Evaluation of Optimal Parameters for Machining of SS 430 with Wire Cut EDM

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Abstract— As the advancement in the technology some new material is comes in a trend which offers high strength, hardness and resistance to heat. For any manufacturing process and particularly, in process related to Wire EDM the correct selection of manufacturing conditions is one of the most important aspects to take in to consideration. In this research, material AISI SS 430 is selected as work piece. AISI 430 is difficult to machine due to greater strength and toughness. The wire EDM machining process is finding out the effect of machining parameter such as current, pulse on time and pulse off time on SS 430. A well designed experimental scheme is used to reduce the total number of experiments. S/N ratios associated with observed values in the experiments are determined by which factor is most affected by the responses. These experiments generate the output responses such as MRR and TWR.

Key words: Taguchi, ANOVA, MRR, TWR

I. Introduction

Electrical Discharge Machine (EDM) is an electro-thermal non-traditional machining Process, where electrical energy is used to generate electrical spark and material removal mainly occurs due to thermal energy of the spark. EDM is mainly used to machine where are difficult-to-machine materials and high strength temperature resistant alloys. EDM can be used to machine difficult geometries in small batches or even on job-shop basis.

II. Literature Review

Ghani et al. [1] investigated the Taguchi optimization methodology to optimize cutting parameters in end milling when machining hardened steel AISI H13 with TiN coated P10 carbide insert tool under semi-finishing and finishing conditions of high speed cutting. Analysis of variance (ANOVA) is employed to analyze the effect of these milling parameters. Mahapatra & Patnaik[2] studied machining performance measures viz. metal removal rate (MRR), surface finish (SF) and cutting width (kerf) are sought to obtain a precision work. Patel et al. [3] investigated the feasibility of fabricating micro holes in SiC_p-Al composites using micro-electro-discharge machining (micro-EDM) with a rotary tube electrode. Material removal rate (MRR), electrode wear rate (EWR), and hole taper were considered as responses for the study. Bhaduri et al. [4] investigated non-conventional machining like electro discharge machining (EDM). Energy dispersive X-ray spectroscopy and X-ray diffraction analysis have also been carried out on the composite matrix to verify the presence of two distinguishable phases of TiN and Al_2O_3. Chakravorty et al. [5] analyzed two sets of past experimental data on EDM processes are analyzed using four PCA-based optimization methods. The optimization performances of these methods are compared with the results achieved by the past researchers, considering expected total signal-to-noise (S/N) ratio as the utility measure. Subrahmanyam & Sarcar [6] investigated multiple responses Material Removal Rate (MRR), surface roughness (Ra) of H13 HOT DIE STEEL on Wire Electrical Discharge Machine. The Grey method and taguchi's L27 (21x38) Orthogonal Array was used to conduct experiments, which correspond to randomly chosen different combinations of process

III. Experimental Setup

A scientific approach to plan the experiments was a necessity for efficient conduct of experiments. In this experiment the whole work is done by a Wire cut EDM model ELCUT 234 from Chandigarh Industrial & Tourism Development Company (CITCO), Industrial area, Phase 1, Chandigarh. The stainless steel 430 was work piece and brass wire.

Fig. 1: Wire Cut EDM (ELCUT 234)

The present chapter gives the application of the Taguchi experimental design method. The objective of this research work is to study machining parameters for optimization of TWR and MRR; the design variable can be summarized as follows:

Controllable factor	Level 1	Level 2	Level 3
Current (A)	0.5	1.0	1.5
pulse on time (μs)	4	5	6
pulse off time (μs)	1	2	3

Table 1 Selected Factors and levels

Run	Current (A)	pulse on time(μs)	pulse off time(μs)
1	0.5	4	1
2	0.5	5	2
3	0.5	6	3
4	1	4	2
5	1	5	3
6	1	6	1
7	1.5	4	3
8	1.5	5	1
9	1.5	6	2

Table 2: L9 Orthogonal array for experiment

IV. CONDUCT THE EXPERIMENT

The experiment was conducted on wire cut EDM machine. The work piece material used was Stainless Steel AISI 430 in the sheet form having 200*120 rectangular sections. This work piece was cut in eighteen pieces. The all nine experiments were run by ELCUT 234 machine as shown in figure 5.1.The Brass wire as a tool of diameter 0.2 mm was used for experiment as shown in figure 2.

