Prediction of Tool wears by Rotary Electrode attachment in EDM

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Abstract— **Rapidly developing technology aims to design in manufacturing the product at miniaturization scale. Hence machining has become considering important and widely used. This paper presents an optimization of Machining parameter i.e. Polarity, Peak current, Rotational speed of electrode and Pulse on time on Tool wear rate (TWR) in Rotary electrode attached Electrical discharge machining. Experiments have been designed as per Taguchi's L18 orthogonal array. S/N ratio and ANOVA is employed to indicate the levels of significant machining parameter on tool Wear rate. the experimental results shows that Polarity is most significant parameter followed by Peak current, Rotational speed of electrode and Pulse on time.**

Keywords— **EDM, Taguchi Method, S/N ratio, ANOVA**

I. INTRODUCTION

Miniaturization of the components is most requirements for the future technological development in bio medical engineering, aerospace engineering, defence application. EDM process can perform on all electrically conductive material irrespective of their hardness.EDM is quite similar to the principal of EDM. It is of thermal process that uses electrode discharge to erode the electrically conducted material. EDM is based on simple theory when two electrodes is separated by die electric medium comes to closer to each other the die electric medium that is initially non conductive break down and become conductive. During this period spark will be generated between the electrode and thermal energy is produced that will be used for the material removal by melting and evaporation.

Ali et al [1] investigated the geometrical tool wear like edge and frontal wear using 1040 steel as work piece. they observed that increasing in peak current increases Tool Wear.B.Pradhan et al [2] investigated the feasibility and optimization of electro discharge micro-machining of titanium super alloy using Taguchi L9 orthogonal array. They also conclude that due to rotational speed of electrode tool wear reduces.

In the Present work rotary Brass lead as electrode was used to machine Tungsten Carbide work piece material. The objective of the present work is to optimize the machining parameter i.e. Polarity, Rotational speed of Electrode, Peak current, Pulse on time for getting Lower the Tool Wear

II. TAGUCHI DESIGN OF EXPERIMENT

Taguchi design of experiment is very useful method for finding out the correlation between the machining parameter and Performance parameter. Then the experimental observation is transformed into a signal to noise ratio. There are three type of quality characteristics in Taghuchi method i.e. smaller the better, larger the better and nominal the best. The objective of the present work is to determine the minimum tool wear assisted to the EDM. Therefore smaller the better type quality characteristic for tool wear was implemented in this study. The S/N ratio for smaller the better type calculated as:

$$(S/N)_{LB} = -10 \log (MSD_{LB}) \quad (1)$$

Where,

$$MSD_{LB} = \frac{1}{n}(y_1^2 + y_2^2 + y_3^2 + \dots + y_n^2)$$

n is the number of repetition, y is the observed value.

The machining parameter chosen for the experiment are: Polarity, Rotational speed of electrode, Peak current and pulse on time. This parameter were selected because they can potentially affects the tool wear in EDM.the machining condition and number of levels of the Maching parameter is given in Table 1.

In this study, an L18 (2^1x3^3) Orthogonal array based on Taghuchi design are used. The layout of the L18 is shown in Table 2.

III. EXPERIMENTAL WORK

The Experiments were conducted on JOEMARS AZ 50 JM 322 electrical discharge machine. The developed Rotary electrode attachment was held in the machine head for performing Rotary Micro machining. In the present Work Tungsten Carbide having 12 mm x 12 mm x 6 mm dimension was prepared. it has wide application in manufacturing of pollution control stack liners, ducts, dampers, scrubbers, stack gas reheaters, Chemical processing components like heat exchangers, reaction vessels, evaporators, and transfer piping, Pharmaceutical and food processing equipment, Marine engineering etc.the brass rod having 2 mm diameter was used as Rotating Electrode Material.

