

Study of the Parameters in EDM through Design of Experiments Using Taguchi Method

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ABSTRACT: The experiment for optimization of EDM process parameter is performed on EN-31 alloy steel using copper electrode of 4 mm diameter in this paper. The process parameters are decided based on the Taguchi method. The various input factors like Pulse ON time, Discharge current and voltage were considered as the input processing parameters, while the MRR and TWR is considered as the output. Optimization using Taguchi method was performed to predict the best combination of inputs towards maximum output. From this experiments it is found that different combination of EDM process parameters are required to achieve higher MRR and lower TWR for EN-31 alloy steel. Mean ratio are used to analyze the effects of parameters on TWR and MRR and also optimize the optimum input parameters.

KEYWORDS: EDM, Taguchi method, EN-31, TWR, Material removal rate, copper electrode, dielectric fluid.

I. INTRODUCTION

Electrical Discharge Machining or EDM is a machining method primarily used for hard metals or those that would be impossible to machine with traditional techniques. The non-contact machining technique has been continuously evolving from a mere tool and dies making process to a micro-scale application machining alternative attracting a significant amount of research interests. EDM is especially well-suited for cutting intricate contours or delicate cavities that would be difficult to produce with a grinder, an end mill or other cutting tools. Metals that can be machined with EDM include hardened tool-steel, titanium and carbide, Inconel etc. One critical limitation, however, is that EDM only works with materials that are electrically conductive. EDM is a thermoelectric process in which heat energy of spark is used to remove material from the workpiece. The workpiece and the tool should be made of electrically conductive material. A spark is produced between the two Electrodes (tool and workpiece) and its location is determined by the narrowest gap between the two.

II. WORKING PRINCIPLE OF EDM

EDM is a thermo electric process in which heat energy of spark is used to remove the material from the work piece. The work piece and tool should be made of electrically conductive materials. A spark is produced between two electrodes (tool and work piece) and its location is determined by the narrowest gap between the two. Duration of each spark is very short. The entire cycle time is a few micro-seconds. The frequency of sparking may be as high as thousands of sparks per second. The area over which a spark is effective is also very small. However, temperature of the area under the spark is very high. As a result, the spark energy is capable of partly melting and partly vaporizing material from localized area on both the electrodes. The material is removed in the form of craters which spread over the entire surface of the work piece. A Very small gap between the two electrodes is to be maintained to have the spark to occur. For this purpose, a tool driven by the servo system is continuously moved towards the workpiece. Finally the cavity is Produced in the work piece is approximately the replica of the tool. To have machined cavity as replica of the tool, tool wear should be zero. To minimize wear of the tool the operating parameters and polarity should be selected carefully. Particles eroded from the electrodes are known as debris. Usually the amount of material eroded from the

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tool surface is much smaller than that from the work piece surface. A During EDM, pulsed DC of 80-100 V at approximately 5 kHz is passed through the electrodes. It results in intense electric field at location where surface irregularity provides the narrowest gap. Negatively charged particles (electrons) break loose from the cathode surface and move towards the anode surface under the influence of the electric field forces.

