3	5	10	2.345	-7.4029
6	A ₂ B ₃ C ₁	3	6	6	2.342	-7.3917
7	A ₃ B ₁ C ₃	4	4	10	2.494	-7.9379
8	A ₃ B ₂ C ₁	4	5	6	3.533	-10.9629
9	A ₃ B ₃ C ₂	4	6	8	5.719	-15.1464

Table 1.9 Signal to Noise Ratios Smaller is better

Level	A	B	C
1	-7.962	-7.072	-8.129
2	-7.347	-9.805	-11.147
3	-11.349	-9.781	-7.382
Delta	4.002	2.732	3.765
Rank	1	3	2

Table 1.10 Mean values

Level	A	B	C
1	2.587	2.267	2.626
2	2.330	3.148	3.863
3	3.915	3.417	2.343
Delta	1.585	1.150	1.521
Rank	1	3	2

Table 1.11 MRR versus TON, TOFF, AMPS

FACTOR	TYPE	LEVELS	VALUES
T ON	FIXED	3	2,3,4
T OFF	FIXED	3	4,5,6
AMPS	FIXED	3	6,8,10

Table 1.12 Analysis of Variance (ANOVA) results for the Roughness

Source	DF	SS	MS	F	P	% of contribution
A	2	4.3445	2.1723	5.52	0.153	39
B	2	2.1722	1.0861	2.76	0.266	19
AMPS	2	3.9237	1.9618	4.99	0.167	35
Error	2	0.7866	0.3933			7
Total	8	11.2270				100

S = 0.627117 R-Sq = 92.99% R-Sq(adj) = 71.98%

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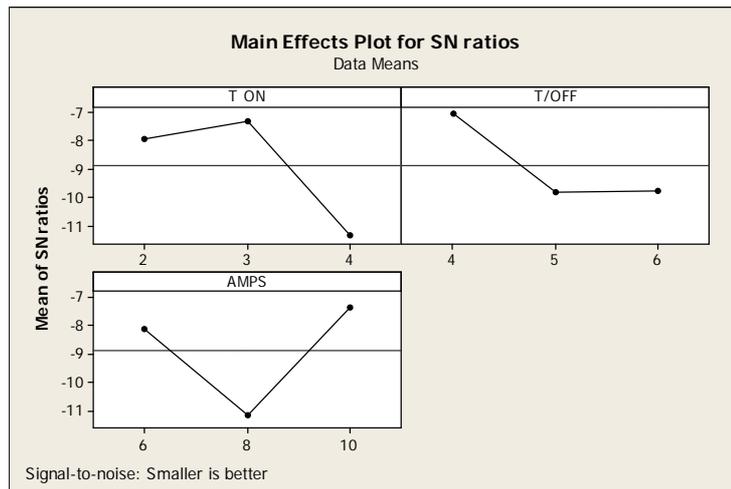


Fig. 1.11 Main effects plot for SN ratios

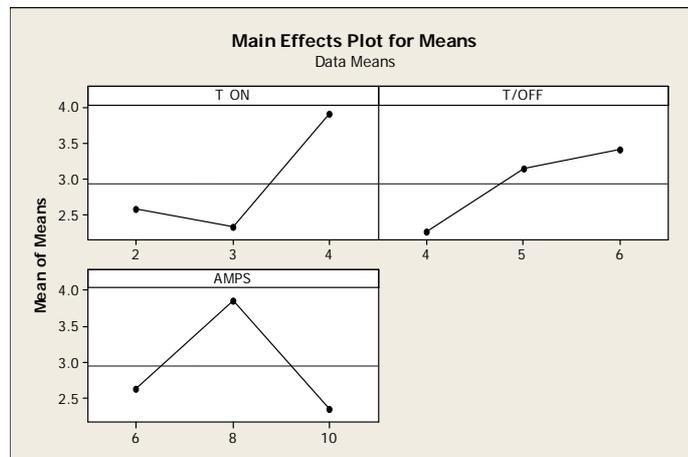


Fig. 1.12 Main effects plot for SN ratios

4.2 Taguchi Analysis: RA versus T ON, T/OFF, AMPS

Table 1.13 Signal to Noise Ratios Smaller is better

LEVEL	T-ON	T-OFF	AMPS
1	-7.962	-7.072	-8.129
2	-7.347	-9.805	-11.147
3	-11.349	-9.781	-7.382
Delta	4.002	2.732	3.765
Rank	3	2	1

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Table 1.12 Mean values

LEVEL	T-ON	T-OFF	AMPS
1	2.587	2.587	2.626
2	2.330	3.149	3.863
3	3.915	3.417	2.343
Delta	1.585	1.150	1.521
Rank	3	2	1

Table 1.13 RA versus T ON, T/OFF, AMPS

Factor	Type	Level values
T-ON	Fixed	3, 2, 3, 4.
T-OFF	Fixed	3, 4, 5, 6.
AMPS	Fixed	3, 6, 8, 10.

Table 1.14 Analysis of Variance for RA, using Adjusted SS for Tests

SOURCE	DF	SEQ SS	ADJ SS	ADJ MS	F	D
T-ON	2	4.3445	4.3445	2.1723	5.52	0.153
T-OFF	2	2.1722	2.1722	1.0861	2.76	0.266
AMPS	2	3.9237	3.9237	1.9618	4.99	0.167
ERROR	2	0.7866	0.7866	0.3933		
TOTAL	8	11.2270				

$$S = 0.627117 \quad R\text{-Sq} = 92.99\% \quad R\text{-Sq(adj)} = 71.98\%$$

V. CONCLUSION

In this study, the Taguchi technique and ANOVA were used to obtain optimal EDM parameters in the machining of OHNS under wet conditions. The experimental results were evaluated using Taguchi technique. The following conclusion can be drawn.

OPTIMAL CONTROL FACTOR

1. Surface Roughness-A1(T-ON – 2 μ s)B2(T-OFF – 5 μ s)C2(Amps-8)
2. Machining Timing-A2 (T-ON – 3 μ s)B3(T-OFF – 6 μ s)C1(Amps-6)
3. Material Removal Rate- A3(T-ON – 4 μ s)B2(T-OFF – 5 μ s)C1(Amps-6)

Percentage of contribution of Process parameter

1. Surface Roughness-Pulse on time- 39%
2. Machining Timing- Amps- 73%
3. Material Removal Rate-Amps57%

REFERENCES

1. Guu Y.H. et al, (2003) 'Effect of electrical discharge machining on surface characteristics and machining damage of AISI D2 tool steel', Materials Science and Engineering, Vol 358, pp37-43.
2. Guu, Y.H.(2001) 'AFM surface imaging of AISI D2 tool steel machined by the EDM process', Applied Surface Science, Vol242, pp 245–250.
3. Pecas, P, et al. (2008) 'Electrical discharge machining using simple and powder-mixed dielectric: The effect of the electrode area in the surface roughness and topography', journal of materials processing technology, vol 200, pp250–258.
4. Kansal, H.K, et al., (2005) 'Parametric optimization of powder mixed electrical discharge machining by response surface methodology', Journal of Materials Processing Technology, vol169, pp427–436.
5. Izquierdo, B, et al (2009) 'A numerical model of the EDM process considering the effect of multiple discharges', International Journal of Machine Tools & Manufacture, Vol 49, Issues 3-4, pp 220-229.