Near Dry EDM Drilling on MS Material

P. Tripathy and V.R. Kar

Abstract--- *The paper deals with the study of Near dry EDM drilling on Mild steel material using copper tubular electrode to drill micro holes. The tool used is a tubular copper electrode of 1mm outside diameter and 0.3 mm of inner diameter. The dielectric used is a combination of liquid and gaseous. The dielectric used during experiment is combination of water and oxygen at a pressure of 2 Mpa. The entire experiments are based on factorial regression and response surface methodology (RSM). The material removal rate (MRR) and tool wear rate (TWR) were calculated and expressed in the form of generalized equations. The combined effect of MRR & TWR (λ) is also taken into account so that there is a balance between MRR and TWR to an extent. Optimization of the input parameters has been done using Linear Programming (LPP) technique.*

Keywords--- *Near-Dry EDM, MRR, λ, TWR, LPP Technique, RSM*

I. INTRODUCTION

DUE to the growing need for high strength materials in technologically advanced industries and the recent advances in the field of material science, there has been an increase in the availability and use of difficult-to-machine materials. Nontraditional machining processes are necessary for machining of such materials. Electro discharge machining has drawn a great deal of attention because of its board industrial application using controlled erosion through a series of electric spark. Thermal energy of the spark leads to intense heat condition of the work piece. Melting and vaporizing of the material takes place under a controlled environment which results in a precision manufacture of the part or component in the macro as well as micro level.

The near dry EDM process compromises both the advantages of wet EDM and dry EDM i.e.it has no fire hazard, no toxic flames are generated and no special treatment for the disposal of the sludge, dielectric waste etc are required. It has a very low tool wear, higher precision can be achieved. It has a smaller Heat Affected Zone (HAZ) It also provides a higher material removal rate (MRR) and also have a good process stability.

Lot of researches is being done to enhance the capability of traditional, dry and near-dry EDM. The present work aims to determine the empirical relationship between the Material Removal Rate (MRR) and Tool Wear Rate (TWR) being out-put with current, on-time, off-time at constant voltage using mild steel as work piece and copper electrode as tool material. The combination effect of MRR & TWR (λ) is considered to optimize the process parameters.

II. EXPERIMENTAL SETUP

Experiments are performed by the authors in the area of near-dry EDM using water as the basic dielectric. Along with water in one case air is used and in other oxygen with 2 Mpa pressure is used.

The entire experiments have been carried out using design of experiment through factorial regression and response surface methodology. The table 1 shows the input parameters, with its absolute values and code. While the table 2 shows the design of experiment as well as the output of the experimental data in the three cases. Table 3 & 4 shows the analysis of variance.

Table 1: Values of Process Parameter

	Gap voltage Volt	Discharge current Amp	Pulse on time (Ton) Msec
High (+1)	40	5	32(5)
Medium (0)	30	4	24(4)
Low (-1)	20	3	18(3)

Figure 1: Experimental Setup

The output of the set of experiment is material removal rate (MRR) and tool wear rate (TWR). From the values we can get the generalized equation for each output. The MRR should be maximum as well as the TWR should be minimum.

III. RESULTS

The work piece used for machining is mild steel (MS) and the tool electrode is copper tubular electrode with outside diameter 1mm and inner diameter as 0.3mm. Three sets of experiments were carried out varying the dielectric used. The dielectrics used are water, water combined with air and water combined with oxygen.

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Table 2: Design of Experiment While Machining MS

SL. no	V	C	Ton	Water + Oxygen	
				MRR gm/sec	TWR gm/sec
1	1	1	1	0.0008	0.00095
2	1	1	-1	0.0005	0.00078
3	1	-1	1	0.0002	0.00016
4	1	-1	-1	0.0007	0.00010
5	-1	1	1	0.0010	0.00093
6	-1	1	-1	0.0005	0.00078
7	-1	-1	1	0.0002	8.5E-05
8	-1	-1	-1	0.0001	6.6E-05
9	0	0	0	0.0004	0.00052
10	0	0	0	0.0005	0.00042
11	0	0	0	0.0005	0.00044
12	0	0	0	0.0006	0.00057

Table 3: Regression Analysis and ANOVA for MRR While Machining MS with Dielectric as Combination of Water & O2

Regression Statistics	
Multiple R	0.97819755
R Square	0.95687045
Adjusted R Square	0.89217613
Standard Error	0.09713185
Observations	6

ANOVA

	df	SS	MS	F	Significance F
Regression	3	0.418631204	0.13954373	14.79064	0.063991663
Residual	2	0.018869194	0.0094346		
Total	5	0.437500398			

