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Research Paper

ESTIMATION OF MRR FOR MICRO-EDM MACHINING OF HASTELLOY C 276 USING TAGUCHI METHODOLOGY

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Micro EDM using solid tool has been extensively used for micromachining of materials like EN-8 steel, composite material, Incoloy etc. This paper presents optimization of Material Removal Rate (MRR) using Rotary electrode attachment. The experiments study was conducted for varying machining parameter like Polarity, Peak current, Rotational speed of Electrode and Pulse on time using Taguchi methodology to investigate the machining characteristics of Hastelloy c 276 with 0.5 mm Graphite rod as Electrode. Significant machining parameter for MRR were identified by using signal to noise ratio and ANOVA,The results of the Experiment state that Polarity is more influshing Parameter than Peak current, Rotational speed of Electrode and Pulse on time for material removal rate.

Keywords: Micro EDM, S/N ratio, ANOVA

INTRODUCTION

In the present day scenario the micro products play a crucial role in the field of bio medical, nuclear, defence, aerospace and automotive industry are increasingly demanded. Micro electric discharge machining is well suitable for machining of micro parts. Due to the high mechanical strength, high corrosion resistance, high wear resistance are properties very difficult to machining Hastelloy c 276 by conventional machining process and conventional tool material so that modern machining techniques such as EDM are increasing being used for machining such a hard material.

Micro EDM is the nontraditional manufacturing process; it is a thermal Process that uses electrical discharge energy to erode electrically conductive materials. Pushpendra *et al.* (2010) investigated the machining characteristics of inconel 718 and they observed that Peak current and Pulse on time are most influencing parameter for MRR. Yan *et al.* (2000) have observed that Polarity

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largely affects the MRR. Chattopadhayay *et al.* (2008) gets higher material removal rate by introducing an induced magnetic field on the work piece during rotary electrical discharge Maching.

Present work rotary graphite lead electrode was used to machine Hastelloy c 276 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 Higher material removal rate.

TAGUCHI DESIGN OF EXPERIMENT

Taguchi's Design of Experiment is a powerful technique for improving process designs and solving productions problems and it is well accepted methodology for experimental design. This method gives the relationship between the machining parameter and performance parameter effectively. The machining parameters selected for this experiment are: Polarity, Rotational speed of Electrode, Peak current and Pulse on time. The machining condition and number of levels of the parameters selected is shown in Table 1. The present experiment was designed based on L18 (21 × 33) Orthogonal Array shown in Table 2. The experimental observed value for MRR are converted in to the signal to noise ratio. It is the quality indicator by which we can evaluate the effect of machining parameter on the performance parameter.

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	MRR	S/N
		RPM	A	μs	mm^3/min	
1.	–	50	0.3	2	0.03126057	–30.100060
2.	–	50	1.5	5	0.10543022	–19.540700
3.	–	50	2.0	9	0.20134715	–13.921090
4.	–	100	0.3	2	0.04015921	–27.924300
5.	–	100	1.5	5	0.11316493	–18.925760
6.	–	100	2.0	9	0.23240897	–12.674940
7.	–	150	0.3	5	0.04554087	–26.831970
8.	–	150	1.5	9	0.25885886	–11.738740
9.	–	150	2.0	2	0.33661628	–9.457298

Table 2 (Cont.)

Exp. No.	Factors				Performance Parameter	
	P	N	Ip	Ton	MRR	S/N
		RPM	A	μs	mm^3/min	
10.	+	50	0.3	9	0.00233003	–52.652770
11.	+	50	1.5	2	0.01372976	–37.246740
12.	+	50	2.0	5	0.02760083	–31.181560
13.	+	100	0.3	5	0.00349444	–49.13245
14.	+	100	1.5	9	0.01655016	–35.62396
15.	+	100	2	2	0.03645378	–28.76515
16.	+	150	0.3	9	0.00591487	–44.5611
17.	+	150	1.5	2	0.02494648	–32.05981
18.	+	150	2	5	0.03904256	–28.16923

There is three type quality characteristics are used to calculate signal to noise ratio in the Taghuchi methodology, i.e., lower the better, Higher the better and nominal the best. In this experiment higher Material removal rate is required so higher the better type quality characteristic is chosen. It is calculated as (Phillip, 2005).

