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Multi-objective optimisation of die sinking electro discharge machining process using Taguchi

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ABSTRACT:

The objective of this paper is to determine the optimal setting of the process parameters on the electro-discharge machining (EDM) machine while machining AISI H13 tool steel. The parameters considered are pulse current, pulse-on-time, pulse-off-time and gap voltage ; whereas the responses are Tool wear ratio (TWR) and material removal rate (MRR). The optimal setting of the parameters are determined through experiments planned, conducted and analysed using the Taguchi method. It is found that the Tool wear ratio reduces substantially, within the region of experimentation, if the parameters are set at their lowest values, while the parameters set at their highest values increase the MRR drastically.

I. INTRODUCTION

Electrical discharge machining (EDM) is one of the most extensively used non-conventional material removal processes. Its unique feature of using thermal energy to machine electrically conductive parts regardless of hardness has been its distinctive advantage in the manufacture of mould, die, automotive, aerospace and surgical components. In addition, EDM does not make direct contact between the electrode and the workpiece eliminating mechanical stresses, chatter and vibration problems during machining [1]. The working principle is based on the thermo electric energy. The thermo electric energy (in form of spark) is created between a workpiece and an electrode submerged in a dielectric fluid with conduction of electric current. The workpiece and the electrode are separated by a specific small gap, the so called 'spark gap', and pulsed discharges occur in this gap filled with an insulating medium [2]. P.M. George, B.K. Raghunath et. Al. [3] studied the effect of various process parameters like Current, Pulse on time and Gap Voltage on Electrode wear rate and Material removal rate. They identify that optimum machining conditions for electrode wear rate, with an expected reduction of 89.28% from the current average value of 0.056 mg/min, is Ip = 1A, Ton = 150 µs and Vg = 20V. Whereas the same for MRR, with an expected increase of 116.67% from the current average value of 0.09mm^3/min, is Ip = 9A, Ton = 750 µs and Vg = 100V. Yih-fong Tzeng, Fu-chen Chen describes the application of the fuzzy logic analysis coupled with Taguchi methods to optimise the precision and accuracy of the high-speed electrical discharge machining (EDM) process. A fuzzy logic system is used to investigate relationships between the machining precision and accuracy for determining the efficiency of each parameter design of the Taguchi dynamic experiments. From the fuzzy inference process, the optimal process conditions for the high-speed EDM process can be easily determined [4]. Jose DuarteMarafona, Arlindo Araujo et. Al. [5] were used Taguchi methodology to study the Influence of workpiece hardness on EDM performance. These results show that workpiece hardness and its interactions have influence on the material removal rate and on the workpiece surface roughness.

II. EXPERIMENTAL SET-UP

A number of experiments were conducted to study the effects of various machining parameters on EDM process. These studies were undertaken to investigate the effects of various machining parameters on Tool wear ratio and Material removal rate. The selected workpiece material for the research work is AISI H 13 tool steel was selected and the composition of work piece material is as follows Cr 5.473, Mn 0.403, C 0.413, Si 0.853, Vn 0.842, Tu 0.060 % by weight due to its emergent range of applications in the field of mould industries. Experiments were conducted on JOEMARS AZ 50 JM-322 die sinking machine using positive polarity. The flushing pressure was 0.5 Kg/cm2. The copper with a diameter of 15 mm was used as a tool electrode and Die-electric fluid-92 (DEF-92) was used as die electric fluid. The test conditions are depicted in Table-1.

The material MRR is expressed as the ratio of the difference of weight of the workpiece before and after machining to the machining time and density of the material as shown in eq. (1).

$$MRR = \frac{(W_{tb} - W_{ta})}{D \times t} \quad (1)$$

Where,
W_{tb} weight before machining of w/p (gm), W_{ta} weight after machining of w/p (gm), D density of work-piece material (gm/mm^3) & t time consumed for machining (min).

TWR is expressed as the volumetric loss of tool per unit time, expressed as

$$TWR = \frac{(W_{tb} - W_{ta})}{D \times t} \quad (2)$$

Where,
W_{tb} weight before machining of tool (gm), W_{ta} weight after machining of tool (gm), D density of tool material (gm/mm^3) & t time consumed for machining (min).

In our investigation the orthogonal array (L 25) was run to calculate the S/N ratio. The analysis of variance (ANOVA) is performed to identify the statistical significant process parameters. Then optimal levels of process parameters are obtained from the analysis.

Table 1: Coding levels of process parameters.