TABLE 1
MACHINING CONDITION AND NUMBER OF LEVEL OF PROCESS PARAMETER

Machining Parameter	Level 1	Level 2	Level 3
A: Polarity, p		+	
B: Rotational Speed of Electrode, N , RPM	50	100	150
C: Peak current , Ip, A	0.3	1.5	2
D: Pulse on time, T_{on}, µs	2	5	9

TABLE 2
L18 OBSERVATIONS TABLE

EXP .No	Factors				Performance parameter	
	P	N	Ip	Ton	TWR	S/N
		RPM	A	µs	mm3/min	
1	-	50	0.3	2	0.00727559	42.762636
2	-	50	1.5	5	0.04686158	26.583661
3	-	50	2	9	0.10282668	19.757884
4	-	100	0.3	2	0.00727222	42.76666
5	-	100	1.5	5	0.02567959	31.808238
6	-	100	2	9	0.06572385	23.64554
7	-	150	0.3	5	0.01438739	36.84036
8	-	150	1.5	9	0.03245455	29.774488
9	-	150	2	2	0.01840339	34.702043
10	+	50	0.3	9	0.00182992	54.751358
11	+	50	1.5	2	0.00582031	44.701078
12	+	50	2	5	0.02981022	30.512696
13	+	100	0.3	5	0.00348459	49.156966
14	+	100	1.5	9	0.00481787	46.342898
15	+	100	2	2	0.00577783	44.764705
16	+	150	0.3	9	0.00338932	49.397749
17	+	150	1.5	2	0.00514627	45.770149
18	+	150	2	5	0.00700999	43.085652

IV. EXPERIMENTAL RESULT

The experiment were conducted to see the affect of Polarity, Rotational speed of electrode, Peak current, Pulse on time on Tool Wear Rate (TWR) using L18 OA.The tool wear was measured by electrical contact at a reference point on the work piece before and after machining. TWR was calculated as: [3]

$$TWR=\frac{\frac{\Pi}{4}d^{2}\times\Delta l}{t} \qquad (2)$$

Where, d is the diameter of electrode, Δl is the change in length of electrode before and after machining is the machining time. the calculated experimental value for TWR and its corresponding S/N ratio are shown in table 2.

V. ANALYSIS AND DISCUSSION

After the conducting experiment the observed value of TWR was transfers in to S/N ratio and main effect plot for TWR is plotted as shown in figure 1.it shows that negative polarity has the most significant effect on the TWR.Because relative heat dissipation on the work piece is high at the end of discharge duration.TWR decreases with increases in rotational speed of electrode.TWR decreases sharply when Peak current increases from 0.3 A to 1.5 A and TWR again gradually reduces from increasing in peak current from 1.5 A to 2 A.TWR reduces with increasing pulse on time but after 5 µs TWR is increasing with increases in Pulse on time. It is

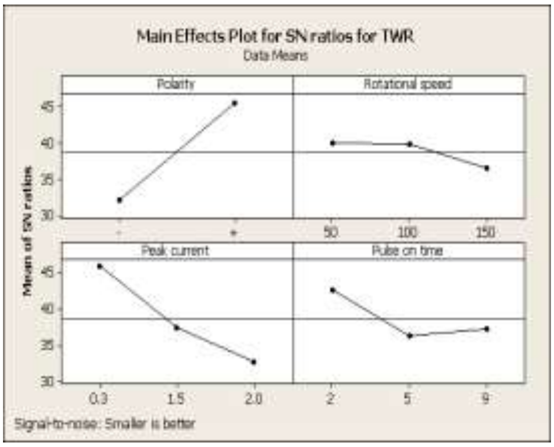

Fig.1 Main effect plots for SN ratios for TWR

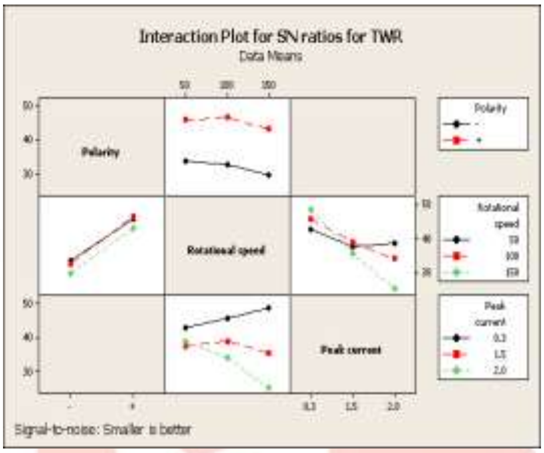

Fig.2 Interaction plot for SN ratios for TWR

Observed from the figure 2. that there is a slight interaction between Rotational speed and peak current while there is very weak interaction between all the other machining parameters in affecting the TWR since the responses at different levels of process parameters for a given level of parameter value are almost parallel.

