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Optimization of Process Parameters of Wire Electrical Discharge Machining of EN31 Steel

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Abstract - *Wire Cut Electrical Discharge machining (WEDM) is non conventional material removal process used to manufacture components with irregular profile. This process is affected by number of WEDM parameters. Effect of WEDM parameters such as Pulse on time (T_{ON}), Pulse off (T_{off}), Peak current (I_p) and Wire tension (W_T) on machining of EN31 is considered in present work. The optimal setting of the parameters are determined through experiments planned, conducted and analyzed using the Taguchi method.*

Key Words: Wire cut electrical discharge machine (WEDM), Taguchi method, orthogonal array, design of experiment, s/n ratio.

1.INTRODUCTION

The wire-cut electrical discharge machining plays an important role in manufacturing sectors especially industries like aerospace, ordinance, automobile and general engineering etc. It is difficult to obtain complicated and complex shapes of the components. To obtain various shapes of components the wire-cut EDM process is important in several cases, but it requires the improved machining efficiency. But wire-cut EDM consists of a number of parameters, which makes it not easy to obtain optimal parametric combinations for machining different materials for various responses like surface roughness, etc.[1]. The selection of machining parameters in a machining process significantly affects production rate and quality of machined components. The selection of these parameters in WEDM is primarily dependent on the operator's experience and machining parameter tables provided by the machine-tool manufacturers. However, such criterion does guarantee neither high production rate nor good surface quality.[2]. Various methods are adopted by different researcher to find optimal parameters of WEDM process [4-7]. Taguchi has standardized methods for each of these DoE application steps. This approach in finding factors that affect a product in a DoE can dramatically reduce the number of trails required to gather necessary data. Thus, DoE using Taguchi approach has become a much more attractive tool to practicing engineers and scientists [3].

2. EXPERIMENTAL SETUP

The experiments were carried out on ELECTRONICA ELEKTRA WEDM machine shown in figure no. 1. The electrode material used was a 0.25 mm diameter brass wire.

Fig- 1: Wire electrical discharge machine.

2.1 Preparation of Work Piece Material

EN31 is high carbon alloy steel which achieves a high degree of hardness with compressive strength and abrasion resistance; it is used in Ball and Roller Bearings, Spinning tools, Beading Rolls, Punches and Dies. It is very difficult to machine EN31 by conventional machining process and moreover, by conventionally used tool materials. Of late, modern machining techniques such as Wire Electrical Discharge Machining (WEDM) are increasingly being used for machining such hard materials. Hence, this study is focused on machining of EN31 using WEDM, in order to satisfy production and quality requirement EN31 was used for the present investigation. The table 1 shows chemical composition and Mechanical properties of EN31.

Table 1 : Chemical composition of EN 31 Steel.

	C	Si	Mn	S	P	Ni	Cr	Mo
Chemical Composition Wt%	1.08	0.25	0.53	0.015	0.02	0.33	1.46	0.06

The EN31 plate of 150mm × 98mm × 10mm size is mounted on the machine tool and specimens of 15mm × 5mm × 10mm size are cut according to Taguchi L_9 design.

2.2 Work Path Profile

Work path profile for this study is as shown in figure 2.

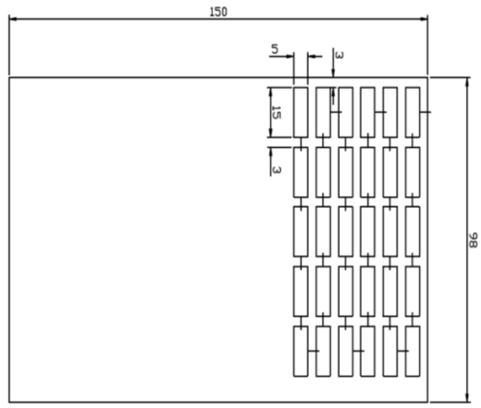

Fig- 2: Work path profile.

2.3 Measurement of Quality Characteristics

1. Machining Time – The machining time is measured by using stop watch.
2. Surface Roughness – A stylus-contact-type device, MITUTOYO surface roughness tester is used to measure the surface roughness of the plate.

3. DESIGN OF EXPERIMENT

Four machining parameters ware selected as control factors, each parameter has three levels as shown in table 2.

Table-2: Control Factors and their Levels

Control Factors	Symbol	Level 1	Level 2	Level 3
Pulse-On Time	T_{ON}	110	115	120
Pulse-Off Time	T_{off}	42	47	52
Peak Current	I_p	70	150	230
Wire Tension	W_T	4	8	12

As there are 4 parameters and each parameter has 3 levels, L_9 array is used for this study. Parameters level combinations for experiments were as shown in table 3.

Minitab software was used for graphical analysis of the obtained data.

