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Experimental Investigation of Process Parameters on Electric Discharge Machine

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Abstract: EDM is widely used machining technique in the world. It is one of the most accurate types of machining processes. The ability to achieve complex geometries and intricate shapes with high degree of accuracy especially when used along with CNC makes it more accurate and superior from any other machining techniques. In spite of all these positive characteristics, the EDM machine has some drawbacks. The most critical problem among these which causes wastage of time, removal or erosion of electrode material from the electrode. As we all know that EDM process works on the erosion of material or work-piece due to the spark produced between the surface of electrode and the work-piece. But during this process, along with the erosion of the work-piece there is erosion of the electrode (tool). To reduce this gap produced by the 'erosion of tool' the companies keeps a set of electrodes available in order to overcome the tool erosion problem. The number of electrodes in excess is kept according to the need and use of electrode. It takes quite long time in making of this electrode along with the wastage of money and labor. We need to give a solution to this problem and find an alternative or a solution which can reduce the requirement of the electrodes in order to save our time and money. For this purpose, we have to minimize the amount of erosion of tool end by specifying the desired or more appropriate input parameters (voltage, current, pulse on-off time etc.) which are to be given to EDM in order to lessen the erosion of electrode.

Keywords: Electric discharge machining, metal removal rate, Electrode erosion.

I. INTRODUCTION

Electrical discharge machining (EDM) is a process of metal removal using an accurately controlled electrical discharge (spark) through a small gap between an electrode and a workpiece filled with dielectric fluid. The technique allows the machining of high-strength and wear- resistance materials into desired shapes since the hardness of the workpiece has no effect on the process. Also, EDM permits the machining to be done even after the hardening process.

Some mathematical models of the material removal rate have been developed previously based on the boundary condition of the plasma formed between the cathode (workpiece) and the anode (electrode). These models are a cathode erosion model [1] and an anode erosion model [2] moreover thermal based model has been developed for the determination of the material removal rate [3] and these model are based on the thermo-physical properties of the plasma applied over the temperature range from solid to liquid melt. However, these models are presented in a complex relationship between the material and the plasma.

This paper presents an alternative mathematical model using dimensional analysis to identify both the electrical and the physical parameters that are of importance in determining the material removal rate. The results predicted using the model are compared with the experimental results.

II. MATERIAL REMOVAL BY ELECTRICAL SPARK ENERGY

Electrical spark from a negatively charged electrode to a positively charged workpiece is converted into heat energy when discharge takes place. The surface of the material is then very strongly heated in the area of the discharge channel. The energy of the spark brings particles of the material to a vaporized state due to the absorption of fast moving electrons at the start of the pulse. These particles immediately re-solidify into small spheres and are flushed away by the dielectric fluid. This action leaves a small eroded area on the workpiece. The cycle of discharge pulse on-time, ton, and off-time, t_{off} is repeated until a reverse image of the electrode is formed on the workpiece. Figure 1 illustrates the material removal process.

The material removal rate is defined as the cavity volume removed by the spark, divided by the sum of the pulse on-time and pause off-time for each cycle of operation [1]. When the gap between the electrode and the workpiece is sufficiently small, the said gap being controlled by a position control servo system, an electrical spark occurs between the gap. First, a high voltage Vs is applied during the delay time td. During this time, a high electric field is formed between the electrode and the work piece (at the position of least resistance).

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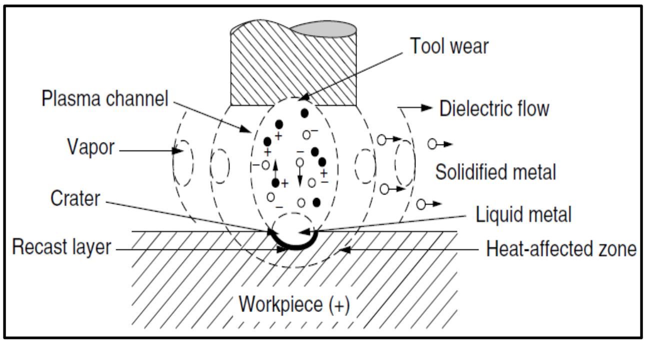

Figure 1: working principle of EDM

At the end of the delay time, the insulation effect of the dielectric fluid breaks down, current begins to flow whilst the voltage falls, signalling the start of the discharge phase. The spark is thus formed and machining takes place during the period of on-time ton with a machining current of Ip.

III. OBJECTIVE

The objective of this project is to study the effect of various parameter such as pulse on current (Ip , Pulse On Time (Ton),Gap Voltage(Vs), etc. on the output parameters Metal Removal Rate (MRR), Tool Wear Rate (TWR) in electric discharge machining process.

Sr. No	Parameters	Abbreviations	Units
1	Material Removal Rate	MRR	mm^3/s
2	Tool Wear Rate	TWR	mm^3/s
2	Gap Voltage	V_s	Volt
3	Pulse on Time	T_{on}	µs
4	Spark Frequency	F_s	Hz
5	Input Current	I_p	A

IV APPROACH

1. Design of experiment: A specific method i.e Taguchi method was selected for the performance of the experiment of boring operation. According to the method, we have to perform the experiment several times and record the data.
2. Performance of the experiment: The performance of the experiment will be done on the EDM machine in the college workshop.
3. Analysis: Once the experiment of the boring operation is done with the 3 different materials, the data recorded will be analyzed in the MINITAB software. MINITAB is often used in conjunction with the implementation of six sigma and other statistics-based process improvement methods.

