Performance Evaluation of Wedm Machining on Incoloy800 by"TAGUCHI Method"

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Abstract- The main objective of the present work is to investigate the effect of different process parameters viz. pulse on time (Ton), pulse off time (Toff), spark voltage (SV), peak current (IP) on the response parameters such as Kerf width, Gap current using coated wire(super alloy) electrode (0.25 mm diameter) in wire electrical discharge machining (WEDM). The Taguchi design methodology is chosen for design of experiment and L_{18} orthogonal array are selected for present work. Analysis of variance (ANOVA) and main effect plot is used to find the significant process parameters and their effect on the response parameters. The optimum machining parameter combination is obtained by analysis of signal to noise (S/N) ratio.

Keywords – Wire Electrical Discharge Machining (WEDM), Taguchi Method, Kerf Width, ANOVA.

I. INTRODUCTION

Demand in present industry which specializes in cutting complex shapes and geometries of conductive metals of any hardness that are difficult or impossible to cut with traditional machining method. Wire electric discharge machine is one of the most commonly used machine which is employed in machining of conductive or hard metals [1]. The literature survey has revealed that very less work has been done in order to achieve optimal levels of process parameters for Incoloy800 super alloy using coated wire electrode and the coated wire has a 0.25 mm diameter. Due to their high temperature mechanical strength and high corrosion resistance properties, super alloy are now a day use in marine, space and other application also Incoloy800 is very chemically reactive and therefore, has a tendency to weld to the cutting tool during machining thus, leading to premature tool failure so it is very difficult to machine Incoloy800 by conventional machining processes [2]. Of late, modern machining techniques such as wire electrical discharge machining (WEDM) are increasingly being use for machining such as hard materials. Hence, this work focused on machining of Incoloy800 using ELEKTRA MAXICUT 734 WEDM. Nihat Tosun [3] investigated to optimization and the effect of processes parameters with CuZn37 master brass wire (0.25) on the kerf and the MRR in WEDM operations. The influence of the processes parameters on the kerf and the MRR is determined by using ANOVA. Based on ANOVA method, 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. The results were found open circuit voltage about three times more important than the pulse duration for controlling the kerf, whereas open circuit voltage for controlling the MRR was about six times more important than the pulse duration. An optimum parameter combination for the minimum kerf and maximum MRR was obtained by using the analysis of signal-to-noise (S/N) ratio. Tosun et.al. [4] modelled the variation of response variables with the machining parameters in WEDM using regression analysis method and then applied simulated annealing approach searching for determination of the machining parameters that can simultaneously optimize all the performance measures, e.g. kerf and MRR. Mahapatra and Patnaik [5] developed relationships between various process parameters and responses like MRR, SR and kerf by means of non-linear regression analysis and then employed genetic algorithm to optimize the WEDM process with multiple objectives. S.B. Prajapati [6] introduced on AISI A2 tool steel with brass wire by WEDM process parameters like pulse on time, pulse off time, voltage, wire feed and wire tension effect on MRR, SR, kerf, and gap current by response. It was found cutting rate and surface roughness, the pulse on and pulse off time is most significant also spark gape set voltage is significant for kerf. Pardeep gupta [7] investigated on high strength low alloy steel (HSLA) with WEDM process parameters like pulse on-time, pulse off time, peak current, wire tension, spark gap voltage effect on kerf width or analysis by response surface methodology (RSM). Results were found the kerf width decreases with increase in pulse on-time, pulse off time, peak current, spark gap voltage but increase with increase in wire tension means analysis of results indicates that the pulse on-time, pulse off time, peak current, spark gap voltage have a significant effect on kerf width. Aniza Alias [8] investigated on Ti-6Al-4V with brass wire in WEDM the importance of process parameters and different machining conditions on kerf width, MRR, surface roughness (RA) and surface topography and it has found the best combination of machining parameters as known the cost and quality of WEDM which depends heavily on process parameters.

II. Proposed Algorithm

A. Taguchi's Method

The experiments are conduct by using the parametric approach of the Taguchi's method. According to the Taguchi quality design concept a set of three levels assigned to each process parameter has two degrees or freedom (DOF). This give a total of 16 DOF for four process parameters selected in this work [9] . The nearest three level orthogonal array available satisfying the criterion of selecting the OA is L18 having 18 row (corresponding to the number of experiments) use in this experiment.