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

where,

$$MSD_{HB} = \frac{1}{n}\left(\frac{1}{y_1^2} + \frac{1}{y_2^2} + \frac{1}{y_3^2} + \dots + \frac{1}{y_n^2}\right) \quad ...(2)$$

n is the number of repetitions and y is the observed value.

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 Hastelloy c 276 having 27 mm × 27 mm × 13 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 graphite rod having 0.5 mm diameter was used as Rotating Electrode Material.

EXPERIMENTAL RESULT

The experiment were conducted to see the affect of Polarity, Rotational speed of electrode, Peak current, Pulse on time on Material Removal Rate (MRR) using L18 OA. Material removal rate was obtained by calculating the weight difference of work material before machining and after machining per unit time and density of Hastelloy. Weight of work piece was measured with the help of electronic weight balance machine having least count of 0.0001 gm. It is calculated as (Kuldeep *et al.*, 2010).

$$MRR = \frac{W_{Jb} - W_{Ja}}{\rho \times t} \quad ...(3)$$

Where, W_{Jb} is weight of work material before machining, W_{Ja} is weight of work material after machining, t is the machining time and ρ is the density of Hastelloy c 276 is 8.89 gm/cm^3. The calculated experimental value for MRR and its S/N ratio are shown in Table 2.

ANALYSIS AND DISCUSSION

The Micro-EDM experiments were conducted by using the parametric approach of the taguchi's Method. The effect of individual Micro-EDM machining parameter on the Material removal rate has been discussed in this section. The main effects of machining parameter for S/N data were plotted in Figure 1. It is used for examining the parametric effects on the performance parameter. It shows that Negative Polarity has the main effect on MRR. It also indicate that MRR increases with increases in Rotational speed of Electrode because of higher centrifugal force generated due to the rotating speed of electrode which helps in removing the debris particle and reducing the effect of carbon deposited particle. MRR increases sharply as peak current increases from 0.3 A to 1.5 A, at lower current a significant portion of total energy is used to vaporize the metal therefore MRR is small, on other hand, when Peak current is too large it produces strong spark, which produce high temperature, causing more material to melt and erode from the work piece. The pulse on time has not significant effect on MRR.

It is seen from the Figure 2 that there is very weak interaction between the machining parameters affecting the MRR since the performance at different levels of machining parameter value are almost parallel. Table 3