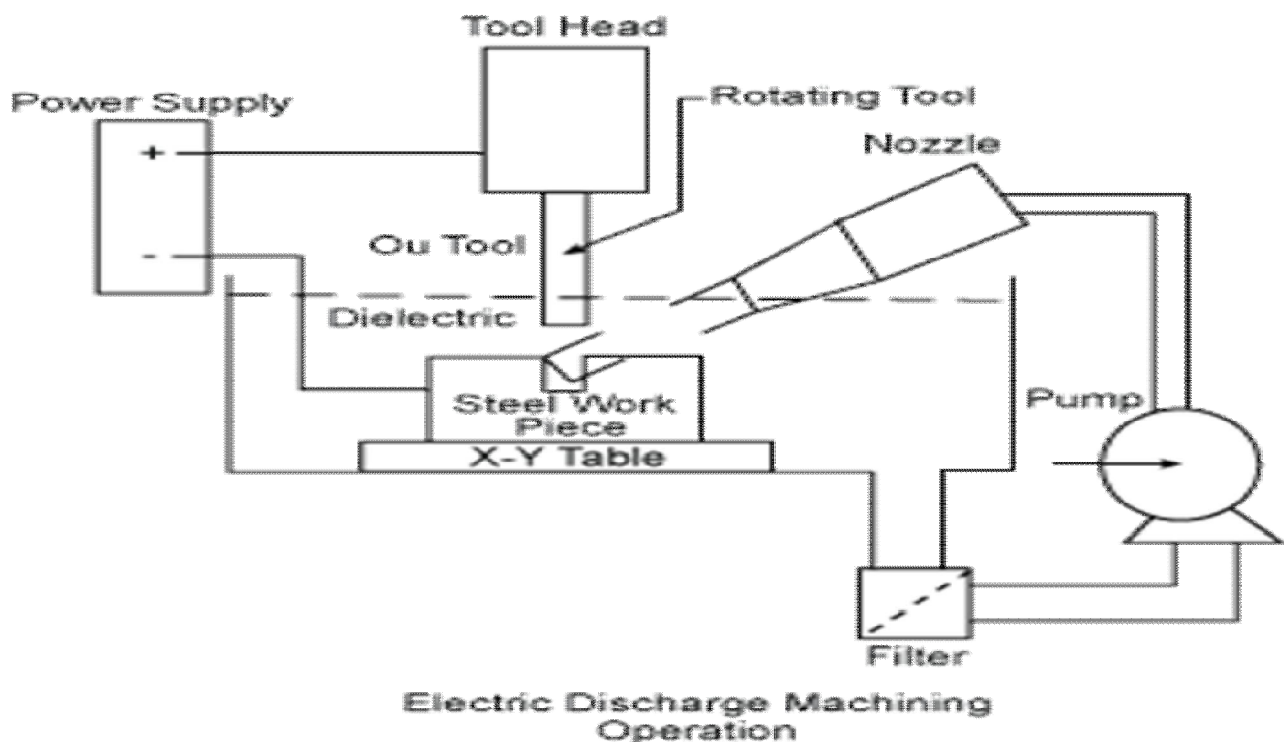


Fig 1 set up of the EDM

III. LITERATURE SURVEY

P. Srinivasan Rao et al. [1] has been developed the mathematical model for predicting die-sinking EDM of AISI 304 stainless steel work piece on response such as TWR, MRR, Ra and HRB using fuzzy logic modelling. A regression analysis of experimental and predicted output was performed to investigate the model. With fuzzy rule relationship was establish through experimentation to reduce the no. of runs S Gopalkannan et al [2] identify the significant process parameters that affect the output characteristics and to develop for MRR, EWR, SR the two main significant factors that affect the MRR are pulse on time and pulse current. The higher pulse off time lowers the EWR value. The value SR increase within increase in pulse on time and pulse current. Ramesh s Habib et al. [3] found out the metal removal rate increases with an increase of pulse on time, peak current and relatively with gap voltage. Metal removal rate decreases with increase of Sic percentage. Raj Mohan et al. [4] the current and pulse off time are more significant process parameters for MRR in EDM 304 stain less steel. For higher removal rate the recommended parametric combination is pulse on time at level1, pulse off time at a level 2, voltage at level 2, current at level 2 for EDM of 304 stainless steel. I Ferrer et al. [5] results provide recommendations of operating conditions for better micro-cavities manufacturing in Stainless steel 316L although more experiments should be done to assure the repeatability. The dimensions of the cavities obtained were close to the desired values achieving percentage of error below 5% however the roughness also should be measured. Vikram Singh et al [6] found that Regression Equation has been successfully used to develop the Material Removal rate, surface Roughness and Cutting rate model, is used to find out the optimum

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value of the parameters for the MRR and TWR, and SR.B.Satyanarayan et al. [7] Found out the assumption of ANOVAs were tested and found to be valid. Then by using annova technique. It was found that the machining variables pulse on time is a significant factor that effect surface roughness. Machining parameter pulse on time most effective factor for the surface roughness. Pulse on time should be continuous for effective surface roughness.Prof. Ashok Choudhury et al. [8] found that Taguchi's experimental design method is used to obtain optimum parameter combination for maximization of MRR.The material removal rate (MRR) mainly affected by peak current (Ip). Duty cycle (DC) has least effect on it. The electrode wear rate (EWR) is mainly influenced by peak current (Ip). The effect of gap voltage (Vg) is less on EWR and has least effect on itM. S. Reza et al. [9] Optimize the controlled parameters of EDM using injection flushing type machining on multi performance characteristics using GRA method. Parameters are optimized on different Response such as MRR, TWR and SR. For this experiment copper tool and AISI 304 stainless steel work piece is utilized. L18 Taguchi's orthogonal array design planned for experiments. Selected machine settings are Ip, Ton, polarity, voltage, dielectric liquid pressure and machining depth have been taken.