B. Analysis of Variance (ANOVA)

The analysis of variance (ANOVA) used to establish statistically significant machining parameters and the percent contribution of these parameters on the Kerf and the Gap current. The relative importance of the machining parameters with respect to the Kerf and Gap current are investigate to determine more accurately the optimum combinations of the machining parameters by using ANOVA [3]. The results of ANOVA for the machining outputs are presented in Tables 5 and 7. Statistically, F-test provides a decision at some confidence level as to whether these estimates are significantly different. Larger F-value indicates that the variation of the process parameter makes a big change on the performance characteristics. F-values of the machining parameters are compared with the appropriate confidence table.

C. S/N Ratio (signal to noise)

In Taguchi method a loss function is used to calculate the deviation between the experimental value and the desired value. This loss function is further transformed into a signal-to-noise (S/N) ratio [10]. There are several S/N ratio available depending on type of characteristics; lower is better (LB), nominal is best (NB), and higher is better (HB). In WEDM, the lower Kerf and higher Gap current are the indication of better performance. For each trial in the L18 array, the levels of process parameters are indicated in table 1.

The equations for calculation S/N ratios for LB, NB or HB characteristics are:

$$S/N_{LB} = -10\log \qquad (1)$$

Where r = Number of tests in a trial

y_i = Machining performance results of repeated number

= Summation of all response values under each trial

V_e = Variance

$$S/N_{NB} = -10\log V_e \qquad (2)$$

$$S/N_{HB} = -10\log \qquad (3)$$

Table- 1 Orthogonal Array for experiment L18 (3^4)

Experiment No.	Pulse on time (Ton) A	Pulse off time Toff) B	Spark voltage (SV) C	Peak current (IP) D
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	1	3
5	2	2	2	1
6	2	3	3	2
7	3	1	2	3
8	3	2	3	1
9	3	3	1	2
10	1	1	3	1
11	1	2	1	2
12	1	3	2	3
13	2	1	2	2
14	2	2	3	3
15	2	3	1	1
16	3	1	3	2
17	3	2	1	3
18	3	3	2	1

III. EXPERIMENT AND RESULT

The experimental work is carry out by Taguchi experimental design method. The experiments are conduct to investigate the effect of process parameters on the response parameters e.g. Kerf width, Gap current. In this experiment the pulse on time, pulse off time, spark voltage, peak current were varied those effect on response parameters.

A. Parameter Assignment

For the present experimental work the four process parameters each at three levels have been decided. It is desirable to have three minimum levels of process parameters to reflect the true behavior of response parameters of study. The process parameters are renamed as factors and they are given in the adjacent column. The levels of the individual process parameters and arrangements of machining parameters level for response parameters according to L18 Orthogonal Array for each trial are indicated in table 2, table 4.

Table -2 Selected levels of the process parameters

Factors	Process parameters	Units	Levels Selected		
			Level 1	Level 2	Level 3
A	Pulse on time (Ton)	µs	2	3	4
B	Pulse off time (Toff)	µs	3	4	5
C	Spark voltage (SV)	V	70	65	60
D	Peak current (IP)	A	1	2	3

Table-3 Fixed input process parameters

S. No.	Machining Parameter	Fixed Value
1	Work material	Incoloy800
2	Cutting Tool	Coated wire (dia.0.25 mm)
3	Flushing Pressure	Lower Flushing Pressure 40lit/min, Upper Flushing Pressure 25 lit/min
4	Work piece height	26 mm
5	Conductivity of Dielectric	40 mho
6	Open Circuit Voltage (V)	60 Volt
7	Type of Dielectric	D.M Water
8	Wire Speed (m/sec)	5 m/min
9	Dielectric Flow (lit/min)	40 lit/min
10	Wire Tension	7 Unit