Figure 1: Main effect plots for SN ratios for MRR

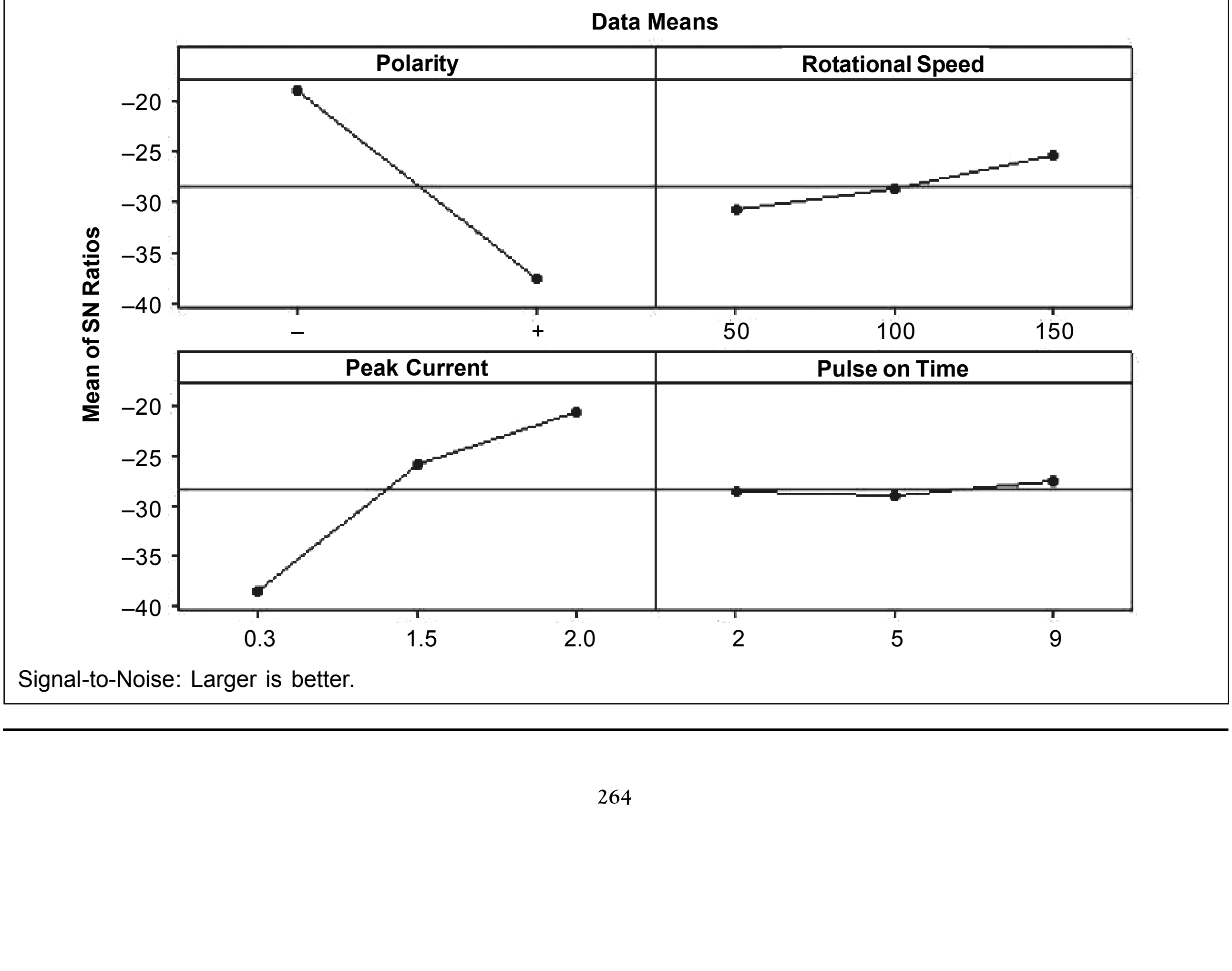
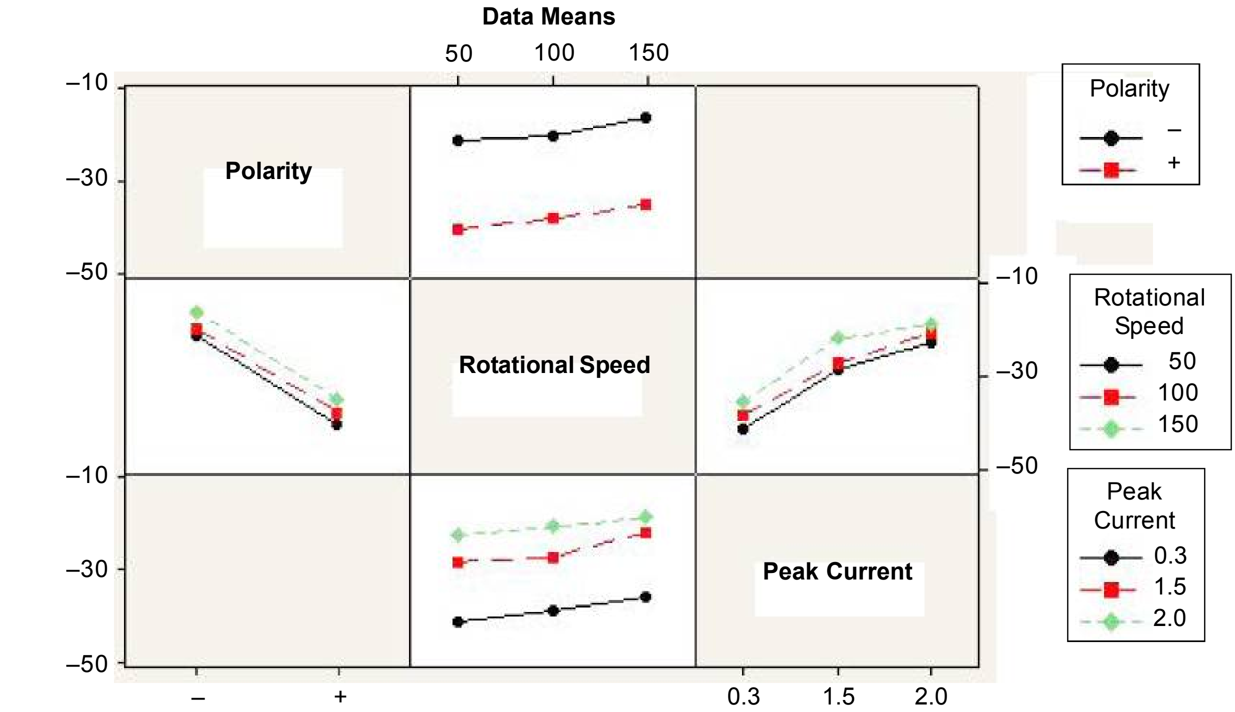