Table-3: L_9 (3^4) Orthogonal Array With controlled Parameters and Their Levels

Experiment Number	Column			
	T_{ON}	T_{off}	I_p	W_T
1	110	42	70	4
2	110	47	150	8
3	110	52	230	12
4	115	42	150	12
5	115	47	230	4
6	115	52	70	8
7	120	42	230	8
8	120	47	70	12
9	120	52	150	4

4. RESULTS AND DISCUSSION

Table-4: Experimental Results for Machining Time

Expt. No.	Machine Time (min)		Average	S/N ratio
	MT_1	MT_2		
1.	78	79	78.50	-37.8976
2.	58	59.51	58.75	-35.3816
3.	131	130.56	130.7	-42.3508
4.	39.51	36.18	37.84	-31.5686
5.	22.13	22.31	22.22	-26.9350
6.	41.10	41.08	41.09	-32.2747
7.	24.54	24.28	24.41	-27.7515
8.	25.52	26.32	25.92	-28.2737
9.	39.34	36.57	37.95	-31.5912

Table 5: Experimental Results for Surface Roughness

Expt. No.	Surface Roughness (RA)		Average	S/N ratio
	RA_1	RA_2		
1.	1.15	1.21	1.18	-1.44045
2.	1.10	1.12	1.11	-0.90681
3.	1.91	1.96	1.93	-5.73434
4.	1.32	1.36	1.34	-2.54306
5.	1.35	1.54	1.44	-3.21609
6.	1.08	1.12	1.01	-0.82929
7.	3.18	1.45	2.31	-7.85860
8.	1.37	1.47	1.42	-3.05115
9.	1.41	1.37	1.39	-2.86120

4.1 Effect of process parameters on Machining Time:

As shown in table 4, nine experiments were carried according to L_9 array. Signal to noise ratios were calculated for each experiment. Machining time is smaller is better type response.

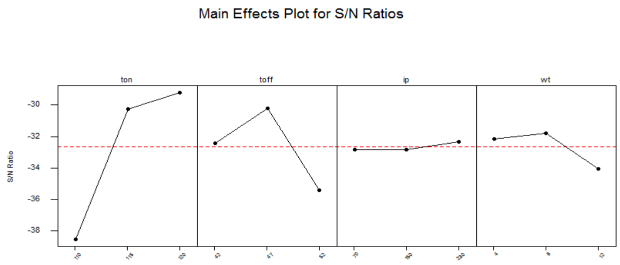

Figure -3: Main effect plot for S/N ratios for machining time.

From figure 3, it is clearly observed that for third level of T_{ON}, second level of T_{OFF}, third level of I_P and second level of W_T, machining time is minimum. Hence optimal parametric combination is $T_{ON}3 – T_{OFF}2 – I_P3 – W_{T2}$.

Table-6: Response Table for S/N Ratios for Machine Time (Smaller is Better)

Level	T_{On}	T_{Off}	I_P	W_T
1	-38.5367	-32.4059	-32.8153	-32.1412
2	-30.2594	-30.1968	-32.8471	-31.8026
3	-29.2055	-35.3989	-32.3391	-34.0577
Delta	9.3312	5.2021	0.5080	2.2551
Rank	1	2	4	3

The response Table 6 shows the average of each response characteristic for each level of each factor. The delta statistics gives the difference between highest average value and lowest average value among the levels of factor. Higher rank indicates the higher effect of parameter on response output. It shows that T_{ON} has greatest effect on machining time followed by T_{OFF}, W_T and I_P.

4.2 Effect of process parameters on Surface Roughness:

As shown in table 5 nine experiments were carried according to L9 array. Signal to noise ratios were calculated for each experiment. Surface roughness is minimum is better type response.

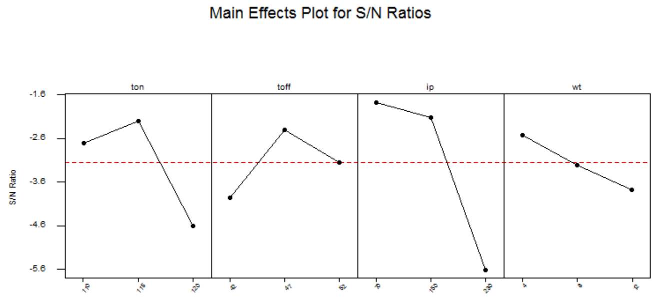

Figure 4: Main effect plot for S/N ratios for surface roughness

From figure 4 it is clearly observed that for second level of T_{ON}, second level of T_{OFF}, first level of I_P and first level of W_T, surface roughness is minimum. Hence optimal parametric combination is $T_{ON}2 – T_{OFF}2 – I_P1 – W_T1$.

Table-7: Response Table for S/N Ratio for Surface Roughness (Smaller is Better)

Level	T_{On}	T_{Off}	I_P	W_T
1	-2.69387	-3.94747	-1.77363	-2.50591
2	-2.19615	-2.39135	-2.10369	-3.19823
3	-4.59031	-3.14161	-5.60301	-3.77619
Delta	2.39417	1.55602	3.82938	1.27028
Rank	2	3	1	4

The response table 7 shows the average of each response characteristic for each level of each factor. The delta statistics gives the difference between highest average value and lowest average value among the levels of factor. Higher rank indicates the higher effect of parameter on response output. It shows that IP has greatest effect on surface roughness followed by T_{ON}, T_{OFF} and W_T.

5. CONCLUSION:

In present study Taguchi optimization method is used to determine optimal parametric combinations for machining time and surface roughness of WEDM process of EN31 steel. Optimal parametric combination for machining time is $T_{ON}3 – T_{OFF}2 – I_P3 – W_T2$ and optimal parametric combination for surface roughness is $T_{ON}2 – T_{OFF}2 – I_P1 – W_T1$. This knowledge is useful while WEDM machining of EN31 Steel.

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