Table- 4 Experimental design using $\mathbf{L_{18}}$ Orthogonal Array

Experiment No.	Pulse on time (Ton) A	Pulse off time (Toff) B	Spark voltage (SV) C	Peak current (IP) D	Kerf width (mm)	Gap current (A)
1	2	3	70	1	0.330	1.2
2	2	4	65	2	0.300	3.1
3	2	5	60	3	0.310	2.8
4	3	3	70	3	0.285	2.9
5	3	4	65	1	0.325	1.3
6	3	5	60	2	0.280	2.0
7	4	3	65	3	0.305	2.4
8	4	4	60	1	0.315	1.9
9	4	5	70	2	0.325	2.0
10	2	3	60	1	0.295	2.4
11	2	4	70	2	0.320	1.5
12	2	5	65	3	0.300	2.5
13	3	3	65	2	0.305	2.1
14	3	4	60	3	0.320	3.0
15	3	5	70	1	0.310	1.3
16	4	3	60	2	0.290	1.4
17	4	4	70	3	0.330	1.9
18	4	5	65	1	0.295	1.5

B. Experimental Results

The WEDM experiments are conducted to study the effect of process parameters over the response parameters with their interactions to columns as given table 4. The experimental results for kerf width and gap current are given in table 6 and 8. The 18 experiments were conducted using Taguchi experimental design methodology also optimal machining performance for kerf and gap current obtained by S/N ratio. In the present study all the designs, plots and analysis have been carried out using Minitab15 statistical software. The following discussion focuses on the different of process parameters to the response parameters value (kerf width and Gap current base on the Taguchi methodology).

Table- 5 ANOVA Means of Kerf Width

Source	DOF	Seq. SS	Adj. MS	F	P
Pulse on time	2	0.0001194	0.0000597	0.28	0.763
Pulse off time	2	0.0010111	0.005056	2.36	0.150
Spark voltage	2	0.0007444	0.0003722	1.74	0.230
Peak current	2	0.0002111	0.0001056	0.49	0.626
Residual Error	9	0.0019250	0.0002139		
Total	17	0.0040111			
DF- Degree of freedom, SS- Sum of squares,MS- Mean squares(variance), F- Ratio of variance of a source to variance of error, P- % Contribution					

Table- 6 Response table for means of Kerf width

Level	Pulse on time	Pulse off time	Spark voltage	Peak current
1	10.203	10.419	10.419	10.134
2	10.351	9.946	10.318	10.373
3	10.183	10.371	9.999	10.229
Delta	0.163	0.473	0.420	0.239
Rank	4	1	2	3

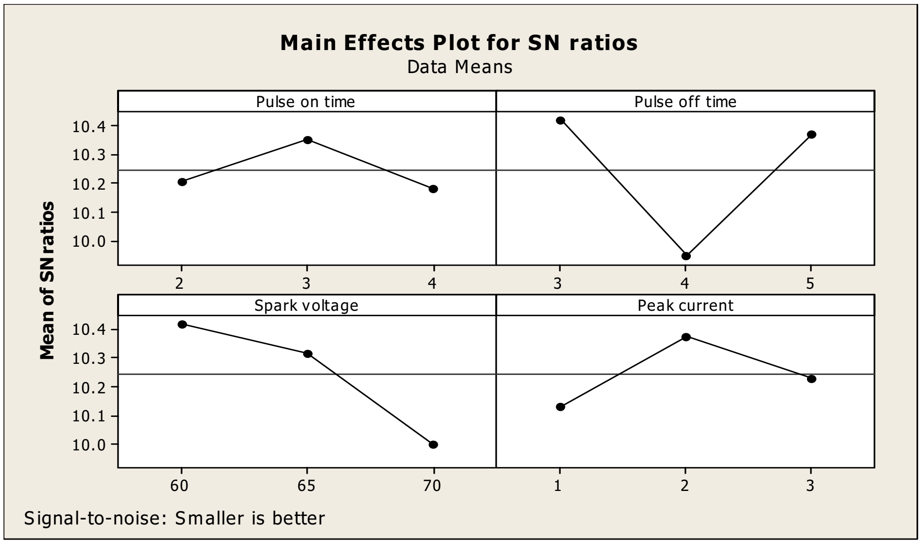

Figure1. Main Effect Plot for S/N Ratio for Kerf Width

B.1 Results for Kerf width

Main effects of Kerf width of each factor for various level conditions are shown in figure 1 with the above graph for S/N ratio for Kerf width and we have found the optimal setting A2B1C1D2 which is Pulse on time at level 2 (3 µs), Pulse off time at level 1 (3 µs), Spark voltage at level 1 (70 Volt), Peak current at level 2 (2 A).