Figure 2: Interaction Plot for SN Ratios for MRR



Signal-to-Noise: Larger is better.

shows the ANOVA for Signal to noise ratio for MRR. It stated that Polarity, Peak current and Rotational speed of Electrode has the most significant effect for MRR. The response table for Signal to Noise ratio for MRR is shown in Table 4. The rank and delta values show that polarity has the greatest effect on MRR and is followed by Peak current, Rotational speed and pulse on time in that order. As Material removal rate is 'higher is better' type quality characteristic, so from Figure 1. Negative polarity, third level of rotational speed of electrode (B3 = 150 rpm), third level of Peak current (C3 = 2 A) and third level of Pulse on time (D3 = 9 μs) provides Maximum Value of Material Removal rate.

Table 3: Analysis of Variance for S/N for MRR

Source	DF	Seq, SS	Adj. SS	Adj. MS	F	P
Polarity	1	1573.19	1573.19	1573.19	513.96	0.000
Rotational speed	2	86.47	86.47	43.24	14.13	0.015
Peak current	2	1011.18	1011.18	505.59	165.18	0.000
Pulse on time	2	5.89	5.90	2.95	0.96	0.455
Polarity * Rotational speed	2	1.15	1.15	0.57	0.19	0.836
Rotational speed * Peak current	4	7.99	7.99	2.00	0.65	0.655
Residual error	4	12.24	12.24	3.06		
Total	17	2698.12				

Table 4: Response Table for S/N Ratio

Level	Polarity	Rotational Speed	Peak Current	Pulse on Time
1	–19.01	–30.77	–38.53	–28.53
2	–37.71	–28.84	–25.86	–28.96
3		–25.47	–20.69	–27.59
Delta	18.70	5.30	17.84	1.37
Rank	1	3	2	4

ESTIMATION OF OPTIMUM MACHINING PARAMTER

In this section, the optimal values of the Material Removal 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 MRR is estimated by:

$$\eta_{opt} = \eta_m + \sum_{i=1}^{n} (\eta_i - \eta_m) \quad ...(4)$$

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 MRR can be computed as:

$$\eta_{opt} = \eta_m + \left\lfloor \left(\overline{A1} - \eta_m\right) + \left(\overline{B3} - \eta_m\right) + \left(\overline{C3} - \eta_m\right) \right\rfloor \quad ...(5)$$

Where, $\overline{A1}$ is the Average value of MRR at the first level of Polarity, $\overline{B3}$ is the Average value of MRR at the third level of Rotational speed of electrode, $\overline{C3}$ is the Average value of MRR at the third level of Peak current.

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 Material removal 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, 9 μs	Negative,150 rpm, 2 A, 9 μs
Significant parameter	Negative,150 rpm, 2 A	Negative,150 rpm, 2 A
MRR (mm^3/min)	0.24517	0.29887

CONCLUSION

The present paper investigated and optimized the machining parameter, i.e., Polarity, rotational speed of electrode, Peak current and pulse on time for MRR of Micro EDM of Hastelloy c 276 using Rotatary electrode. The significant parameter for MRR is determined by using S/N ratio and ANOVA. The important conclusion summarized below:

- The Maximum material removal rate is obtained at Negative polarity, Rotational speed of electrode at 150 rpm, Peak current at 2 A, Pulse on time at 9 μs.

- Material removal rate is less at 50 rpm and it increases up to higher value of Rotational speed of electrode due to higher centrifugal force are produced and debris are removed easily. Similarly MRR is low at low peak current of 0.3 A and it increases up to higher value peak current of 2 A.

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