IV. MATERIAL PROPERTIES

[A] WORKPIECE MATERIAL

EN-31 contains the alloying element as per table given below:-

ELEMENT	Mn	C	Si	Cr
%	0.52	1.50	0.22	1.30
ELEMENT	S	P	Mg	-
%	0.5	0.5	-	

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[B] TOOL MATERIAL

In this experiment the copper is selected as a tool material with the properties listed in Table2.

TABLE 2.MECHANICAL AND THERMAL PROPERTIES OF
COPPER TOOL

Electrical resistivity	1.96mico-Ohm/cm
Melting point	1083°C
Electrical conductivity	92%
Thermal conductivity	380.7W/mk
Specific heat	0.092cal/g°C
Coefficient of thermal expansion	6.6X10 ⁻⁶ °C
Density	8.9gm/cm ³

V. EXPERIMENTAL DATA

The machining parameters chosen for the present experiment are current, open circuit voltage and Pulse-on time (Ton) is the duration of time (in μ s) the current is allowed to flow per cycle.

TABLE 3. THE MACHINING PARAMETERS AND THEIR LEVELS

Machining parameters	Symbols	Unit	Levels		
			Level1	Level2	Level3
Current	Ip	A	10	15	20
Voltage	Vg	V	35	40	45
Pulse on time	Ton	μ s	100	150	200

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Work piece was cut in the form of 1.5inch* 1.5inch * 6inch. Subsequently nominal cut on lathe was carried out to remove rust and corrosion. After machining it was thoroughly cleaned with Acid to remove the carbon deposition, and the weight measurements were taken on electronic weighing machine, which has a resolution of 0.001 grams. Each experiment was carried out and weight loss of material and electrode are measured. Initial weights of the work piece and copper electrodes are given in the Table

VI. EXPERIMENTAL PROCEDURE

TABLE 4. INITIALS AND FINAL WEIGHTS OF WORK PIECES AND ELECTRODES

No.	Work piece (gm)		Electrode (gm)	
	Wbm	Wam	Wtb	Wta
1	1892.098	1891.848	37.0288	37.0269
2	1891.848	1891.508	37.0269	37.0172
3	1891.508	1891.228	37.0172	37.0168
4	1891.228	1890.838	37.0168	37.0154
5	1890.838	1890.343	37.0154	37.0115
6	1890.343	1889.833	37.0115	37.0076
7	1889.833	1889.368	37.0076	37.0068
8	1889.368	1888.615	37.0068	37.0027
9	1889.615	1888.001	37.0027	37.001

Table 4 show the initial and the final weight of the work piece and tool, during experiments which can be find out before and after machining these calculation are useful for find out the MRR and TWR.

MRR(Material removal rate) = Difference in Weight of work piece before and after machining/Time of machining

EWR (Electrode wear rate) = Difference in Weight of electrode before and after machining/ Time of machining

Whereas Wbm = weight of the work piece before machining, Wam = weight of the work piece after machining

Wtb = weight of the work tool after machining, Wta = weight of the tool before machining

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During the experiment we have taken total 9 readings on the copper electrode. Time taken for machining was recorded by digital stop watch and then weight loss of work piece and electrode are calculated. From the equations given in above chapter electrode wear rate (EWR) and material removal rate (MRR) are measured which is given in the table described below. Other working parameters are kept constant like depth of cut and diameter of electrode is 4 mm...