V. EXPERIMENTAL SETUP

Figure 2: Electric Discharge Machine Setup

All the experimentations of the project are carried out on EDM E-20 machine. It works on the principle of spark erosion as discussed earlier. Figure 2 shows the actual setup of the electric discharge machine (EDM).

The specifications of the electric discharge machine (EDM) are given in the table 3 The EDM machine is a non-conventional type of machine which finds its applications in mould making industries.

Table 2: Specification of Electric Discharge Machine

Mechanism Of Process	Controlled Erosion Through A Series Of Electric Spark
Spark Gap	0.01 – 0.500 Mm
Spark Frequency	200 – 500 Khz
Peak Voltage Across The Gap	30 – 250 V
Metal Removal Rate-Max	5000 Mm^3/Min
Specific Power Consumption	2 – 10 W/Mm^3/Min
Dielectric Fluid	EDM Oil Kerosene Liquid Paraffin, Deionised Water
Tool Material	Copper, Cu-Alloys, Graphite
Material That Can Be Machined	All Conducting Metals And Alloys
Shapes	Micro holes, narrow slots, blind cavities

V. EXPERIMENTATION

[A] Design of Experiments:

Experimental readings were taken by considering three levels of each control parameter as shown in table. Total 9 reading were taken by keeping two parameter constant and varying one parameters.

Table 3: Control Parameters of EDM

Parameter	**Symbol**	**Unit**	**Levels**		
			1	**2**	**3**
Peak Current	I_p	A	10	12	14
Spark Voltage	V_s	V	35	40	45
Pulse on Time	T_{on}	µs	290	380	430

Apart from control parameters some other parameters were kept constant during over all machining process those are Flushing pressure, pulse off time, duty cycle.

[B] Experimentation:

Electric discharge machining of EN-31 material as workpiece were carried out on die-sinking electric discharge machine with copper as tool electrode and by varying machining parameters settings. During machining variation in voltage was set by gap control knob, the value of input current, duty cycle and pulse on time is fed to machine through thumb wheel controls. To calculate the Material removal rate and tool wear rate initial and final weight is measured by digital weighing machine.

[C] Experimental Readings:

Table 4: Data for MRR for circular electrode

Exp	Ip (A)	Ton (µs)	(Vo)	W_b gm	W_a gm	Difference (gm)
C-1	10	29	35	370	366	4
C-2	10	38	40	366	361	5
C-3	10	43	45	361	347	13
C-4	14	29	40	394	377	16
C-5	14	38	45	377	358	18
C-6	14	43	35	358	337	21
C-7	20	29	45	398	373	24
C-8	20	38	35	675	650	24
C-9	20	43	40	650	627	22

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Table 5: Data for MRR for square electrode

Exp.	Ip (A)	Ton (µs)	(Vo)	W_b gm	W_a gm	Difference (gm)
S-1	10	43	35	436	427	9
S-2	10	63	35	427	418	8
S-3	10	83	40	418	412	6
S-4	14	43	35	427	410	16
S-5	14	63	40	410	395	15
S-6	14	83	35	395	377	18
S-7	20	43	40	627	611	15
S-8	20	63	35	611	591	19
S-9	20	83	35	591	571	20

Calculation of MRR:

$$\mathbf{MRR} = \frac{(\mathbf{Wb} - \mathbf{Wa}) * \mathbf{1000}}{\mathbf{7.8} * \mathbf{T}}$$

Where,

W_b= Initial weight of work piece in gm

W_a= Final weight of work piece in gm

T = Period of trails in minutes

7.8=Density of OHNS in gm/cc

Sample MRR Calculation for First Reading (C-1)

$$\text{MRR} = \frac{(\text{Wb} - \text{Wa}) * 1000}{7.8 * \text{T}} = \frac{(370.46 - 366.75) * 1000}{7.8 * 60}$$

$$= \frac{(3.71) * 1000}{7.8 * 60} = 7.927 \text{ mm}^3/\text{min}$$

Average performance of parameters at each level

Average MRR of a Factor at a Level= $\frac{\text{Sum of MRR At a Level}}{\text{Numbers Of Levels}}$

Ex. Consider Factor Ip at Level 1

$$= \frac{7.927 + 10.812 + 29.679}{3} = \frac{48.418}{3}$$

$= 16.14 \text{ mm}^3/\text{min}$

Table 6: Response table for Mean MRR

LEVEL	IP	TON	VO
1	16.14	32.27	36.02
2	40.67	34.30	31.91
3	51.67	41.90	40.54
DELTA	35.53	9.63	8.63
RANK	1	2	3

Table shows the mean response of MRR on various levels of the parameters Pulse Current (I_P), Pulse on Time (T_{ON}) and Voltage (V_o). The maximum difference among the mean values of MRR at different levels give the value of delta, which is directly proportional to the effect of that parameter on the response. That means higher the value of delta for a particular parameter, more will be its effect on the response. The rank are given to the parameters in order of their respective delta values.