Coefficients

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	-4.8750273	0.249170921	-19.564993	0.002602	-5.94712319	-3.8029313	-5.94712319	-3.80293131
VOLTAGE	-0.0020961	0.004747492	-0.4415166	0.701986	-0.02252290	0.01833071	-0.02252291	0.018330712
CURRENT	0.26882433	0.05954375	4.51473632	0.045722	0.012628252	0.52502041	0.012628252	0.525020411
T_{ON}	0.01814474	0.006858912	2.64542576	0.118107	-0.01136677	0.04765626	-0.01136677	0.047656262

Table 4: Regression Analysis and ANOVA for TWR While Machining MS with Dielectric as Combination of Water & O2

Regression Statistics	
Multiple R	0.95704194
R Square	0.91592927
Adjusted R Square	0.88440274
Standard Error	0.14365821
Observations	12

ANOVA

	df	SS	MS	F	Significance F
Regression	3	1.798738372	0.59957946	29.05266	0.000118727
Residual	8	0.16510145	0.02063768		
Total	11	1.963839822			

Coefficients

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	-5.6870257	0.31309581	-18.163851	8.67E-08	-6.409025959	-4.9650255	-6.409025959	-4.9650255
VOLTAGE	0.00620485	0.005079085	1.22164667	0.256616	-0.005507543	0.017917237	-0.005507543	0.017917237
CURRENT	0.46768961	0.050790847	9.20814754	1.57E-05	0.350565711	0.584813518	0.350565711	0.584813518
T_{ON}	0.00676643	0.007231281	0.93571718	0.3768	-0.00990893	0.023441797	-0.00990893	0.023441797

Summary Output:

With Oxygen and water (Dielectric):

The Mild Steel is machined with a dielectric fluid as a combination of oxygenat 2 Mpa and water, with a tubular copper electrode of 1mm outer diameter and 0.3mm inner diameter. From the above regression analysis we get:

$$MRR= 0.00038 \text{ x } V^{0.007455} C^{0.211687} T^{0.000752}$$

$$TWR= 0.00022 \text{ x } V^{0.006204} C^{0.467689} T^{0.006766}$$

The combined effect of the MRR & TWR can be expressed as

$$\lambda=MRR/TWR=1.6956 \text{ x } V^{0.001251} C^{-0.256002} T^{-0.00601}$$

IV. OPTIMIZATION OF INPUT PARAMETER

The main objective of optimization is maximizing λ. From the above equation of λ we can see that the significance of voltage is very low as compared to current and Ton. Optimization is done for λ using LPP technique.

Linear programming is a technique for the optimization of a linear objective function, subject to linear equality and linear inequality constraints. Its feasible region is a convex polyhedron, which is a set defined as the intersection of finitely many half spaces, each of which is defined by a linear inequality. Its objective function is a real-valued affine function defined on this polyhedron. A linear programming algorithm finds a point in the polyhedron where this function has the smallest (or largest) value if such point exists.

Linear programs are problems that can be expressed in canonical form:

$$\begin{array}{ll} \text{maximize} & \mathbf{c}^{\top}\mathbf{x} \\ \text{subject to} & A\mathbf{x} \leq \mathbf{b} \\ \text{and} & \mathbf{x} \geq \mathbf{0} \end{array}$$

The objective function to maximization of MRR with constraints of current, Ton and powder concentration can be written as,

Objective: To maximize λ

$$Y= |Øz|_{max} = 1.6956 \text{ x } V^{0.001251} C^{-0.256002} Ton^{-0.00601}$$

Subject to : $20 \leq V \leq 40$;

$3 \leq C \leq 5$;

$18 \leq Ton \leq 32$.

Taking Log on both side of equation,

$$Y= |Øz|_{max} = \text{Log } \lambda = \log 1.695 + 0.0012 \log V - 0.2560 \log C - 0.0060 \log Ton$$

$$|Øz|_{max}=0.2293 + 0.0012(X1) - 0.2560(X2) - 0.0060(X3)$$

Constant values having no effect on values of X_1 and X_2 and X3, subject to $X_{1,2,3} \geq 0$ non negativity constraints.

$|Øz|_{max.} = 0.001251 (X1) - 0.256002 (X2) - 0.00601(X3)$

Subject to

$$1.30103 \leq X1 \leq 1.6020$$
$$0.4771 \leq X2 \leq 0.6989$$
$$1.2552 \leq X3 \leq 1.5051$$
$$X1, X2, X3 \geq 0$$

Simplex algorithm can be utilized to get the optimum values of $X_{1 \text{ and }}$ X_2 and X3, where V, Ton and C are antilog of $X_{1,}$ X2, and X3 respectively.

