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Effect Of Process Parameters On Mrr In Wire Electrical Discharge Machining Of En31 Steel

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ABSTRACT

Wire Electrical Discharge Machining (WEDM) is extensively used in machining of materials when precision is of major factor. Selection of optimum machining parameter combinations for obtaining higher accuracy is a challenging task in WEDM due to the presence of large number of process variables and complex stochastic process mechanisms. In this paper a attempt was made to study the influence of various machining parameters Pulse on, Pulse off, Bed speed and Current on metal removal Rate (MRR). The relationship between control parameters and Output parameter (MRR) is developed by means of linear regression. Taguchi's L16 (4*4) Orthogonal Array (OA) designs have been used on EN-31 tool steel to achieve maximum metal removal rate.

Keyword: Wire Electrical Discharge Machining (WEDM), Taguchi Method, orthogonal Array (OA), Process Parameters, MRR and EN31.

1. INTRODUCTION

Wire Electrical Discharge Machining (WEDM) is a nontraditional, thermoelectric process which erodes material from the work piece by a series of discrete sparks between a work and tool, with de-ionized water as the dielectric medium, produce complex two and three dimensional shapes according to a numerically controlled (NC) path. The schematic representation of the WEDM cutting process is shown in Figure-1.

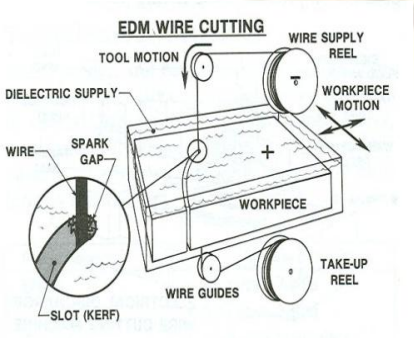

Figure 1: Principle of WEDM

WEDM is a specialized thermal machining process capable of accurately machining parts with varying hardness or complex shapes, which have sharp edges that are very difficult to be machined by the main stream machining process. At present, WEDM is a widespread technique used in industry for high-precision machining of all types of conductive materials.

2. LITERATURE RIVIEW

For determining the better parametric settings, lot of work has been done in the engineering design. The WEDM processes are having several performance characteristics like Metal Removal Rate, Surface roughness, Kerf width; Dimensional error etc. The optimal parametric settings with respect to different performance characteristics are different. Some of the research contributions to cite are SS. Mahapatra and Amar patnaik [1] have described in their paper about Parametric Optimization of Wire Electrical Discharge Machining (WEDM) Process using Taguchi Method. In this study27 experiments are Performed based on the Orthogonal array of L27 considering Discharge current, Pulse duration, Pulse frequency, wire speed, Wire tension and dielectric flow rate as control factors and the responses measured are Surface finish (Ra) and MRR. with Zinc coated copper wire electrode and proposed some optimized parameter settings for desired yielding. R.Ramakrishnan & L.Karunamoorthy[2], in their paper have applied the Taguchi's method, which is one of the methods of robust design of experiments to optimize multi responses of the wire cut electric discharge machining operations. Experimentation was carried out using L_{16} orthogonal array . Each experiment was conducted under different cutting conditions of pulse-on time, wire tension, delay time, wire feed, speed, and ignition current intensity. to measure material removal rate, surface roughness, and wire wear ratio as the multi responses..

Jose Marafona and Catherine Wykes [3] have investigated a new method of optimizing MRR using EDM with copper-tungsten electrodes. This paper describes an investigation into the

optimization of the process which uses the effect of carbon which has migrated from the dielectric to tungsten copper electrodes. This work has led to the development of a two stage EDM machining process where different EDM settings are used for the two stages of the process giving a significantly improved material removal rate for a given wear ratio. C Bhaskar Reddy et.al [4] also conducted the experiments in wire EDM based on L16 Orthogonal array selecting P20 Die tool steel as work material with 0.18 mm Molybdenum wire as electrode. They recommended better parameter settings to achieve higher MRR and better surface roughness. Regression analysis was carried out to predict performance characteristics.

C. L. Lin, et al, [5] have described, the grey relational analysis based on an orthogonal array and fuzzy-based Taguchi method is applied for optimizing the multi-response process. They have used both the grey relational analysis method without using the S/N (Signal/Noise) ratio and fuzzy logic analysis in orthogonal array Table in carrying out experiments for solving the multiple responses in the electrical discharge machining process. After observing the experimental results, both methods can be used to optimize the machining parameters Pulse-ON, Pulse-OFF, voltage, feed, wire feed, offset by considering the multiple responses Electrode wear ratio, metal removal rate, accuracy, surface finish effectively. Though many researchers have conducted experimentation on various materials still there is a lacuna in finding correct parameter setting to machine EN31 steel for better quality with reduced costs. With this above aim an attempt has been made in this paper.