Table 7: TWR for circular electrode

Exp.	Ip (A)	Ton (µs)	(Vo)	Wt_b gm	Wt_a gm	Difference (gm)
C-1	10	29	35	105.52	105.51	0.01
C-2	10	38	40	105.51	105.48	0.03
C-3	10	43	45	105.44	105.41	0.03
C-4	14	29	40	101.60	101.43	0.17
C-5	14	38	45	101.43	101.32	0.11
C-6	14	43	35	101.32	101.24	0.08
C-7	20	29	45	100.46	99.92	0.54
C-8	20	38	35	101.22	101.02	0.20
C-9	20	43	40	101.02	100.85	0.17

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Table 8: TWR for Square electrode

Exp.	Ip (A)	Ton (µs)	(Vo)	Wt_b gm	Wt_a gm	Difference (gm)
S-1	10	43	35	140.74	140.7	0.04
S-2	10	63	35	140.7	140.68	0.02
S-3	10	83	40	140.68	140.65	0.03
S-4	14	43	35	140.70	140.63	0.07
S-5	14	63	40	140.63	140.55	0.08
S-6	14	83	35	140.55	140.5	0.05
S-7	20	43	40	146.68	146.58	0.10
S-8	20	63	35	146.58	146.5	0.08
S-9	20	83	35	146.5	146.43	0.07

Calculation of TWR:

$$\mathbf{TWR} = \frac{(\mathbf{Tb} - \mathbf{Ta}) * \mathbf{1000}}{\mathbf{8.9} * \mathbf{T}}$$

Where,
Wt_b= Initial weight of Tool in gm
Wt_a= Final weight of Tool in gm
T= Period of trails in minutes
8.9=Density of Copper in gm/cc

Sample TWR Calculation for First Reading (C-1)

$$\text{TWR} = \frac{(\text{Tb} - \text{Ta}) * 1000}{8.9 * \text{T}} = \frac{(105.52 - 105.51) * 1000}{8.9 * 60}$$

$$= \frac{(0.01) * 1000}{8.9 * 60}$$

$$= 0.0187\text{mm3/min}$$

Average performance of parameters at each level

$$\text{Average TWR of factor at a Level} = \frac{\text{Sum of TWR At a Level}}{\text{Numbers Of Levels}}$$

Ex. Consider Factor Ip at Level 1

$$= \frac{0.0187 + 0.05617 + 0.05617}{3} \qquad = \frac{0.13104}{3}$$

$$= 0.0436$$

Table 9: Response table of mean TWR

LEVEL	IP	Ton	V_O
1	0.0436	0.449	0.183
2	0.0226	0.212	0.231
3	0.0567	0.177	0.424
DELTA	0.0524	0.272	0.241
RANK	1	2	3

Table shows the mean response of TWR on various levels of the parameters Pulse-current (Ip), Pulse-on time (T_{on}) and Voltage (V). The maximum difference among the mean value of TWR at different levels gives the value of Delta which is directly proportional to the effect of that parameter on the response. That means higher the value of Delta for a particular parameter more is its effects on response. The rank are given to the parameter in order of their respective value.

V. RESULTS AND DISCUSSION

1. Check for Validity of Data

There are three assumptions in ANOVA analysis: normality, constant variance, and independence. The normality plot of the residuals is used to check the normality of the treatment data.

If the distribution of residuals is normal, the plot will resemble a straight line. Here, since the distribution of residuals is about the straight line, it confirms the normality of treatment data. The constant variance assumption is checked by the

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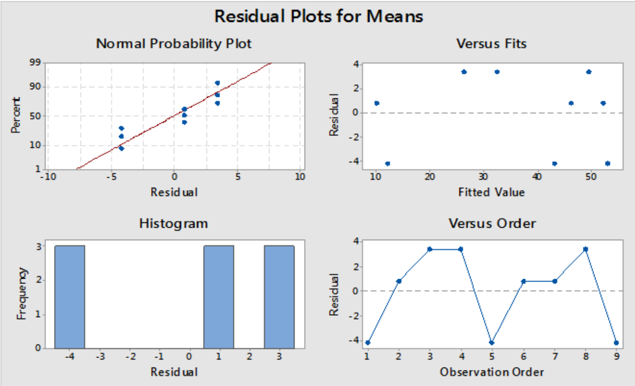
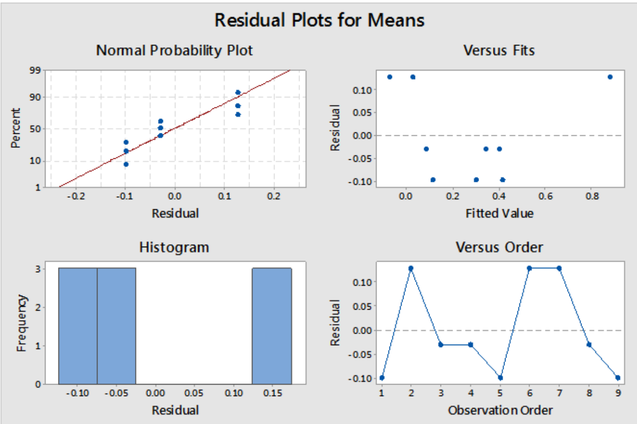
plot of residuals versus fitted values. If the plot of residual vs. fitted values (treatment) does not show any pattern, the constant variance assumption is satisfied.