Table- 7 ANOVA Means of Gap Current

Source	DOF	Seq. SS	Adj. MS	F	P
Pulse on time	2	0.4900	0.2450	0.87	0.453
Pulse off time	2	0.0300	0.0150	0.05	0.949
Spark voltage	2	0.6700	0.3350	1.18	0.350
Peak current	2	2.9233	1.4617	5.17	0.032
Residual Error	9	2.5467	0.2830		
Total	17	6.6600			
DF- Degree of freedom, SS- Sum of squares,MS- Mean squares(variance), F- Ratio of variance of a source to variance of error, P- % Contribution					

Table- 8 Response table for means of Gap Current

Level	Pulse on time	Pulse off time	Spark voltage	Peak current
1	6.573	5.901	6.768	3.807
2	5.969	6.053	6.273	5.793
3	5.203	5.791	4.705	8.145
Delta	1.370	0.263	2.063	4.338
Rank	3	4	2	1

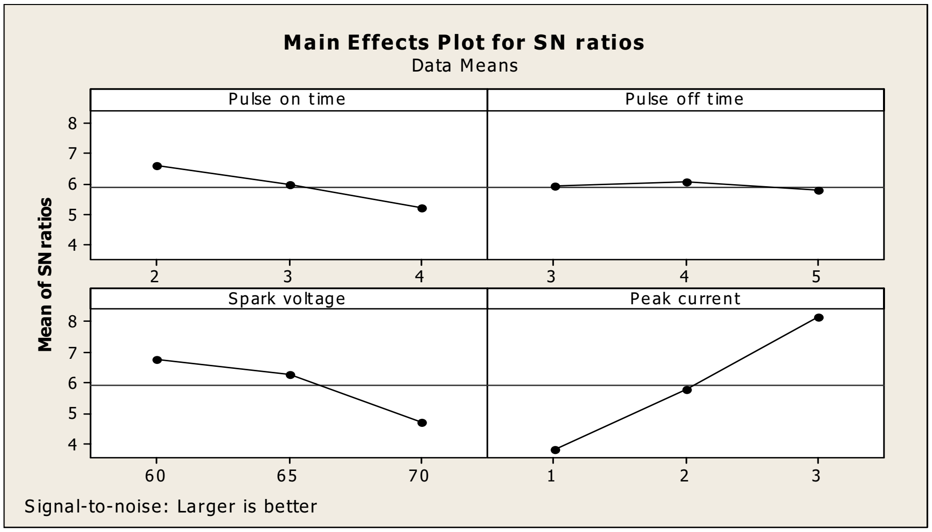

Figure1. Main Effect Plot for S/N Ratio for Gap current

B.2 Results for Gap current

Figure 2 the main effects of each factor for level conditions with the above graph for S/N ratio for Gap current and we have found the optimal setting A1B2C1D3 which is Pulse on time at level 1 (2 µs), Pulse off time at level 2 (3 µs), Spark voltage at level 1 (70 Volt), Peak current at level 3 (3 A).

IV.CONCLUSION

All concludes, hence the effect of process parameters on response parameters (kerf width, Gap current) and optimal set of process parameters that yields the optimum quality features to machined parts produced by WEDM process also obtain. This paper has presented an investigation on the optimization and the effect of machining parameters on the Kerf and the Gap current in WEDM operations. The level of importance of the machining parameters on the kerf and Gap current is determined by using Taguchi analysis. According to Taguchi analysis for kerf width, Pulse off time is the most significant factor because it is having 1 rank then having 2 rank of Spark voltage, 3 rank of Peak current and 4 rank of Pulse on time are less effective factors in case of Kerf width and predicted optimal setting is A2B1C1D2. Similarly for the Gap current, the most significant factor is Peak current because it is having 1 rank then 2 rank of spark voltage, 3 rank of Pulse on time and , 4 rank Pulse off time are less effective factors in case of Gap current and predicted optimal setting is A1B2C1D3.

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