TABLE 5: - OBSERVATION TABLE

S.NO.	Ip	Vg	Ton(μ s)	Weight loss(W)(gm)	Weight loss(T)(Gm)	MRR (mm ³ /min)	TWR (mm ³ /min)
1	10	35	100	0.250	0.0019	4.5787	0.0642
2	10	40	150	0.340	0.0097	6.2271	0.0157
3	10	45	200	0.280	0.0004	5.1282	0.0065
4	15	35	150	0.390	0.0014	7.1428	0.0196
5	15	40	200	0.495	0.0039	9.0659	0.0115
6	15	45	100	0.510	0.0039	9.3408	0.0632
7	20	35	200	0.465	0.0008	8.5164	0.0142
8	20	40	100	0.753	0.0041	13.791	0.0674
9	20	45	150	1.614	0.0017	11.227	0.0275

VII. SIGNAL TO NOISE RATION OR S/N RATIO

The S/N ratios for MRR are calculated as given in Equation [1]. Taguchi method is used to analysis the result of response of machining parameter for “larger is better” criteria for MRR, lower is the batter for TWR.

$$LB: \eta = -10 \log [1/n \sum_i^n Y_i^{-2}]$$

Where η denotes the S/N ratios calculated from observed values, y_i represents the experimentally observed value of the i th experiment and $n=1$ is the repeated number of each experiment in L-9 Orthogonal Array is conducted. With full factorial as a design of experiment, value of MRR for each sample will be obtained. Then, MINITAB 9.0 software will be used for further analysis. Figure 2, 3 and 4 showsall the result.

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TABLE 6:- OBSERVATION TABLE OF S/N RATIO (TWR)

S.NO.	1	2	3	4	5	6	7	8	9
TWR	0.0642	0.0157	0.0065	0.0196	0.0115	0.0632	0.0142	0.0674	0.0275
Mm ³ /min									
S/N ratio	23.8492	36.0820	43.7417	34.1548	38.7860	23.9855	36.9855	23.4262	31.2133
dB									

Table 6 is the table of the TWR and S/N ratio of the TWR this table will be used for plotting the graph manual method between controllable factor and S/N ratio for study of the maximum tool wear rate and minimum tool wear rate.

TABLE 7 MEAN RESPONSE TABLE FOR MEANS (MRR)

SYMBOLS	CONTROLLABLE FACTOR	Mean (MRR)		
		Low	Medium	High
V	Voltage	6.7459	9.6932	8.5653
I	Current	5.3113	8.5165	11.1781
Ton	Pulse on time	9.2368	8.1989	7.5685

Table 7 show the mean of the means for MRR for controllable factors it show the mean at three levels low, medium and high. Which are very important for find out the optimum parameters for higher material removal rate, and these all values are very important for plot the graph between mean of means v/s controllable factor.

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TABLE 8 MEAN RESPONSE TABLE FOR MEANS (TWR)

SYMBOLS	CONTROLLABLE FACTOR	Mean (TWR)		
		Low	Medium	High
V	Voltage	0.0326	0.0314	0.0323
I	Current	0.02880	0.03443	0.03637
Ton	Pulse on time	0.06473	0.0209	0.01066

Table 8 show the mean of the means for MRR for controllable factors it show the mean at three levels low, medium and high. Which are very important for find out the optimum parameters for minimum tool wear rate, and these all values are very important for plot the graph. Between mean of means v/s controllable factor.

TABLE 9 MEAN RESPONSE TABLE FOR S/N RATIO FOR TWR

Symbol	Controllable factor	S/N ratio of TWR		
		Low	Medium	High
V	Voltage	31.6527	32.7647	32.9888
I	Current	34.5576	32.3100	30.5300
μ s	TON	23.7500	33.8200	39.8300

Table 9 show the mean of the S/N ratio for TWR for controllable factors it show the mean at three levels low, medium and high. Which are very important for find out the optimum parameters for minimum tool wear rate, and these all values are very important for plot the graph. Between mean S/N ratio v/s controllable factor. According to this lower is the better criteria are used.

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VIII. RESULTS AND DISCUSSION FOR MRR

