Optimization of Process Parameters in Wire Electric Discharge Machining Process

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Abstract

Wire Electric Discharge Machining (WEDM) is electrical machining process, electrical energy is used directly to cut the material to final shape and size but the demands for alloy materials having high hardness, toughness and impact resistance are increasing. Nevertheless, such materials are difficult to be machined by traditional machining methods. Hence, non-traditional machining methods including electrochemical machining, ultrasonic machining, Electrical Discharging Machine (EDM) etc. are applied to machine such difficult to machine materials. WEDM process with a thin wire as an electrode transforms electrical energy to thermal energy for cutting materials. With this process, alloy steel, conductive ceramics and aerospace materials can be machined irrespective to their hardness and toughness. The Material Removal Rate (MRR) is the important performance attributes of WEDM process. The machining parameters that achieve the highest MRR strongly depend on the size of machining surface i.e. the engaged wire electrode and workpiece surface. With widely application of Titanium grade -2, machining has become an important area which needs to be investigated in detail.

A well designed many set of experiments can be examined by using the L 27 Orthogonal Array(OA) experimental design with input factors like Pulse on Time, Pulse off Time, Peak Current(I_p), Flushing Pressure(W_p), Wire Feed Rate(W_f), Wire Tension(W_t), Servo Feed Rate(S_f) was considered for investigation. The effect of machining parameters on the response such as MRR was investigated. In this research work, Taguchi analysis was used to find out the optimal level of the parameters.

Keywords

Wire Electric Discharge Machining (WEDM), Titanium Grade-2, Orthogonal Array (OA), Taguchi analysis, Material Removal Rate (MRR).

I. Introduction

WEDM is a thermo-electrical process in which material is eroded from the work material by a series of separate sparks between the work material and the wire electrode i.e. tool (wire) and workpiece material, separated by a thin film of dielectric fluid (Distilled water oil) that is continuously fed to the machining zone to flushing away the evaporated particles. WEDM was first introduced to the manufacturing industry in the late 1960s. The movement of wire is controlled numerically to achieve the desired 3D (3-dimensional) shape and accuracy of the work piece. In addition, the WEDM process is able to machine exotic and High Strength and Temperature Resistive (HSTR) materials and eliminate the geometrical changes occurring in the machining of heat-treated steels. After Computer Numerical Control (CNC) system was initiated into WEDM that brought about a recommended path and removes material from the work piece. WEDM uses electro-thermal mechanisms to cut electrically conductive materials. The material is removed by a continuous of sparks between the wire electrode and the work material in the presence of dielectric (distilled water), which creates a path for each discharge as the fluid becomes ionized in the gap between tool (wire) work material. The area where discharge takes place is heated to extremely high temperature, so that the surface is evaporated and removed. WEDM techniques have developed in many areas.

II. Experimental Details

A. Experimental Setup

All the experiments were carried out on the WEDM setup (Model: Electronica ELPULS 5S ultima 2f), the photograph which is shown in fig. 1.

Fig. 1: WEDM Setup

It mainly consists of Wire electrode, control unit, and dielectric circulation system. The machining takes place in the chamber while various process parameters are regulated through control units. Dielectric liquid is pumped through the reservoir where dielectric liquid flow rate can also be varied.

B. Selection of Work Piece, Tool Material and Dielectric Fluid

Workpiece of 80mm length, 80mm breadth and 5mm thickness of **CP Titanium grade-2** was selected. The tool wire made up of brass with 0.25mm diameter was selected as anode. Dielectric fluid is a non-conductive liquid (deionized water) was taken as dielectric fluid for coolant medium of workpiece and tool wire during the cutting process.

C. Machining Parameters and Responses

The machining efficiency depends largely on machining parameters. So the judicious selection of parameters is of prime importance. From the literature review, the process parameters like Pulse on Time, Pulse off Time, Peak Current (I_p), Flushing Pressure(W_p), Wire Feed Rate(W_f), Wire Tension(W_t), Servo Feed Rate(S_f) were chosen for current experiment since they were found to have significant influences of MRR.