3. DESIGN OF EXPERIMENTS

3.1 SELECTION OF ORTHOGONAL ARRAY

The experiment designs were done based on the Taguchi Method. Genichi Taguchi a Japanese scientist developed a technique based on Orthogonal Array of experiments. This technique has been widely used in different fields of engineering to optimize the process parameters [6]. The control factors considered for the study are Pulse-on, Pulse-off, Bed speed and Current. Four levels for each control factor will be used. Based on number of control factors and their levels, L'_{16} orthogonal array (OA) was selected.Table-1 represents various levels of control factors and table-2 represents experimental plan with assigned values.

Table-1: Levels of various control factors

		Levels			
Control Factors		**I**	**II**	**III**	**IV**
A	Pulse-on	12	16	20	24
B	Pulse-off	6	7	8	9
C	Bed speed	20	25	30	35
D	Current	2	3	4	5

Table -2: Experimental plan with assigned values

S. No	Pulse On	Pulse Off	Bed Speed	Current
1	12	6	20	2
2	12	7	25	3
3	12	8	30	4
4	12	9	35	5
5	16	6	25	4
6	16	7	20	5
7	16	8	35	2
8	16	9	30	3
9	20	6	30	5
10	20	7	35	4
11	20	8	20	3
12	20	9	25	2
13	24	6	35	3
14	24	7	30	2
15	24	8	25	5
16	24	9	20	4

3.2 SELECTION OF MATERIAL

The work piece material used in this study is EN-31 tool steel and its chemical composition is given in Table -3 and parameters are given in table-4

Table-3: Chemical Composition of EN-31 Tool Steel

S.No	element	% of composition
1.	Carbon (C)	0.90 - 1.10
2.	Silicon (Si)	0.10 - 0.35
3.	Manganese (Mn)	1.10 max
4.	Phosphorus (P)	0.05 max
5.	Sulfur (S)	0.05 max
6.	Chromium (Cr)	1.00 - 1.501

3.3 EXPERIMENTAL WORK

The experiments were performed on CONCORD DK7720C four axis CNC Wire-cut electrical discharge machining (WEDM). The basic parts of the WEDM machine consists of a wire Electrode, a work table, and a servo control system**,** a power supply and dielectric supply system. Various components used in CONCORD CNC wire cut EDM are as shown Figure -2

Figure- 2(a): Wire cut EDM Machine

Figure -2(b): Controller used in CNC Wire cut EDM

Table- 4: Parameters of CONCORD DK7720C CNC WEDM

Control Factors	Symbols
Pulse-On	A
Pulse-Off	B
Bed Speed	C
Current	D

Fixed Parameters	
Wire used	Molybdenum wire of dia 0.180mm
Shape cut	10mm square
Location of the work piece on work table	At the center of table
Angle of cut	Vertical
Thickness/Height of the work piece	43mm
Stability	Servo control
Number of passes	One

VMRR is calculated with the formula $VMRR = \frac{\text{Volume of metal Removed}}{\text{Machining Time}}$

4. RESULTS AND DISCUSSION:

The results obtained are analyzed using S/N Ratios, Response table and Response Graphs with the help of Minitab software. Minitab is a computer program designed to perform basic and advanced statistical functions. It is a popular statistical analysis package for scientific applications, in particular for design and analysis of experiments. In this experimental results are analyzed and Regression equation is developed to predict the metal removal rate and graphs

Table-5: Results Table

Run	Pulse- on	Pulse- off	Bed Speed	Current	Machining Time	VMRR
1	12	6	20	2	122.13	3.17
2	12	7	25	3	95.8	4.04
3	12	8	30	4	80.32	4.81
4	12	9	35	5	67.68	5.71
5	16	6	25	4	60.92	6.35
6	16	7	20	5	60.00	6.45
7	16	8	35	2	93.2	4.15
8	16	9	30	3	70.63	5.47
9	20	6	30	5	38.48	10.05
10	20	7	35	4	45.75	8.45
11	20	8	20	3	72.85	5.31
12	20	9	25	2	92.27	4.19
13	24	6	35	3	47.43	8.15
14	24	7	30	2	75.67	5.11
15	24	8	25	5	45.02	8.59
16	24	9	20	4	59.23	6.53

4.1 SELECTION OF BEST PARAMETER COMBINATION

- Taguchi Analysis: MRR versus P on, P off, Bed speed, Current is carried out and average of each level is the parameter for raw data is given in table-6 and average of each level in terms of S/N ratios are given in table-7.and response graphs for means is shown in figure -3 and S/N ratios are shown in figure-4. And optimal parameter setting to obtain maximum material removal rate is given in table-8.