Graph 1: Residual plots for mean MMR

The residuals v/s fitted value plot confirms the second assumption of constant variance as there is no specific pattern can be detected. If the plot of residual vs. run order (time order of data collection) does not reveal any pattern, the independence assumption is satisfied. Here as there is no specific pattern detected, the assumption of independence is satisfied.



Graph 2: Residual plot for mean TWR

2. ANOVA Analysis for MRR

ANOVA TERMS
DOF – Degree of freedom
SS- Sum of Squares
MS- Mean Square
F P- Statistical Parameters of ANOVA
Percent Contribution – It shows how an input factor contributes to the output factor

Table 10: ANOVA table for MRR

Source	DF	SS	MS	F-Value	P-Value	% Contribution
I_p	2	1984	992	22.20	0.043	84.79 %
T_{on}	2	154	77	1.73	0.366	6.61 %
V_o	2	111	55	1.25	0.444	4.77 %
Error	2	89	44			
Total	8	2340				

Regression Equation:

Material removal rate MRR = 36.16 - 20.02 pulse current Ip_10 + 4.51 pulse current Ip_14
+ 15.51 pulse current Ip_20 - 3.89 Pulse on time Ton_29

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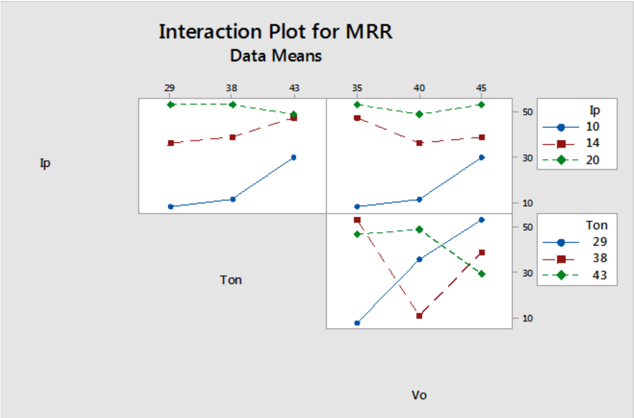
- 1.86 Pulse on time Ton_38 + 5.75 Pulse on time Ton_43
- 0.14 Gap voltage Vo_35 - 4.25 Gap voltage Vo_40
+ 4.38 Gap voltage Vo_45

Table 11: Model Summary

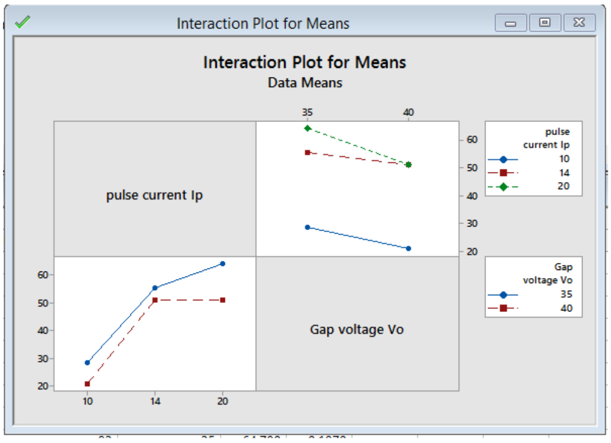
S	R-sq.	R-sq. (adj)	R-sq. (pred)
6.68554	96.18 %	84.72 %	22.67 %

When the effect of one factor depends on the level of the other factor, one can use an interaction plot to visualize possible interactions. Parallel lines in an interaction plot indicate no interaction. The greater is the difference in slope between the lines, the higher the degree of interaction. However, the interaction plot doesn't alert you if the interaction is statistically significant.



Graph 3: Interaction plots for MRR

Since the factors are more than two, the matrix for interaction plot is shown in the graph. In this graph, the first row shows the interaction plot between Pulse on current (Ip) Vs. Pulse on time (Ton) Vs Gap Voltage (Vo). From this we can conclude that there is no interaction between Pulse on current (Ip), Pulse on time (Ton), Gap Voltage (Vo).
The second row shows the interaction plot between Ton vs.Vo. As different lines have steep slope and intersecting each other, there is significant interaction.
When the effect of one factor depends on the level of the other factor, one can use an interaction plot to visualize possible interactions. Parallel lines in an interaction plot indicate no interaction. The greater is the difference in slope between the lines, the higher the degree of interaction. However, the interaction plot doesn't alert you if the interaction is statistically significant.



Graph 4: Interaction plots for MRR Square

Since the factors are more than two, the matrix for interaction plot is shown in the graph. In this graph, the first row shows the interaction plot between Pulse on current (Ip) Vs. Pulse on time (Ton) Vs Gap Voltage (Vo). From this we can conclude that there is little interaction between Pulse on current (Ip), Pulse on time (Ton), Gap Voltage (Vo).