Fig. 2: Working tank of Wire EDM

A. *Stainless Steel 410(SS430)*

SS 430 is general-purpose martensitic stainless steels. Martensitic stainless steels are fabricated using techniques that require final heat treatment. These grades are less resistant to corrosion when compared to that of austenitic grades. The chemical composition of SS 430 is given in table 3 below.

Contituent	% Composition
C	0.0525 %
Cr	17 %
Mn	0.5425 %
Si	0.3681 %
P	0.02550 %
S	0.00927 %
Cu	0.0319 %
V	0.1189 %
Mo	0.0342 %

Table 3 Chemical Composition of SS430

The chemical composition of SS410 shown in table 3.1 but these can change according to use. The mechanical, physical and electrical properties of SS410 as shown in table 4

Tensile Strength (MPa)	552
Yield Strength (MPa)	310
Hardness(HV)	325
Density (kg/m3)	7750
Elastic Modulus(GPa)	200
Specific Heat(J/Kg K) 0-100^0 C	460
Thermal Conductivity(W/m.K) at 100^0 C	26.1
Electrical Resistivity (nΩ.m)	600

Table 4 Mechanical, Physical and Electrical properties

Orthogonal array for this experiment is given below.

Run	Current (A)	pulse on time(μs)	pulse off time(μs)	MRR1 (g/min)	MRR2 (g/min)	Mean (g/min)	S/N ratio
1	0.5	4	1	0.125	0.108	0.1165	-18.7429
2	0.5	5	2	0.114	0.132	0.1230	-18.2717
3	0.5	6	3	0.094	0.101	0.0975	-20.2367
4	1	4	2	0.128	0.109	0.1185	-18.6095
5	1	5	3	0.115	0.104	0.1095	-19.2446
6	1	6	1	0.075	0.108	0.0915	-21.1977
7	1.5	4	3	0.097	0.110	0.1035	-19.7526
8	1.5	5	1	0.128	0.133	0.1305	-17.6926
9	1.5	6	2	0.130	0.127	0.1285	-17.8237

Table 5: L9 Orthogonal array of material removal rate

Run	Current (A)	pulse on time(μs)	pulse off time(μs)	TWR1 (g/min)	TWR2 (g/min)	Mean (g/min)	S/N ratio
1	0.5	4	1	0.079	0.082	0.0805	21.8826
2	0.5	5	2	0.065	0.063	0.0640	23.8753
3	0.5	6	3	0.050	0.055	0.0525	25.5870
4	1	4	2	0.099	0.103	0.1010	19.9119
5	1	5	3	0.080	0.077	0.0785	22.1010
6	1	6	1	0.060	0.062	0.0610	24.2922
7	1.5	4	3	0.069	0.065	0.0670	23.4746
8	1.5	5	1	0.052	0.050	0.0510	25.8469
9	1.5	6	2	0.046	0.053	0.0495	26.0862

Table 6 L9 Orthogonal array of tool wear rate

V. RESULT AND ANALYSIS

From the tables 7 and 8 on the basis of rank shown in tables, it has been analyzed that the parameter pulse off time is the most significant factor which affect the MRR.

Level	current	Ton	Toff
1	0.1123	0.1128	0.1128
2	0.1065	0.1210	0.1233
3	0.1208	0.1058	0.1035
Delta	0.0143	0.0152	0.0198
Rank	3	2	1

Table 7 Average effect response table for raw data

Level	current	Ton	Toff
1	-19.08	-19.03	-19.21
2	-19.68	-18.40	-18.23
3	-18.42	-19.75	-19.74
Delta	1.26	1.35	1.51
Rank	3	2	1

Table 8 Average effect response table for S/N ratio

The average effect response table for raw data and S/N ratio for TWR shown below.

