

PERFORMANCE EVALUATION OF WIRE ELECTRO DISCHARGE MACHINING ON D3-TOOL STEEL

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ABSTRACT

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The machining of D3-tool steel using wire electro-discharge machining (WEDM) with wire has been used as the tool electrode. The main purpose of this study was to investigate the influenced of various parameters involved namely pulse on, pulse off, peak current and servo voltage on the machining characteristics, namely surface roughness, sparking gap and cutting speed. The Full Factorial Design of Experiment approach with two-level was used to formulate the experimental layout, to analyze the effect of each parameter on the machining characteristics and to predict the optimal setting for each WEDM parameters. Confirmation tests were also conducted for the optimum conditions for each machining characteristics in order to verify and compare the results from the theoretical prediction using Design Expert software and experimental confirmation tests. In general, results revealed that pulse on and peak current have appeared to be the significant effect to all responses investigated. Experimental observations are based on Taguchi's L-8 orthogonal array has been done. Signal to-Noise (S/N) ratio, Analysis of Variance (ANOVA) and various plots are used to find the optimum process parameter with a least surface roughness. The confirmation experiments has been done for validate the results calculated by using taguchi method.

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1. INTRODUCTION

WEDM With the increasing demands of high surface finish, machining of complex shape and accompanying the development of aerospace materials, 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. When the gap voltage is sufficiently large (i.e. reaches the breakdown voltage of dielectric fluid), high power spark is produced, which increase the temperature about 10,000 degrees Celsius. By this way, alloy steel, conductive ceramics and aerospace materials can be machined

irrespective to their hardness and toughness. Furthermore, WEDM is capable of producing a fine, precise, corrosion and wear resistant surface. WEDM is an electro-thermal, non-conventional machining process where electrical energy is used to generate electrical spark and material removal mainly occurs due to thermal energy of the spark. WEDM is mainly used to machine difficult-to-machine materials and high strength temperature resistant alloys. WEDM is considered as a unique adoption of the conventional EDM process, which uses an electrode to initialize the sparking process. However, WEDM utilizes a continuously travelling wire electrode made of thin copper, brass or tungsten of diameter 0.05-0.30 mm, which is capable of achieving very small corner radii. The wire is kept in tension using a mechanical tensioning device reducing the tendency of producing inaccurate part. During the WEDM process, the material is eroded ahead of the wire and there is no direct contact between the work piece and the wire, eliminating the mechanical stresses during machining.

Material Selection - D-3 Steel tool Material, Cold-work tool steels which include D2, D3, D4, D5, and D7 steels are high-carbon, high-chromium steels.

Apart from D3 steel all group D steels have 1% Mo and are air hardened. Type D3 steel is oil-quenched; though small sections can be gas quenched after austenitization using vacuum. As a result, tools made with type D3 steel tend to be brittle during hardening. Type D2 steel is the most commonly used steel among the group D steels. The D3 steels contain 1.5 to 2.35% of carbon and 12% of chromium.

Composition of D3 steel tool material

Chemical composition of D3 tool steels: Carbon- 2.00-2.35%, manganese - 0.60%, Silicon-0.60%, chromium- 11.0-13.5%, Nickel-0.305%, tungsten- 1%, Sulphur-0.03, phosphorus-0.03%, Copper-0.25%, vanadium-1%.

Wire EDM Process

The experiments were conducted using Ecocut CNC WEDM manufactured by Electronica Corporation. The input parameters were chosen based on the type and size of the material. Brass wire of 0.25 mm was used as the electrode and de-ionized water was used as the dielectric medium. The photograph of ECOCUT - CNC Wire cut EDM used in this work is shown in Figure 1. Surface roughness of the machined component was measured using surface roughness tester (Surfcorder SE 3500) and was shown in Figure 2.



Figure 1 Photograph of ECOCUT – CNC wire EDM



Figure 2 Surface Roughness Testers

DESIGN AND ANALYSIS OF EXPERIMENTS

Taguchi Design of Experiments

To evaluate the effects of machining parameters on performance characteristics (CS, Ra and MRR) and to identify the performance characteristics under the optimal machining parameters, a special design experimental procedure is required. In this study the Taguchi method, a powerful tool for optimizing the process parameters is applied. Taguchi methods focus on design- the development of superior performance designs. Taguchi method systematically reveals the complex cause effect relationship between parameters and performance.

Taguchi Procedure for Experimental design and Analysis

1. Selection of Orthogonal Array
2. Assignment of parameters and interactions to orthogonal Array
3. Data Analysis
4. Determination of Confidence Intervals
5. Confirmation Experiment.

SELECTION OF METHOD

In this present work Taguchi's Doe approach along with Utility concept is used to find out the optimal setting of the process parameters. Taguchi's L_9 , a mixed type of Orthogonal array (OA) is used to conduct the experiments. In L_9 OA, one parameter having three levels and other parameters are set on three levels each. Studies have been undertaken to investigate the effects of important parameters viz., Pulse on time and Pulse off time on cutting speed, material removal rate and surface roughness. In the present investigation an L_9 orthogonal array was chosen and shown in Table 1.