Experimental variable	**Level**				
Parameters	1	2	3	4	5
Current (amp) [A]	13	17	21	28	36
Pulse on time (μs) [B]	40	60	60	70	80
Pulse off time (μs) [C]	20	30	40	50	60
Spark gap voltage (volt) [D]	8	9	10	11	12

III. RESULTS AND DISCUSSION

Table 2: Experimental Responses

Experiment no.	Material removal rate (MRR) (mm3/min.)	Tool wear rate (TWR) (mm3/min.)
1	21.6237	0.0809
2	18.2513	0.3708
3	15.1868	0.2337
4	6.5815	0.1337
5	2.0386	0.0831
6	21.3905	0.5135
7	22.6469	0.1798
8	19.3028	0.0618
9	14.8621	0.0719
10	3.4304	0.0135
11	16.0000	1.1606
12	32.0283	0.0314
13	17.1598	0.1270
14	30.1688	0.0135
15	5.1121	0.0472
16	20.5760	1.9775
17	30.8505	0.4123
18	62.5813	0.0143
19	49.4013	0.0886
20	9.2320	0.0270
21	14.5696	3.2517
22	73.8772	0.1958
23	105.0203	0.2532
24	94.3858	0.2585
25	47.0760	0.0483

Figure 1: Workpiece material of AISI H13 tool steel

The weight of the work piece and tool is measured on precise weighing machine having least count of 0.001 gm. Work piece density is taken 0.00776 gm/mm^3.

Blind hole done for 10 minutes in each experiment which is shown in figure 2.1., During the EDM process.

Table 3: Analysis of Variance for MRR

Source	DF	Seq SS	Adj SS	Adj MS	F	P	% Contribution
Ip	4	9857.5	9857.5	2464.4	9.26	0.003	54.44
Ton	3	3355.9	3355.9	1118.6	4.20	0.041	18.54
Toff	4	1955.8	1955.8	488.9	1.84	0.206	10.80
V	4	542.0	542.0	135.5	0.51	0.731	2.99
Error	9	2395.7	2395.7	266.2	--	--	13.23
Total	24	18106.9					
S = 16.3152 R-Sq = 86.77% R-Sq(adj) = 64.72%							

Table 4: Response Table for Signal to Noise Ratios

Level	Ip	Ton	Toff	V
1	19.62	25.38	28.06	28.00
2	22.71	30.00	28.06	25.28
3	24.53	28.55	26.72	28.61
4	29.03	16.77	26.38	23.37
5	34.80	--	21.47	25.45
Delta	15.18	13.23	6.59	5.25
Rank	1	2	3	4

Table 5: Analysis of Variance for TWR

Source	DF	Seq SS	Adj SS	Adj MS	F	P	% Contribution
Ip	4	1.4420	1.4420	0.3605	1.35	0.324	11.10
Ton	3	6.4584	6.4584	2.1528	8.07	0.006	49.66
Toff	4	1.4406	1.4406	0.3602	1.35	0.324	11.08
V	4	1.2625	1.2625	0.3156	1.18	0.381	9.71
Error	9	2.4014	2.4014	0.2668			18.46
Total	24	13.0050					
S = 0.516549 R-Sq = 81.53% R-Sq(adj) = 50.76%							

Table4.6: Response Table for Signal to Noise Ratios

Level	Ip	Ton	Toff	V
1	16.434	2.034	29.537	23.614
2	21.026	17.900	14.782	13.953
3	22.121	22.108	13.872	17.965
4	18.218	28.643	18.424	17.111
5	10.785		11.970	15.942
Delta	11.336	26.609	17.567	9.662
Rank	3	1	2	4

The Linear regression equations are:

TWR = 0.540 + 0.0287 Ip - 0.0338 Ton + 0.0165 Toff + 0.0626 V (3)

MRR = 19.1 + 2.33 Ip - 0.022 Ton - 0.596 Toff - 1.73 V (4)

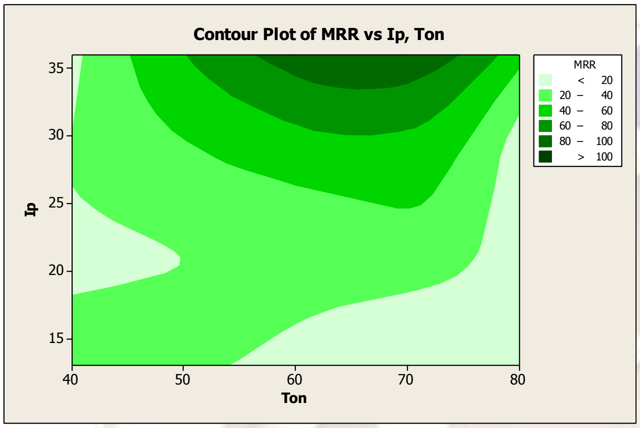

Figure 2: Effect of Ip & Ton on MRR

Figure: 2 shows the estimated response surface for Material removal rate in relation to the process parameters of Ip and Ton. It can be seen from the figure, the MRR tends to increase significantly with the increase in Ip for any value of Ton. However, the MRR tends to increase with increase in Ton, especially at higher Ip. Hence, Maximum MRR is obtained at high peak current 35 amps and high pulse on time 65 µs in this investigation. This is due to their dominant control over the input energy.