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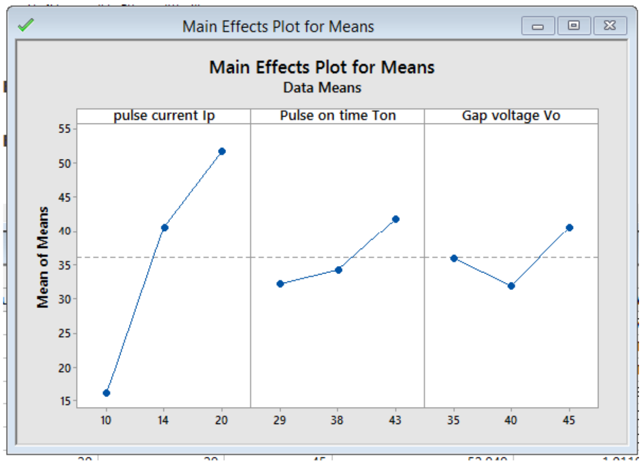
The second row shows the interaction plot between Tonvs. Vo. As different lines have steep slope and intersecting each other, there is no interaction.

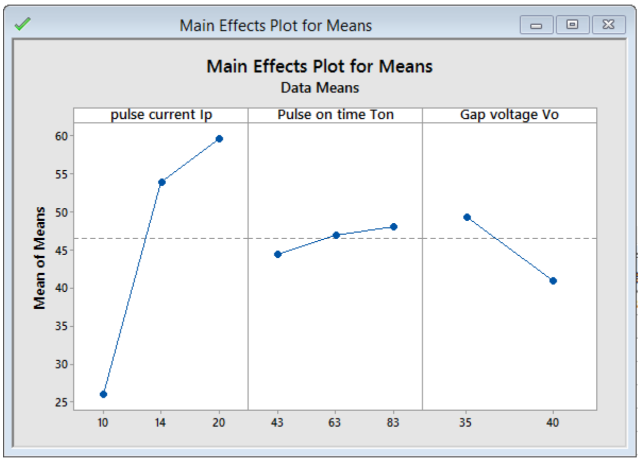
3. Means plot for MRR for circular tool



Graph 5: Means plot for MRR

The graph shown in the figure are generated using MINITAB-17. The increasing nature of the graph with increasing nature of Pulse current (IP) shows that MRR increases with increase in the value of pulse current. The increasing nature of the graph with increasing nature of Pulse on Time (Ton) shows that MRR increases with increase in the value of pulse on time. The variant nature of the third graph shows that the Voltage (V) has random effect on our response MRR.

4. Means plot for MRR for Square tool



Graph 6: Means plot for MRR for Square tool

The graph shown in the figure are generated using MINITAB-17. The increasing nature of the graph with increasing nature of Pulse current (IP) shows that MRR increases with increase in the value of pulse current. The increasing nature of the graph with increasing nature of Pulse on Time (Ton) shows that MRR increases with increase in the value of pulse on time. The decreasing nature of the third graph shows that the Voltage (V) has deceasing effect on our response MRR.

5. S/N RATIO ANALYSIS FOR METAL REMOVAL RATE (LARGER IS BETTER)

The S/N ratio is another way of analyzing the experimental data. As in this case we want MRR to be as large as possible. We will be using, Larger is better S/N ratio, which is given by the formula:

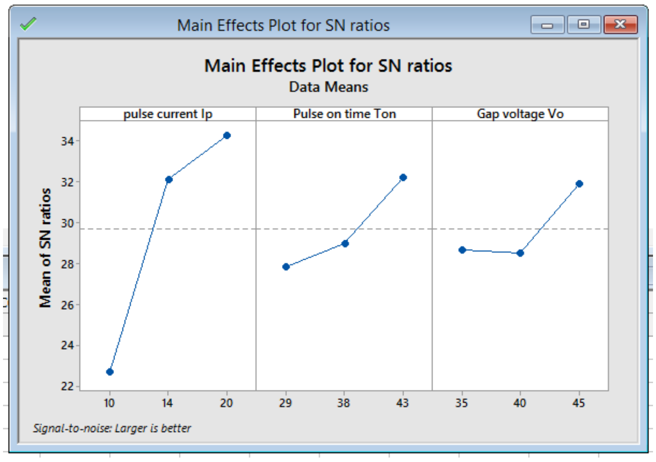
Signal noise ratio (larger is better)= $-10 * \log(\sum(\frac{1}{y^2})/n)$

y is a response variable
n is a number of a level
The S/N ratio calculated using above formula are tabulated in the following table:

LEVEL	IP	TON	VO
1	22.70	27.86	28.64
2	32.13	29.00	28.53
3	34.26	32.23	31.92
DELTA	11.56	4.38	3.39
RANK	1	2	3

The maximum difference among the S/N ratio values of MRR at different levels give the value of delta, which is directly proportional to the effect of that parameter on the response. That means higher the value of delta for a particular parameter, more will be its effect on the response. The rank are given to the parameters in order of their respective delta values.