From the tables 9 and 10 on the basis of rank shown in tables, it has been analyzed that the parameter pulse on time is the most significant factor which affect the TWR.

Level	current	Ton	Toff
1	0.06567	0.08283	0.06417
2	0.08017	0.06450	0.07150
3	0.05583	0.05433	0.06600
Delta	0.02433	0.02850	0.00733
Rank	2	1	3

Table 9 Average effect response table for raw data

Level	current	Ton	Toff
1	23.78	21.76	24.01
2	22.10	23.94	23.29
3	25.14	25.32	23.72
Delta	3.03	3.57	0.72
Rank	2	1	3

Table 10 Average effect response table for S/N ratio

Source	DF	SS	MS	F
Current	2	0.000312	0.000156	1.27
Ton	2	0.000346	0.000173	1.41
Toff	2	0.000591	0.000295	2.41
Residual Error	2	0.000245	0.000123	
Total	8	0.001494		

Table 11: Analysis of variance table for MRR

The results are analyzed using ANOVA for identified the significant factor affecting the performance measure. The ANOVA for MRR is taken at 95 % of confidence level. The principal of F test is that larger the F values for a particular parameter, greater the effect on performance characteristics due to change in process parameters. In this case ANOVA is not capable to give results due to lesser number of variables. So result is analyzed by for means and S/N ratio table it is analyzed that pulse off time is most significant parameter than current and pulse on time. Pulse off time, pulse on time and current is assigned as rank 1, 2 and 3 respectively according to their larger value of delta.

Source	DF	SS	MS	F
current	2	0.000899	0.000450	18.20
Ton	2	0.001252	0.000626	25.34
Toff	2	0.000087	0.000044	1.77
Residual Error	2	0.000049	0.000025	
Total	8	0.002288		

Table 12: Analysis of variance table for TWR

Pulse on time, current and pulse off time is assigned as rank 1, 2 and 3 respectively according to their larger value of delta.

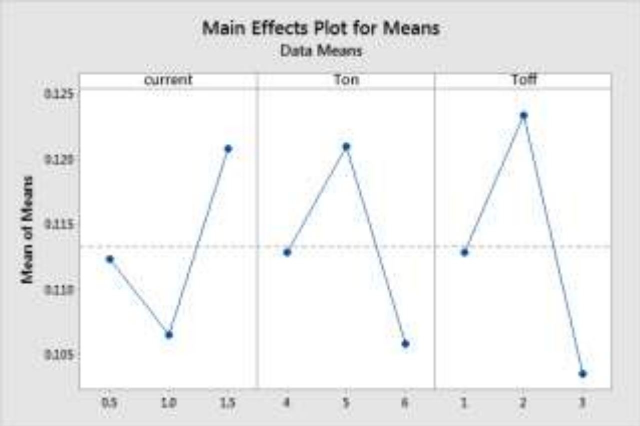

Fig. 3 Response Graph of three machining parameters for mean for MRR

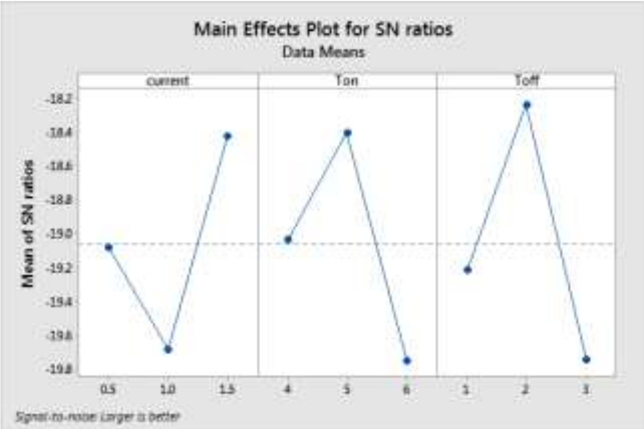

Fig. 4: Response Graph of three machining parameters for S/N ratio for MRR

In the experimental analysis, main effect plot of S/N ratio is used for estimating the S/N ratio of TWR with optimal design condition. As shown in graph 6.4 level three for current (A3=1.5 A) has highest value and level three of pulse on time (B3=6µs) and the level one of pulse off time (C1= 1 µs) have also indicated the optimum situation.