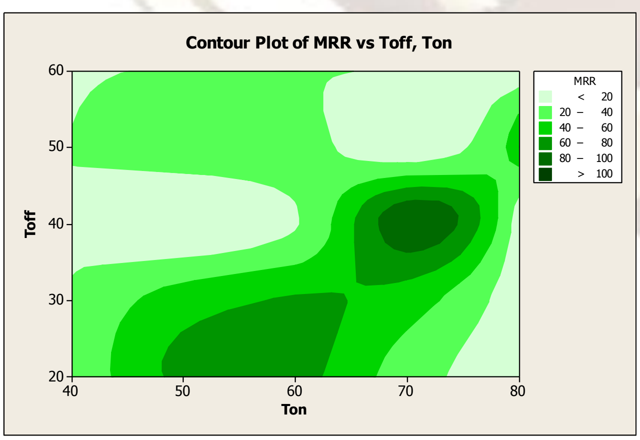

Figure 3: Effect of Ion & Toff on MRR

Figure 3 represents MRR as a function of Ton and Toff. It is observed that the MRR values are low when Ton is low with higher Toff. From the analysis it is said that the interaction of Ton and Toff is significant. Although the influence of this two parameter is very less when compared with the effect of Ip on MRR.

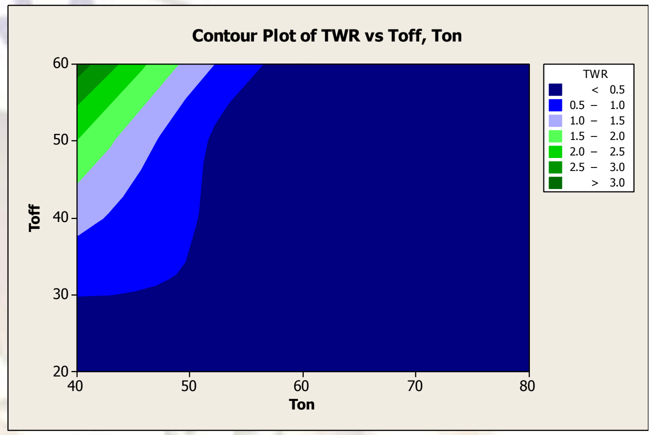

Figure 4: Effect of Ip & Ton on TWR

Figure 4 represents TWR as a function of Ton and Toff. It is observed that the TWR values are high with high Toff. It means that the Tool wear ratio is depending on total machining time.

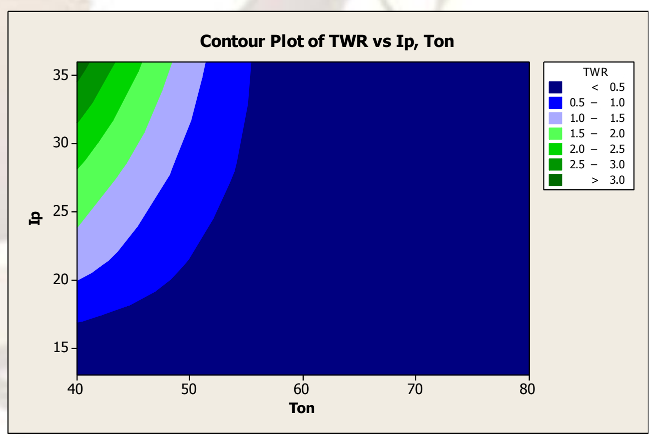

Figure 5: Effect of Ip & Ton on TWR

From Figure 5 the TWR is found to have an increasing trend with the increase of current and pulse on time. TWR is increasing nonlinearly with the current. This is obvious, as the Ip increases, the pulse energy increases, and thus more heat is produced in the tool work piece interface that leads to increase the melting and evaporation of the electrode. One can interpret that Ip has a significant direct impact on TWR.

IV. CONCLUSION

In present study parametric analysis has been carried out for two responses, MRR and TWR. The experiments were conducted using L25 Orthogonal Array. Minitab 15 software was used for analyze the experimental data. Linear Regression analysis is used to investigate and model the relationship between a response variable. Following conclusions drawn after analysis

- Process parameters do not have same effect for every response. Significant parameters and its percentage contribution changes as per the behavior of the parameter with objective response.
- MRR and TWR are found to have an increasing trend with the increase of current and pulse on time Maximum MRR 105.0203 mm^3/min achieved at 36 amp Current and 60 µs Pulse on time. Pulses off time have very little effect on MRR and TWR.
- TWR is found to have an increasing trend with the increase of pulse on and pulse off time. This establishes the fact that TWR is also proportional to the total machining time with rate of energy supplied.
- Pulse on time and Current have major effect on MRR and TWR significantly. Current plays significant role for MRR as it's % contribution obtain is more (54.44%) . Pulse on time plays significant role for TWR as it's % contribution obtain is more (49.66%) .

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