Machining Parameters Optimization of WEDM Process Using Taguchi Method

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Abstract- WEDM is a widely recognized unconventional material cutting process used to manufacture components with complex shapes and profiles of hard materials. In this thermal erosion process, there is no physical contact between the wire tool and work materials. Wire Electrical Discharge Machining (WEDM) is getting more tasks in fields like dies, punches, aero and many more. It is the very difficult task to get optimum process parameters for higher cutting efficiency. Accuracy is becoming a predominant factor nowadays. In this paper EN31 is taken for study. The design of experiments (DOE) is done in taguchi L27 orthogonal array (OA). In WEDM process rough machining gives lesser accuracy and finish machining gives fine surface finish, but it reduces the machining speed. Hence we have to improve the MRR and reduce the Ra as the objective, which is done by taguchi method.

Index Terms- WEDM,DOE, Orthogonal array,MRR,Ra,Taguchi method

I. INTRODUCTION

In this paper, Machining parameter of the WEDM process can be optimized by using taguchi method. Taguchi method is based on “ORTHOGONAL ARRAY’’. It provides a set of well balanced experiments, which gives much reduced “variance’’ for the experiment with “optimal setting’’ of control parameters.

J.L. Lin et al [1] the application of the taguchi method with fuzzy logic for optimizing the electrical discharge machining process with multiple performance characteristics has been reported. The machining parameters (the work piece polarity, pulse-on time, duty factor, and open discharge voltage, discharge current and dielectric fluid) are optimized with considerations of the multiple performance characteristics (electrode wear ratio and material removal rate). Nihat Tosun et al [2] find on the effect and optimization of machining parameters on the notch and material removal rate (MRR) in wire electrical discharge machining (WEDM) operations. The experimental studies were conducted under varying pulse duration, open circuit voltage, wire speed and discharge flushing pressure. The settings of machining parameters were determined by using taguchi experimental design method. Can Cogun [3] the settings of machining parameters were determined by using taguchi experimental design method. The level of importance of the machining parameters on the kerf and the MRR is determined by using ANOVA. The highly effective parameters on both the kerf and the MRR were found as open circuit voltage and pulse duration, whereas wire speed and dielectric flushing pressure were less effective factors. Amar Patnaik et al [4] Introducing zinc coated copper as electrode tool with the process parameters of discharge current, pulse duration, pulse frequency, wire speed, wire tension, dielectric flow rate. By using factors, maximization of MRR and minimization of surface roughness is done in WEDM process using taguchi method. Tanimura et al [5] projected new EDM process using water mist, which requires no tank for the working fluid. They also pointed out that the mist-EDM/WEDM enables non-electrolytic machining even, when electrically conductive water is used as the working liquid. Fu-chen Chen et al [6] Research is based on fuzzy logic analysis coupled with taguchi methods to optimize the precision and accuracy of the high-speed electrical discharge machining (EDM) process, pulse time, duty cycle, peak value of discharge current as the most important parameters, powder concentration, powder size are found to have relatively weaker impacts on the process design of the high speed EDM. The most important factors affecting the precision and accuracy of the high-speed EDM process have been identified as pulse time, duty cycle, and peak value of discharge current. Dry EDM has many advantages such as, extremely low tool wear ratio, higher precision, smaller heat affected zone. The experimental studies were conducted under varying pulse duration, open circuit voltage, wire speed and dielectric flushing pressure. H.Singh et al [7] analyze the effects of various input process parameters like pulse on time, pulse off time, gap voltage, peak current , wire feed and wire tension have been investigated and impact on MRR is obtained. Finally they reported MRR increase with increase in pulse on time and peak current. MRR decrease with increase in pulse off time and servo voltage. Wire feed and wire tension has no effect on MRR. A.K.M. Nurul Amin et al [8] Conducting experiments on cutting of tungsten carbide ceramic using electro-discharge machining (EDM) with a graphite electrode by using taguchi methodology. The taguchi method is used to formulate the experimental layout, to analyze the effect of each parameter on the machining characteristics, and to predict the optimal choice for each EDM parameter such as peak current, voltage, pulse duration and interval time. It is found that these parameters have a significant influence on machining characteristic, such as metal removal rate (MRR), electrode wear rate (EWR) and surface roughness (SR). The peak current significantly affects the EWR and SR, while, the pulse duration mainly affects the MRR. Taguchi method has been used to determine the main effects, significant factors and optimum machining condition to the performance of EDM. Kuo-Wei Lin et al [9] conduct test Wire Electrical Discharge Machining (WEDM) of magnesium alloy parts via the taguchi method-based gray analysis was conducted, they considered multiple quality characteristics required include material removal rate and surface roughness following WEDM. This work machines magnesium alloy parts under controlled machine parameter settings, and measures the above quality characteristics. The optimized machine parameter settings clearly improve quality characteristics of the machined work piece compared to quality levels achieved for initial machine parameter settings. The complex interactions in WEDM involve wire feed rate, pulse-on time, pulse-off time, no load voltage, servo voltage, and wire tension. Kamal Jangra et al [10] Investigated on Influence of taper angle, peak current, pulse-on time, pulse-off time, wire tension and dielectric flow rate are investigated for material removal rate (MRR) and surface roughness (SR) during intricate machining of a carbide block. In order to optimize MRR and SR simultaneously, grey relational analysis (GRA) is employed along with taguchi method. WC-Co composite is studied, grey relational analysis (GRA) is employed along with taguchi method, the percentage error between experimental values and predicted results are less than 4% for both machining characteristics.