The MRR can be defined as rate of dissolution of material from the workpiece. MRR of Titanium grade-2 has been considered as the performances measure and was calculated by following formula:

$$\text{MRR} = \frac{\text{Inetial weight} - \text{Final weight}}{\text{density} \times \text{time}}$$

Initial and final weights of the work piece were measured by Electronic Weighing Machine of accuracy of 0.001g.

D. Design of Experiments

The experiments were planned as per three levels L27 Taguchi orthogonal array. The design was generated and analyzed by using MINITAB 17 statistical software. Seven factors at three levels were considered for the experimentation. The L27 orthogonal array (OA) for MRR is represented by Table 1.

Table 1: Taguchi L27 Orthogonal array for MRR

Run no.	Pulse on Time (µsec)	Pulse off Time (µsec)	Peak Current (ampere)	Flushing Pressure (kg-pascal)	Wire Feed (m/min)	Wire Tension (kgf)	Servo Feed Rate (mm^3/min)	Material removal rate in (mm^3/min)
1	120	40	11	110	7	7	2150	0.0080
2	120	40	11	110	8	8	2250	0.0101
3	120	40	11	110	9	9	2350	0.005
4	120	50	12	120	7	7	2150	0.0053
5	120	50	12	120	8	8	2250	0.0082
6	120	50	12	120	9	9	2350	0.0080
7	120	60	13	130	7	7	2150	0.0056
8	120	60	13	130	8	8	2250	0.0059
9	120	60	13	130	9	9	2350	0.0078
10	122	40	12	130	7	8	2350	0.0077
11	122	40	12	130	8	9	2150	0.0064
12	122	40	12	130	9	7	2250	0.0059
13	122	50	13	110	7	8	2350	0.0064
14	122	50	13	110	8	9	2150	0.0064
15	122	50	13	110	9	7	2250	0.0046
16	122	60	11	120	7	8	2350	0.0070
17	122	60	11	120	8	9	2150	0.0056
18	122	60	11	120	9	7	2250	0.0041
19	124	40	13	120	7	9	2250	0.0085
20	124	40	13	120	8	7	2350	0.0085
21	124	40	13	120	9	8	2150	0.0075
22	124	50	11	130	7	9	2250	0.0066
23	124	50	11	130	8	7	2350	0.0081
24	124	50	11	130	9	8	2150	0.0072
25	124	60	12	110	7	9	2250	0.0077
26	124	60	12	110	8	7	2350	0.0062
27	124	60	12	110	9	8	2150	0.0064

III. Results and Discussion

A. Influence of Cutting Parameters on Responses Measured

Taguchi design of experiment uses small number of runs to study the effect of process parameters by using orthogonal array in its design. Taguchi method mainly focuses on the average performance characteristics data close to the ideal target data rather than any other data within specified range, method based on "Orthogonal Array" experiments which gives much reduced "variance" for the experiment with "optimum settings" of control parameters. Thus the marriage of Design of Experiments with optimization of control parameters to obtain best results is achieved in the Taguchi Method. "Orthogonal Arrays" (OA) provide a set of well balanced (minimum) experiments and Dr. Taguchi's Signal-to-Noise ratios (S/N), which are log functions of desired output, serve as objective functions for optimization, help in data analysis and prediction of optimum results. The influence of different cutting parameters on different performance characteristics are explained in following sections:-

B. Main Effect Plot

The main effect plot is the graph of the average or means of response at each level of the factor or input parameters. The main effect plot help to determine the influence of individual input parameters on the responses measured, by disregarding the effect of any other input parameter present. The main effect plot of each response are explained below:-

C. Material Removal Rate(MRR)

Although the material removal rate in WEDM process is very low as compare to that of conventional machining but it's still a preferable option for machining of difficult-to-cut materials such as nickel-based super alloy and Titanium alloy. The productivity of WEDM can be determined through MRR, so it is necessary to know the influence of the machining parameters on the MRR during WEDM of Titanium Grade-2.