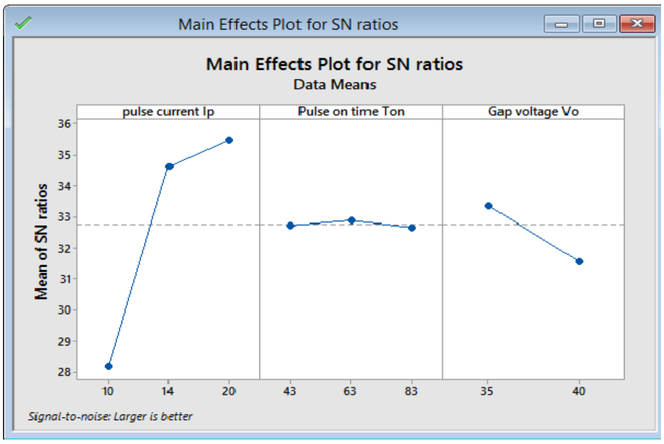
6. S/N plot for MRR for circular tool



Graph 7: S/N plot for MRR

The graph shown in the figure are generated using MINITAB-17. The increasing nature of the graph with increasing nature of Pulse current (IP) shows that S/N ratio increases with increase in the value of pulse current. The increasing nature of the graph with increasing nature of Pulse on Time (Ton) shows that S/N ratio increases with increase in the value of pulse on time. The variant nature of the third graph shows that the Voltage (V) has random effect on our response S/N ratio.

7. S/N plot for MRR Square tool



Graph 8: S/N plot for MRR Square tool

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ANOVA Analysis for TWR
ANOVA terms
DOF – Degree of freedom
SS- Sum of Squares
MS- Mean Square
F P- Statistical Parameters of ANOVA
Percent Contribution – It shows how an input factor contributes to the output factor

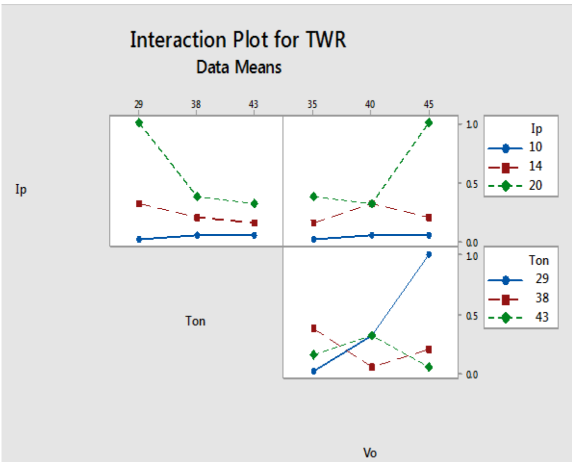
Table 4 ANOVA table for TWR

Source	DF	SS	MS	F-Value	P-Value	% Contribution
Ip	2	0.424	0.212	5.2	0.16	57.7 %
Ton	2	0.131	0.065	1.6	0.38	17.92 %
Vo	2	0.098	0.049	1.2	0.45	13.33 %
Error	2	0.080	0.040			
Total	8	0.735				

Regression Equation:
Material removal rate TWR = 0.2794 - 0.2357 Ip_10 - 0.0529 Ip_14 + 0.2886 Ip_20
+ 0.1700 Ton_29 - 0.0671 Ton_38 - 0.1028 Ton_43
- 0.0966 Vo_35 - 0.0484 Vo_40 + 0.1450 Vo_45

Table 5: Model Summary

S	R-sq.	R-sq. (adj)	R-sq. (pred)
0.201030	89.02 %	56.06 %	0.00 %



Graph 8: Interaction plot for TWR

When the effect of one factor depends on the level of the other factor, one can use an interaction plot to visualize possible interactions. Parallel lines in an interaction plot indicate no interaction. The greater is the difference in slope between the lines, the higher the degree of interaction. However, the interaction plot doesn't alert you if the interaction is statistically significant.

Since the factors are more than two, the matrix for interaction plot is shown in the graph. In this graph, the first row shows the interaction plot between Pulse on current (Ip) Vs. Pulse on time (Ton) Vs Gap Voltage (Vo). From this we can conclude that there is interaction between Pulse on current (Ip), Pulse on time (Ton), Gap Voltage (Vo).

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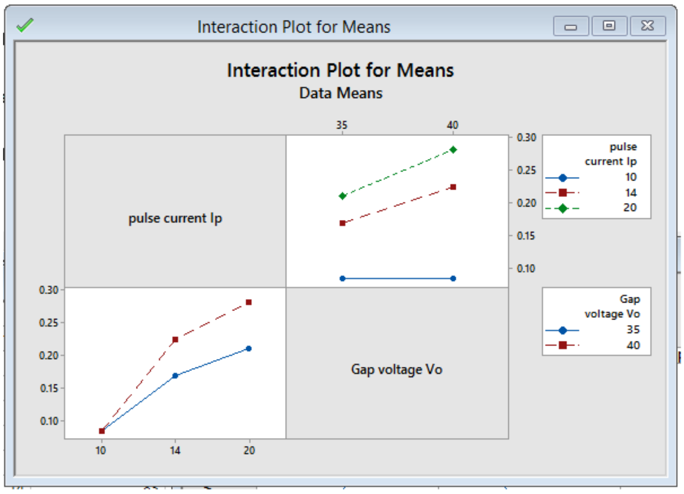
The second row shows the interaction plot between Tonvs. Vo. As different lines have steep slope and intersecting each other, there is significant interaction.
Figure shows the graphs of response i.e. TWR plotted against the various levels of each of the parameter taken into consideration.