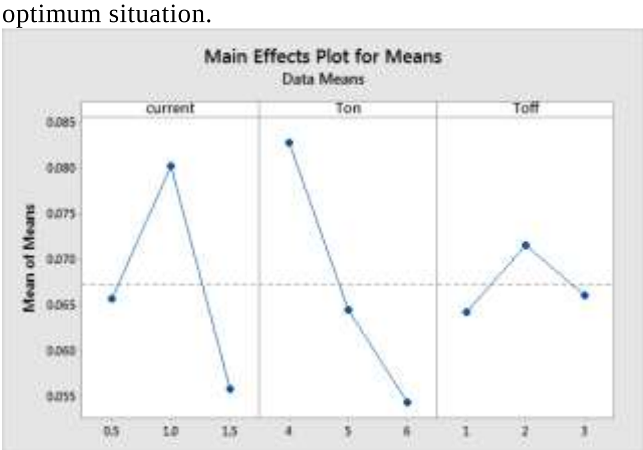

Fig. 5: Response Graph of three machining parameters for mean for TWR

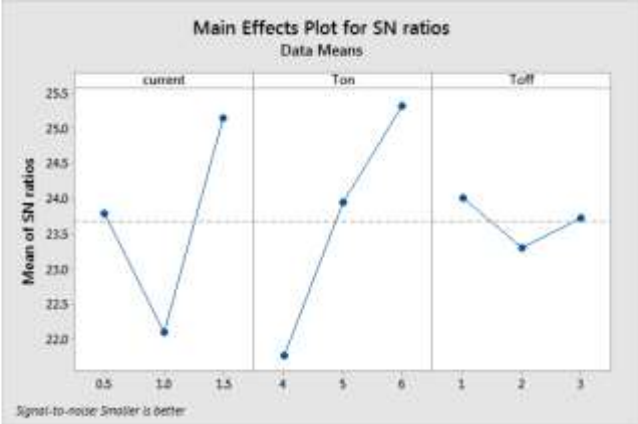

Fig. 6 Response Graph of three machining parameters for S/N ratio for TWR

VI. Conclusion

1) In MRR, increase in current from 0.5A to 1A MRR decrease then from 1A to 1.5 A MRR increases within specified test range.
2) In MRR, increase in Ton from 4µs to 5µs MRR increases then from 5µs to 6µs MRR decreases within specified test range.
3) In MRR, increase in Toff from 1µs to 2µs MRR increases then from 2µs to 3µs MRR decreases within specified test range.
4) In TWR, increase in current from 0.5A to 1A TWR increase then from 1A to 1.5 A TWR decreases within specified test range.
5) In TWR, increase in Ton from 4µs to 6µs TWR decreases within specified test range.
6) In TWR, increase in Toff from 1µs to 2µs TWR increases then from 2µs to 3µs TWR decreases within specified test range.
7) In MRR, use of current (1.5 A), pulse on time (5µs) and pulse off time (2µs) are optimized parameters to obtained better material removal rate for the specific test range in a SS430 material.
8) . In TWR, use of current (1.5 A), pulse on time (6µs) and pulse off time (1µs) are optimized parameters to obtained lower tool wear rate for the specific test range in a SS430 material.
9) From this investigation it has been analyzed that T_{off} is most significant factor which affect the MRR.
10) From this investigation it has been analyzed that T_{on} is most significant factor which affect the TWR.

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