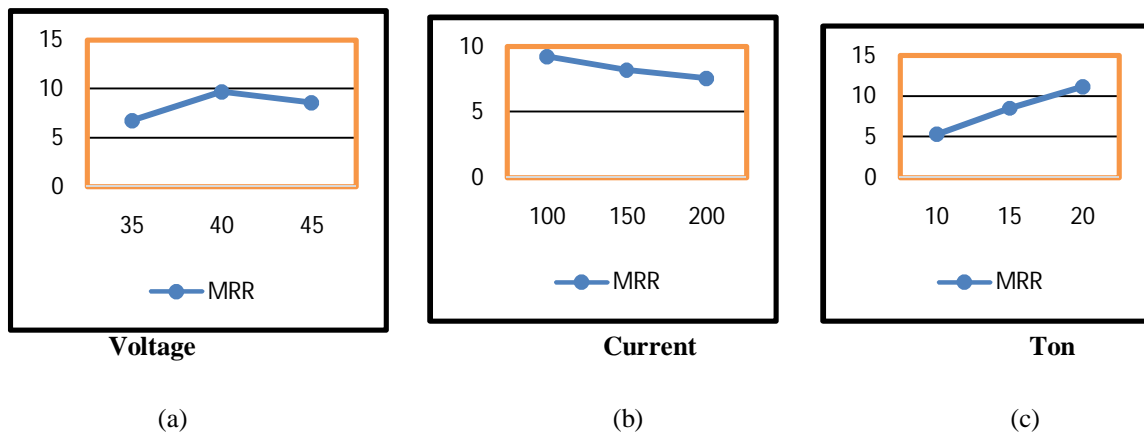
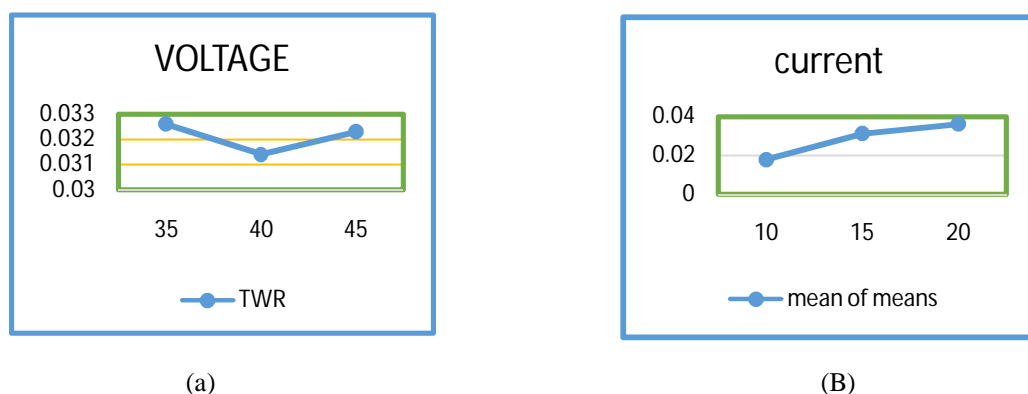


Fig.2 Main effects plot for means of MRR

Fig.show The Material removal increases with increase in the current continuously and the effects of the voltage will increase the material removal rate between 35 V -40 V after that the voltage graph decrease continuously 40 v- 45v with voltage. And the effect of the pulse on time on the material removal rate is high at the staring at low pulse on time, decrease with linear manner in the graph which decrease the material removal rate.