Table- 6: Response Table for Means

Level	Pulse On	Pulse Off	Bed Speed	Current
1	4.433	6.930	5.365	4.155
2	5.605	6.013	5.793	5.742
3	7.000	5.715	6.360	6.535
4	7.095	5.475	6.615	7.700
Delta	2.663	1.455	1.250	3.545
Rank	2	4	3	1

Table-7: Response Table for S / N ratios

Level	Pulse On	Pulse Off	Bed Speed	Current
1	12.73	16.09	14.25	12.25
2	14.84	15.26	14.83	14.90
3	16.38	14.80	15.65	16.13
4	16.84	14.66	16.06	17.51
Delta	4.11	1.43	1.81	5.26
Rank	2	4	3	1

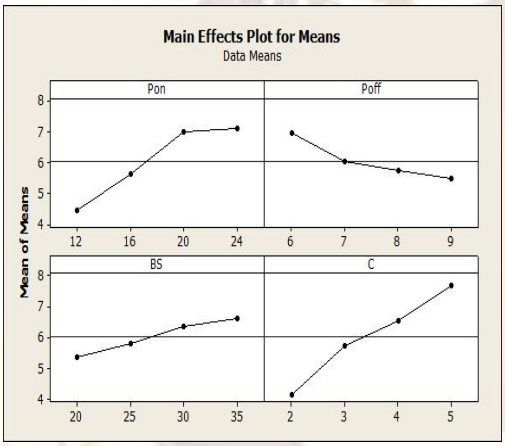

Figure-3: Response Graphs for Means

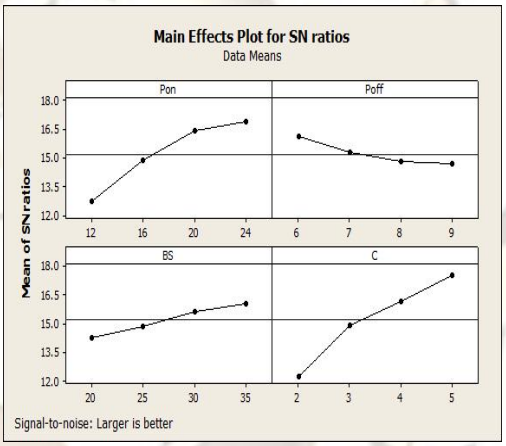

Figure-4: Response Graphs for S/N ratios

Table-8; Optimal parameter Combination

Control Factors	Optimum Level
Pulse-On	24
Pulse-Off	6
Bed Speed	35
Current	5

4.2 DEVOLOPEMENT OF REGRESSION EQUATION

The objective of multiple regression analysis is to construct a model that explains as much as possible, the variability in a dependent variable, using several independent variables.

- Regression Equation for MRR

VMRR = - 1.07 + 0.235 Pon - 0.466 P off + 0.0864 BS + 1.14 C

With the help of Regression equation the predicted values of MRR is estimated and their deviation is tabulated. It is observed that the predicted values are closer to experimental values as in Table-9 and shown in graphical form in figure-5.

Table –9: Actual and predicted values of MRR

VMRR	Predicted VMRR	Deviation
3.17	2.962	0.208
4.04	4.068	-0.028
4.81	5.174	-0.364
5.71	6.280	-0.570
6.35	6.614	-0.264
6.45	6.856	-0.406
4.15	4.266	-0.116
5.47	4.508	0.962
10.05	9.126	0.924
8.45	7.952	0.498
5.31	5.050	0.260
4.19	3.876	0.314
8.15	8.218	-0.068
5.11	6.180	-1.070
8.59	8.702	-0.112
6.53	6.664	-0.134

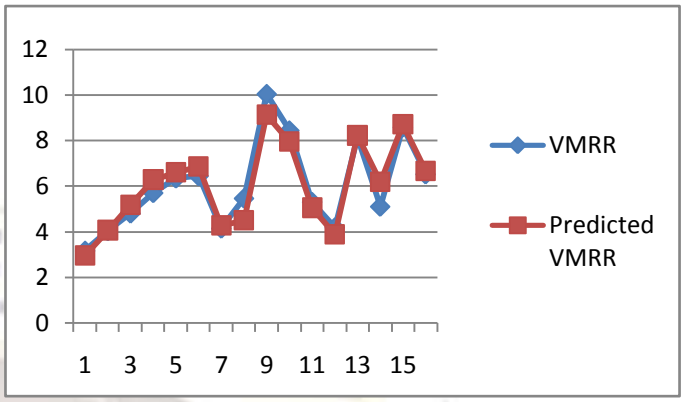

Figure-5: Comparison between predicted and experimental values.

5. CONCLUSION

Based the results and discussion the following conclusions are drawn,

- The better Parameter setting is Pulse on 24µs, pulse off 6 µs, Bed speed 35 µm/s and Current to obtain maximum metal removal rate.
- The order strength of parameters are found from response table is current, pulse on, Bed speed and pulse off.
- Regression analysis is used to predict the MRR with 6.77% error

6. FUTURE WORK

- The work may be continued for machining different materials for finding optimal combination of parameters.
- The work may be extended by varying the wire materials to find out the best material of the wire.
- The present work was carried out by multiple regression analysis to estimate the MRR and Ra etc. Further this work can be extended by considering analysis of variance (ANOVA)
- The present work was carried out by Taguchi analysis; further this work can be extended by considering any combination of fuzzy control, Grey relational analysis with Taguchi's orthogonal array technique.

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