Table.1 Parameters of the setting

Control factors	**Symbols**	**Fixed parameters**	
Applied voltage	Factor -A	Wire	Molybdenum wire
Pulse width	Factor- B	Shape	Rectangular product
Pulse interval Speed	Factor -C Factor- D	Location of work piece on work table	At the centre of the table
		Thickness of work piece	8 mm
		Stability	Servo control
		Height of work piece	50 mm
		Wire type	Molybdenum wire, Diameter 0.20 mm

Table.2 Levels for various control factors

Factors	Levels			
Control factors	I	II	III	Units
A. Applied voltage	75	90	105	Volts
B. Pulse width	3	4	5	µs
C. Pulse interval	20	25	30	µs
D. Speed	250	500	750	Rpm

II. EXPERIMENTAL DATA COLLECTION

This section describes the experimental setup, explains the method of conducting experiments, and design of experiment based on Taguchi method.

2.1. Experimental set up

Experiments were conducted on ST CNC-E3 (MCJ) wire cut EDM machine. It was made by Steer Corporation this machine is numerically controlled wire EDM machine. The X and Y axis of the table movement can be controlled by using servo controller. In X axis the table will move at a distance of 300 mm and in Y axis the table will move at a distance of 250 mm. According to the convention of normal polarity, the work-piece is connected to the positive terminal of the source and the tool is attached to the negative terminal of the source.

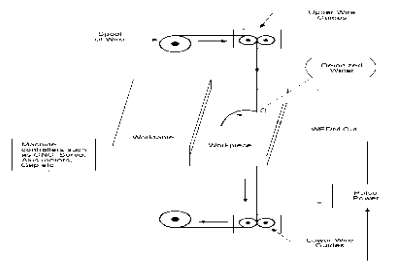


Fig. 1 Experimental setup

Figure 1 shows that arrangement of wire cut EDM machine the experimental data based on the DOE were collected to study the effect of various machining parameters of the EDM process. These studies had been undertaken to investigate the effect of applied voltage, discharge current, pulse width, pulse interval on the Metal removal rate and surface roughness.

2.2. Experimental procedure

The experiments were conducted on EN 31 alloy steel material having composition of (1.00% C, 0.50% Mn, 1.40% Cr, and 0.20% Si.) as a work specimen. The work piece is in the form of rectangle plate having dimensions of $100mm \times 50mm \times 8mm \cdot$ Work piece had been machined using molybdenum wire is used as a tool having diameter of 0.20mm and de-ionized water as a dielectric fluid. Each sample had been machined for a length of 4mm. Machining time were measured using a stop watch. After machining to calculate the MRR and Ra values were measured using Mitutoyo SJ.201P surface tester. Meter has a stylus stroke of 350µm, resolution of 0.01 µm, minimum cut-off of 0.25mm and 2µm stylus radius was used. The measurement length was set to 3mm.

2.3 Design of experiment based on Taguchi method

Table.3 Experimental design using L_{27} orthogonal array

S. N O	A	B	C	D	MRR (mm^3/ min)	S/N Ratio (db)	Ra (mµ)	S/N Ratio (db)
1	1	1	1	1	3.315	10.4097	3.32	-10.4228
2	1	1	2	2	4.975	13.9359	3.31	-10.3966
3	1	1	3	3	2.663	8.507423	3.13	-9.91089
4	2	2	1	2	7.889	17.94044	3.64	-11.222
5	2	2	2	3	7.206	17.15389	3.42	-10.6805
6	2	2	3	1	3.810	11.6185	3.42	-10.6805
7	3	3	1	3	11.40	21.1381	3.65	-11.2459
8	3	3	2	1	6.932	16.81717	3.59	-11.1019
9	3	3	3	2	5.649	15.03943	3.75	-11.4806
10	2	3	1	2	7.130	17.06179	3.5	-10.8814
11	2	3	2	3	7.144	17.07883	3.41	-10.6551
12	2	3	3	1	7.024	16.93169	3.71	-11.3875
13	3	1	1	3	6.969	16.86341	3.37	-10.5526
14	3	1	2	1	4.002	12.04554	3.56	-11.029
15	3	1	3	2	4.580	13.21731	3.46	-10.7815
16	1	2	1	1	4.527	13.11621	3.32	-10.4228
17	1	2	2	2	2.257	7.070631	3.42	-10.6805
18	1	2	3	3	6.130	15.74921	3.34	-10.4749
19	3	2	1	3	7.999	18.06071	3.45	-10.7564
20	3	2	2	1	5.664	15.06246	3.46	-10.7815
21	3	2	3	2	4.898	13.80038	3.46	-10.7815
22	1	3	1	1	4.181	12.4256	3.49	-10.8565
23	1	3	2	2	6.083	15.68236	3.63	-11.1981
24	1	3	3	3	5.690	15.10225	3.31	-10.3966
25	2	1	1	3	3.892	11.80346	3.32	-10.4228
26	2	1	2	2	5.872	15.37572	3.2	-10.103
27	2	1	3	1	3.657	11.2625	3.24	-10.2109