Table No. 5: LPP for λ

	Log (1.6956)	X_1	X_2	X_3	Øz	λ
x1x2x3	0.2293	1.301	0.477	1.255	0.101	1.262
x1x2x33	0.2293	1.301	0.477	1.505	0.099	1.258
x1x22x33	0.2293	1.301	0.698	1.505	0.042	1.103
x1x22x3	0.2293	1.301	0.698	1.255	0.044	1.107
x11x2x3	0.2293	1.602	0.477	1.255	0.101	1.263
x11x2x33	0.2293	1.602	0.477	1.505	0.100	1.259
x11x22x33	0.2293	1.602	0.698	1.505	0.043	1.104
x11x22x3	0.2293	1.602	0.698	1.255	0.044	1.108

λ is the 'higher the better' type of quality characteristic. Therefore, greater values of λ are considered to be optimal. From the above table λ is maximum at x11x2x3 where X11=1.60206, X2=0.477121, X3=0.101639

Thus optimum values of input parameters for maximum MRR are:

V =40 Volt

C = 3 Amp

Ton = 18 µsec

V. RESPONSE SURFACE METHODOLOGY (RSM) FOR Λ

The fig.4 shows the effect of λ on the input parameters voltage (V) and pulse time on (Ton). The legend shows the variation of λ. Maximum effect of the λ is at the maximum value of voltage (40 V) and minimum value of Ton (18 µsec). This shows that the optimization values are same as that of the surface response methodology.

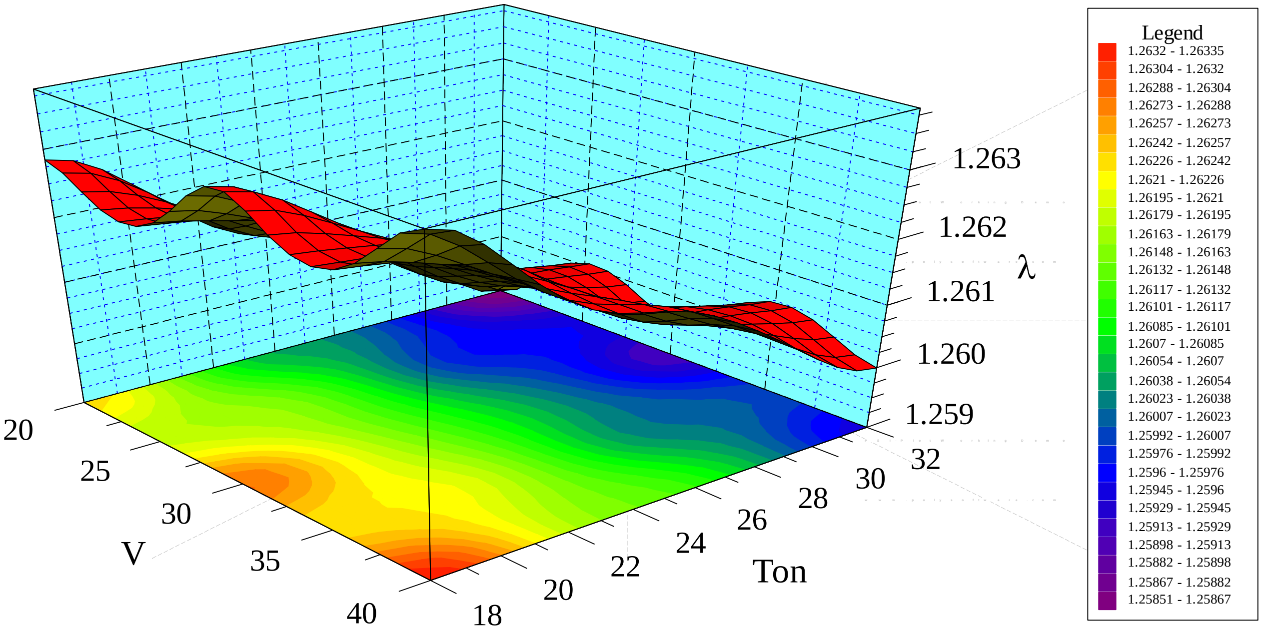

Figure 2: Response Surface Methodology (RSM) for λ

VI. CONCLUSION

Form the experimental results and its analysis we can conclude that the MRR and TWR depends on the input parameters. From optimization technique we can see that the effect of λ is maximum at value of V =40 Volt, C = 3 Amp, Ton = 18 μsec

VII. FUTURE SCOPE

We can use different materials as well as different electrodes can be used for experimentation. We can also vary different dielectric for the experimentation. We can also use some inert gases as gaseous dielectric. The optimization can be done by different methods to get the exact value of the input parameters.

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