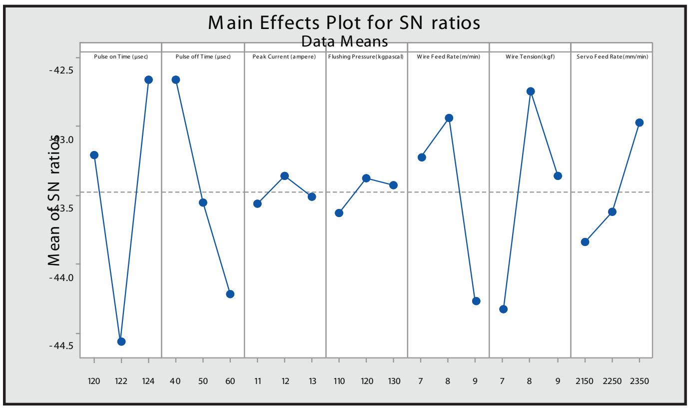

Fig. 2: Main Effect Plots for S/N ratios MRR

During the process of Wire Electric Discharge Machining, the influence of various machining parameters like Pulse on Time, Pulse off Time, Peak Current(I_p), Flushing Pressure(W_p), Wire Feed Rate(W_f), Wire Tension(W_t), Servo Feed Rate(S_f) has significant effect on MRR, as shown in main effect plot on S/N ratio of MRR in fig. 2.

D. Analysis of Variance (ANOVA)

ANOVA is a hypothesis- testing technique used to test the equality of two or more treatment means by examining the variances of samples that are taken. ANOVA is based on comparing the variance (or variation) between the data samples to variation within each particular sample. Percentage of contribution of each factor can also be deducted from the ANOVA table.

Table 2: ANOVA for S/N Ratios (MRR)

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Pulse on Time (µsec)	2	0.000010	0.000005	2.93	0.092
Pulse off Time (µsec)	2	0.000007	0.000004	2.17	0.157
Peak Current (ampere)	2	0.000000	0.000000	0.01	0.993
Flushing Pressure(kgpascal)	2	0.000000	0.000000	0.07	0.935
Wire Feed Rate(m/min)	2	0.000005	0.000002	1.40	0.283
Wire Tension(kgf)	2	0.000006	0.000003	1.72	0.221
Servo Feed Rate(mm^3/min)	2	0.000002	0.000001	0.66	0.532
Error	12	0.000020	0.000002		
Total	26	0.000050			

E. Response Table for Outputs

Response table also indicate which process parameters has greater influence on the responses measured by giving the process parameter a rank. Also one can infer the optimal condition from the response table. The highest value corresponding to the particular level in the response table is the optimal one for the MRR.

Table 3: Response Table for S/N Ratios Larger is Better (MRR)

Level	Pulse onTime (µsec)	Pulse off Time (µsec)	Peak Current (ampere)	Flushing Pressure (kg-pascal)	Wire Feed Rate (m/min)	Wire Tension (kgf)	Servo Feed Rate (mm^3/min)
1	-43.20	-42.66	-43.56	-43.63	-43.22	-44.33	-43.83
2	-44.57	-43.55	-43.36	-43.38	-42.93	-42.74	-43.62
3	-42.66	-44.22	-43.51	-43.42	-44.27	-43.36	-42.97
Delta	1.91	1.56	0.20	0.25	1.33	1.58	0.86
Rank	1	3	7	6	4	2	5

From the response table of MRR (Table 3) it can be also inferred that the pulse on time

VI. Conclusion

1. None of the process parameters was found to have a significant effect on MRR of the Specimen material.
2. The following combination gives the setting of optimal level of the process parameters, which was not found in the L27 orthogonal array in Table 4.

Table 4: Optimal Combination

Run no.	Pulse on Time (µsec)	Pulse off Time (µsec)	Peak Current (ampere)	Flushing Pressure (kg-pascal)	Wire Feed (m/min)	Wire Tension (kgf)	Servo Feed Rate (mm^3/min)
1.	124	40	12	120	8	8	2350

3. Therefore more number of trial runs are recommended apart from the above 27 combinations.

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