The experiment is carried out on ST CNC-E3 (MCJ) wire cut EDM machine, the input parameters range can be given as input based on literature survey. Then machining the specimen using WEDM machine and measureable values can be recorded to evaluate the effects of machining parameters on performance characteristics (MRR, and Ra) and to identify the performance characteristics under the optimal machining parameters.

III. Result and Discussion

Figures 2, 3 shows graphically the effect of the four control factors on MRR, Ra. By using MINITAB 16 software the effect of control factors can be predicted.

Fig. 2 Effect of control factors on MRR

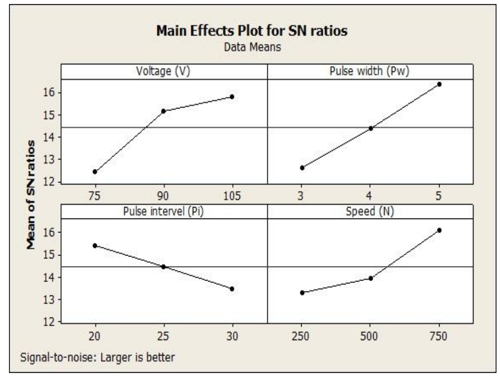
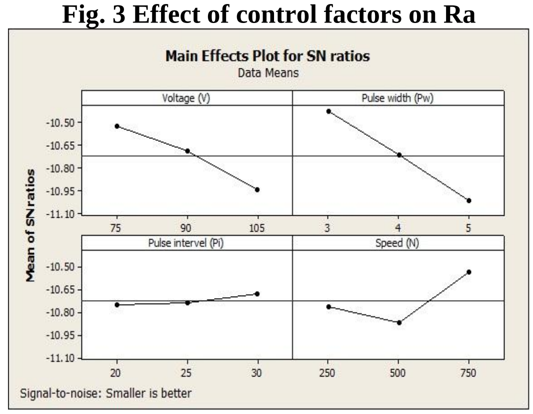


Fig. 3 Effect of control factors on Ra



The S/N ratio response table and response graphs are shown for S/N ratio for MRR in Table 3 and Fig. 2 respectively. Similarly, response table and response graphs are shown for S/N ratio for Ra in Table 3 and Fig. 3 respectively. Analysis of the result leads to the conclusion that factors at level A3, B3, C1, D3 gives maximum MRR. Although factors C factor is not show significant effect on material removal rate and surface finish as shown in Fig. 2. Factor C is having least significance effect for improving MRR. Similarly, it is recommended to use the factors at level A3, B3, C1, D2 for minimization of Ra as shown in Fig. 3. Factors C and D have least contribution for minimization of R_a

IV. Conformation Test

The optimal combination of machining parameters has been determined in the previous analysis. However, the final step is to predict and verify the improvement of the observed values through the use of the optimal combination level of machining parameters. The estimated S/N ratio for MRR and Ra are shown in table 4&5.

Table 4 S/N ratio response table for MRR

	A	B	C	D
Level 1	12.44	12.60	15.42	13.30
Level 2	15.14	14.40	14.47	13.95

Level 3	15.78	16.36	13.47	16.11
Delta	3.34	3.76	1.95	2.82
Rank	2	1	4	3

Table 5 S/N ratio response table for Ra

	A	B	C	D
Level 1	-10.53	-10.43	-10.75	-10.77
Level 2	-10.69	-10.72	-10.74	-10.87
Level 3	-10.95	-11.02	-10.68	-10.53
Delta	0.42	0.60	0.08	0.34
Rank	2	1	4	3

The predicted and experimental value comparison for MRR and Ra from the optimal values by Minitab16 is shown in tables 6&7.

Table 6 Results of the confirmation experiment for MRR

	Optimal machining parameter	
	Prediction	Experimental
Level	$A_3B_3C_1D_3$	$A_3B_3C_1D_3$
MRR(mm3/min)	9.57367	9.611

Table 7 Results of the confirmation experiment for Ra

	Optimal machining parameter	
	Prediction	Experimental
Level	$A_3B_3C_1D_2$	$A_3B_3C_1D_2$
Ra(µm)	3.15556	3.12

V. CONCLUSION

In this article, an attempt was made to determine the significant machining parameters for performance measures like MRR and Ra separately in the WEDM process. Factors like Voltage, Pulse width and Speed have been found to play a significant role for MRR and surface roughness. Taguchi's method is used to obtain optimum parameters combination for maximization of MRR and minimization of Ra. The conformation experiments were conducted to evaluate the result predicted from Taguchi Optimization.

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