In order to study the significance of the machining parameter towards TWR, Analysis of variance (ANOVA) was performed. The ANOVA of the S/N ratio for TWR is given in table 3.from the table, it is observed that Polarity, Peak current, Pulse on time and interaction of Rotational speed of electrode and Peak current have significant effect on TWR. The response table for Signal to Noise ratio for TWR is shown in table 4.The rank and delta values show that polarity has the greatest effect on TWR and is followed by Peak current, pulse on time and Rotational speed in that order. As TWR has "lower is better" characteristic, from the figure 1, first level of polarity (A1=Negative), third level of rotational speed (B3=150 rpm), third level of Peak current (C3=2 A), second level of pulse on time (D2= 5 μs) for reducing Tool Wear Rate.

VI. ESTIMATION OF OPTIMUM MACHINING PARAMETER

TABLE 3
L18 OBSERVATIONS TABLE

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Polarity	1	797.89	797.891	797.891	233.33	0.000
Rotational speed	2	44.36	44.358	22.179	6.49	0.056
Peak current	2	536.48	536.484	268.242	78.44	0.001
Pulse on time	2	70.83	70.839	35.419	10.36	0.026
Polarity*Rotational speed	2	2.38	2.383	1.191	0.35	0.725
Rotational speed*Peak current	4	129.97	129.973	32.493	9.50	0.025
Residual Error	4	13.68	13.678	3.420		
Total	17	1595.59				

TABLE 4
RESPONSE TABLE FOR S/N RATIO

Level	Polarity	Rotational speed	Peak current	Pulse on time
1	32.07	39.93	45.95	42.58
2	45.39	39.75	37.50	36.33
3		36.51	32.74	37.28
Delta	13.32	3.42	13.20	6.25
Rank	1	4	2	3

In this section, the optimal values of the Tool Wear rate have been predicated at the selected levels of significant machining parameter which have been found from ANOVA and S/N ratio. The mean at the optimal value of TWR is estimated by: [4]

$$\eta_{opt} = \eta_m + \sum_{i=1}^{n} (\eta_i - \eta_m) \qquad (3)$$

Where, η_m is total mean of the process parameter, η_i is The average value of the significant parameter at respectively levels, n is the Number of process parameters that significantly affects the machining characteristics. The estimated mean of TWR can be computed as:

$$\eta_{opt} = \eta_m + \left[\left(\overline{A1} - \eta_m \right) + \left(\overline{C3} - \eta_m \right) + \left(\overline{D2} - \eta_m \right) \right]$$

Where, η_m is the Total mean of the TWR, $\overline{A1}$ is the Average value of TWR at the first level of Polarity, $\overline{C3}$ is the Average value of TWR at the Third level of Peak current $\overline{D2}$ is the Average value of TWR at the second level of pulse on time .

VII. CONFIRMATION EXPERIMENT

In order to validate the results obtained, the confirmation experiments were conducted at the optimum machining parameters. The confirmation experiment were conducted for Tool Wear rate and results obtained and compared with predicted values are shown in table 5.

TABLE 5
Predicated optimal value and confirmation experimental result

	Predicted	Experimented
Optimal Parameter combination	Negative,150 rpm, 2 A, 5 µs	Negative,150 rpm, 2A, 9 µs
Significant Parameter	Negative,2 A,5 µs	Negative,150 rpm, 2A
TWR (mm^3/min)	0.052338	0.052211

VIII. CONCLUSION

The present paper investigated and optimized the machining parameter i.e. Polarity, rotational speed of electrode, Peak current and pulse on time for TWR of EDM of Tungsten Carbide using Rotary electrode. The significant parameter for TWR is determined by using S/N ratio and ANOVA. The important conclusion summarized below:

- The minimum tool wear rate is obtained at Negative polarity, Rotational speed of electrode at 150 rpm, peak current at 2 A and Pulse on time at 5 µs.

- Tool wear rate reduces with increase in rotational speed of electrode and Peak current upto higher value of both. Tool wear rate is low at low pulse on time of 2 µs and it reduces upto 5 µs and then increases upto higher value of pulse on time of 9 µs.

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