Interaction plot for TWR Square tool



Graph 9: Interaction plot for TWR Square tool

When the effect of one factor depends on the level of the other factor, one can use an interaction plot to visualize possible interactions. Parallel lines in an interaction plot indicate no interaction. The greater is the difference in slope between the lines, the higher the degree of interaction. However, the interaction plot doesn't alert you if the interaction is statistically significant.

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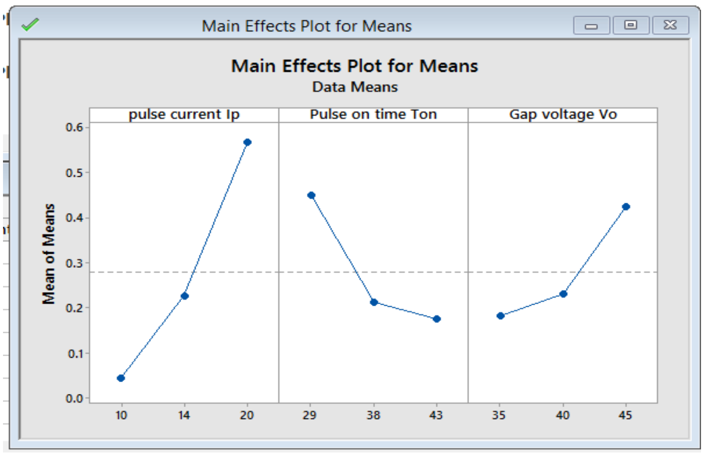
The second row shows the interaction plot between Tonvs. Vo. As different lines have steep slope and intersecting each other, there little interaction.

8. Mean plot for TWR for circular tool



Graph 10: Mean plot for TWR

The graph shown in the figure are generated using MINITAB-17.The increasing nature of the graph with increasing level of Pulse-Current (Ip) shows that TWR increases with increase in the value of Pulse-Current. With increase in Pulse-On time the graph decreases showing that TWR decreases with increasing Pulse-On time. Similarly, it can be noted from the third graph that with increase in Voltage the TWR increases.

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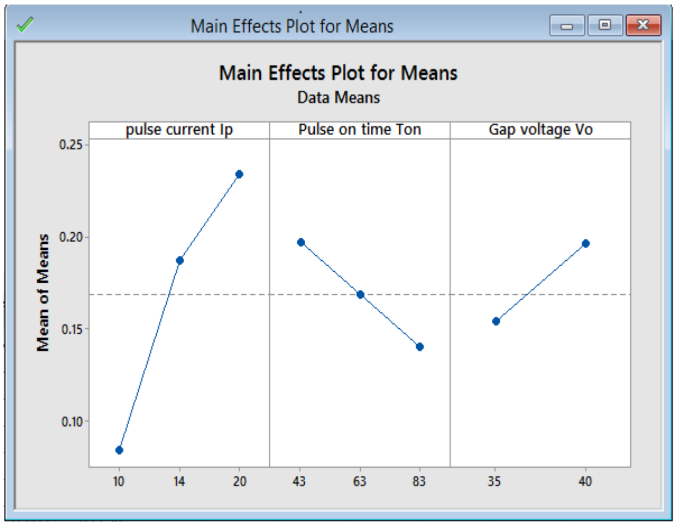
9. Mean plot for TWR Square tool



Graph 7.11: Mean plot for TWR Square tool

The graph shown in the figure are generated using MINITAB-17.The increasing nature of the graph with increasing level of Pulse-Current (Ip) shows that TWR increases with increase in the value of Pulse-Current. With increase in Pulse-On time the graph decreases showing that TWR decreases with increasing Pulse-On time. Similarly, it can be noted from the third graph that with increase in Voltage the TWR increases.

10. S/N RATIO ANALYSIS FOR TOOL WEAR RATE (SMALLER IS BETTER)

The S/N ratio is another way of analyzing the experimental data. As in this case we want TWR to be as small as possible. We will be using smaller is better S/N ratio which is given by the formula.

Signal noise ratio (Smaller is better)
$= -10 * \log(\sum(y2)/n)$
y is a response variable
n is a number of a level

The S/N ratio calculated using above formula are tabulated in the following table.
Table: S/N ratio for TWR

Table 7.6: Response table for S/N ration of TWR

LEVEL	Ip	TON	VO
1	28.194	14.804	19.762
2	13.286	15.755	14.965
3	6.125	17.048	12.879
DELTA	22.069	2.244	6.883
RANK	1	3	2

The maximum difference among the S/N ratio value of TWR at different levels gives the value of Delta which is directly proportional to the effect of that parameter on the response. That means higher the value of Delta for a particular parameter more is its effects on response. The rank are given to the parameter in order of their respective value.