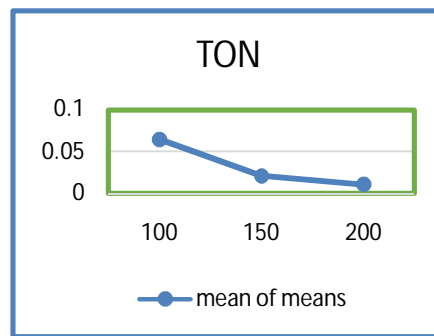
IX. RESULTS AND DISCUSSION FOR TWR



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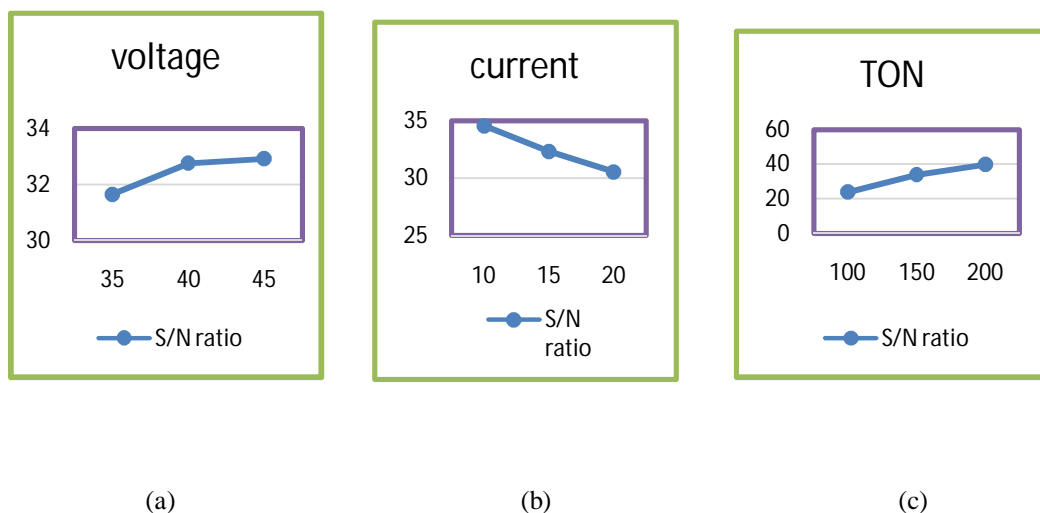
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(C)

Fig.3 Main effects plot for means of TWR

Fig. show the results of the mean of the means for TWR according the fig. 3 (a) of current V/S mean of means in this figure When the current increase the mean of the means increase continuously with increases in current. And the effects of the pulse on time are shown in the figure 3 (c) of Ton v/s mean of means, in this figure when increase in the pulse on time the mean of means decrease, according to the pulse on time.it decrease quickly from 100 μ s to 150 μ s and after that id decrease slowly shown in fig. 3 (c) And the effects of the voltage is negligible mean of means decrease from 35 v to 40 v after that it Increase at 40v to 45 v shown in fig.3 (a)



(a)

(b)

(c)

Fig. 4 S/N ratio curve for TWR

The tool wear rate mainly affect by the current, when the increase the pulse on time the tool wear rate increase with pulse on time according to the fig.4(c). Pulse on time increase quickly from 100 μ s – 150 μ s after that it's increase continuously with increase in pulse on time to 150 μ s -200 μ s.so that tool wear rate increase as shown in figure 4. Tool wear rate decrease with increases in current and the tool wear increase with decreases in current shown in fig.4 (b). And the effect of the voltage, when the increase in voltage from 35 v -40 v, the tool wear rate small increase in

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linear manner after 40 v – 45 v the tool wear rate increase with the increase in the voltage in fig.4 (a). The main investigation for maximum material removal rate, the optimum parameters should be high current, high pulse on time and the medium voltage for EN-31 work piece. And for tool wear rate the optimum parameters should be medium voltage, low current and high pulse on time for copper tool electrode.

CONFIRMATION OF EXPERIMENTS

For maximum MRR the combination of the optimum parameters (V_2 , I_3 , and $Ton1$) it means medium voltage, high current and high pulse on time. For this combination $V_2 = 40v$, $I_3 = 20$ amp, and $TON = 100\mu s$ the MRR is $13.791 \text{ mm}^3/\text{min}$. For minimum TWR the combination of optimum parameters (V_2 , I_1 , and $Ton3$) it means medium voltage and low current and high TON. For this combination $V_2 = 35$, $I_1 = 10$ amp and $TON = 200\mu s$, the TWR is $0.0065 \text{ mm}^3/\text{min}$. For minimum TWR, the S/N ratio combination of optimum parameters (V_2 , I_3 , and $Ton1$) it means medium voltage, high current and low Ton. For this combination $V_2 = 40$, $I_1 = 20$ amp, $Ton = 100\mu s$

X. CONCLUSION

The EDM performance of copper tools was examined with EN-31 tool Steel. In this work, an attempt was made to determine the important machining parameters for performance measures like MRR, TWR. In the EDM process factors like discharge current, pulse on time and voltage Taguchi's experimental design method is used to obtain optimum parameter combination for maximization of MRR and minimization of TWR

- The material removal rate (MRR) mainly affected by peak current (I_p). Voltage has least effect on it.
- The electrode wear rate (EWR) is mainly influenced by peak current and by pulse on time. The effect of gap voltage (V_g) is less on EWR and has least effect on it. For minimum TWR, the S/N ratio combination of optimum parameters (V_2 , I_3 , and $Ton1$) it means medium voltage, high current and low Ton. For this combination $V_2 = 40$, $I_1 = 20$ amp, $Ton = 100\mu s$.

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