11. S/N ratio plot for TWR for circular tool

The graphs shown in the figure are plotted using S/N ratio smaller the better. The decreasing graph with increasing level of Ip shows that TWR increases with increasing Pulse-Current. On a contrary TWR decreases with increasing Ton which is seen from increasing graph of S/N ratio with levels of Ton. The decreasing graph with increasing level of Ip shows that TWR increases with increasing Voltage.

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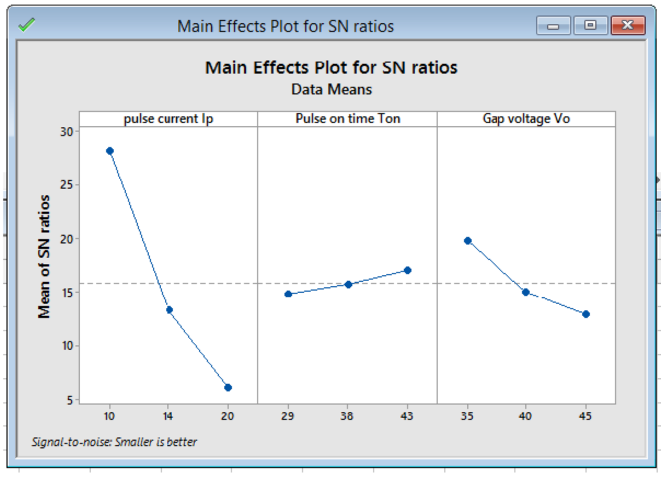
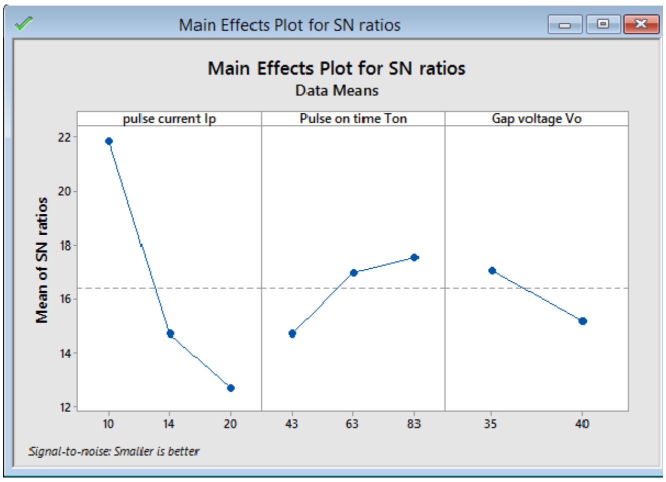


Graph 7.12: S/N ratio plot for TWR

12. S/N ratio plot for TWR Square tool



Graph 7.13: S/N ratio plot for TWR Square tool

The graphs shown in the figure are plotted using S/N ratio smaller the better. The decreasing graph with increasing level of Ip shows that TWR increases with increasing Pulse-Current. On a contrary TWR decreases with increasing Ton which is seen from increasing graph of S/N ratio with levels of Ton. The decreasing graph with increasing level of Ip shows that TWR increases with increasing Voltage.

VI. CONCLUSION

1. For circular tool

The conclusion derived from the experimentation about MRR where that the MMR increases with increase Of Current (Ip) and is low for less value of Ip. MRR also have positive effect of increasing Pulse on time that mean MRR increases with increase in Pulse on time (Ton). The effect of variable Voltage is random on MRR i.e. MRR varies randomly with increase and decrease of voltage.

The effect of this parameters on TWR were also study. It is seen that TWR increases with increases current on the contrary the effect of Pulse on time is reverse that means TWR decreases with increasing Pulse on time. Similarly gap voltage has random effect on TWR.

2. **For Square tool**

The conclusion derived from the experimentation using square electrode about MRR where that the MMR increases with increase Of Current (Ip) and is low for less value of Ip. MRR also have positive effect of increasing Pulse on time that mean MRR increases with increase in Pulse on time (Ton). It was also seen that MRR decreases with increasing Voltage.

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The effect of this parameters on TWR were also study. It is seen that TWR increases with increases current on the contrary the effect of Pulse on time is reverse that means TWR decreases with increasing Pulse on time. With increasing in Voltage the increase in tool wear was also seen.

From the ANOVA analysis of data obtained percentage contribution of each factor on MMR and TWR were calculated. The most dominating factor in machining of OHNS was found to be Ip followed by Ton and voltage.

The conclusion made from this work was that the MRR increases with increasing in Ip-current which is most dominating factor in the process. The machining of OHNS work-piece by copper electrode has greater effect of Ip followed by Ton and Vo. Thus for low wear it is found that Ip value should be in medium range with maximum Ton value and minimum voltages for low wear rate.

VII. FUTURE SCOPE

In future this work can be extended by investigating the effect of various parameters in finishing setting i.e. by considering the effect of various parameters on surface roughness of machined surface as an output parameter. In future the tool erosion can also be studied. The 2-dimensional and 3-dimentional analysis of tool wear on various parameters is also in future scope to this work.

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