Table 1 Levels for D3 steel tool material:

Sl.No	Factor	Level-	Level-	Level-
1	Pulse on	5	8	12
2	Pulse off	14	50	120
3	Wire	60	80	140
4	Wire	30	100	180

Table 2 Experimental Design Using L₉**Orthogonal Array**

S.NO	P _{ON} (μ s)	P _{OFF} (μ s)	W _T (Grams)	W _F (M/min)	Trial No	P ON	P OFF	Wire tension	Wire Feed	SUR FACE ROUGH NESS	SNRA1	MEAN1
1	5	14	60	30	1	1	1	1	1	2.606	8.319	2.606
2	5	50	80	100	2	1	2	2	2	2.303	7.245	2.303
3	5	120	140	180	3	1	3	3	3	2.406	7.625	2.406
4	8	14	80	180	4	2	1	2	3	2.178	6.761	2.178
5	8	50	140	30	5	2	2	3	1	2.561	8.168	2.561
6	8	120	60	100	6	2	3	1	2	2.32	7.309	2.32
7	12	14	140	100	7	3	1	3	2	2.254	7.059	2.254
8	12	50	60	180	8	3	2	1	3	2.363	7.469	2.363
9	12	120	80	30	9	3	3	2	1	2.123	6.539	2.123

Table 3 Experimental Results

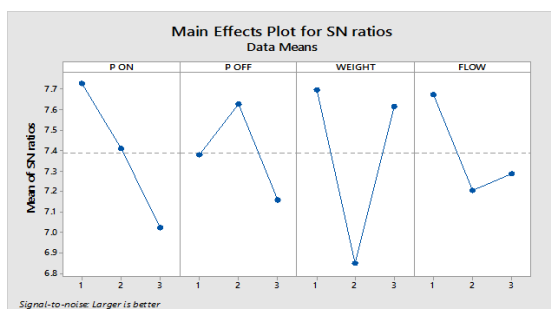
RESULTS AND DISCUSSION

The WEDM experiments were conducted to study the effect of input process parameters over the output responses such as MRR, R_a . The GRG of the response characteristics for each variable at different levels were calculated from experimental data. The main effects of process variables of GRG were plotted. The response graphs are used for examining the parametric effects on the response characteristics. The analysis of variance (ANOVA) of GRG is carried out to identify the significant variables and to quantify their effects on the response characteristics. The most optimal settings of process variables in terms of mean response characteristics are established by analyzing the response graphs and the ANOVA tables. The experimental results along with their Grey Relational Coefficients and GRG were given in Table 3.

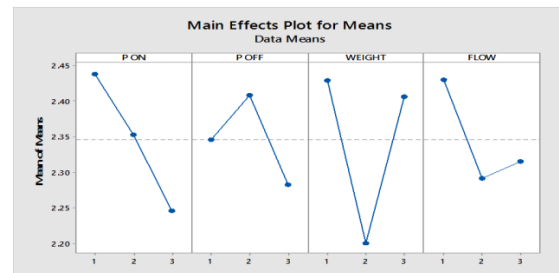
In this study all the designs, plots and analysis have been carried out using Minitab statistical software. Figure 4 shows that the GRG increases with decrease in gap voltage, pulse on time, pulse off time & wire feed. The response Table 4 shows the average of each response characteristic for each level of each factor. The table includes ranks based on delta statistics, which compare the relative magnitude of effects. The delta statistic is the highest minus the lowest average for each factor. Ranks are assigned based on delta values; rank 1 to the highest delta value, rank 2 to the second highest, and so on. The ranks indicate the relative importance of each factor to the response. The ranks and the delta values show that gap voltage has the greatest effect on GRG and is followed by wire feed, pulse off time and pulse on time in that order. It can be seen from Figure 4 that the 1 level of gap voltage, 2level of pulse on time, 2 level of pulse off time and 1 level of wire feed provide maximum GRG. Response Table 4 for Signal to Noise Ratios Larger is better.

Response Table 4 for Signal to Noise**Ratios**

SL NO	Ton (μ s)	Toff (μ s)	Wire feed (mm/min)	Wire tension (N/mm ²)
1	7.73 0	7.380	7.700	7.676
2	7.41 3	7.628	6.849	7.205
3	7.02 2	7.158	7.618	7.285
Delta	0.70 8	0.470	0.851	0.471
Rank	2	4	1	3

**Figure 3 Effects of SN ratio**
Table 5 Response Table for Mean

S.NO	Ton (μ s)	Toff (μ s)	Wire feed (mm/min)	Wire tension (N/mm ²)
1	2.438	2.346	2.430	2.430
2	2.353	2.409	2.201	2.292
3	2.247	2.283	2.407	2.316
Delta	0.192	0.126	0.228	0.138
Rank	2	4	1	3

**4 Response Graphs for Means**

In order to study the significance of the process variables towards GRG, ANOVA was performed. From ANOVA table 5 we see that gap voltage and wire dia were most influential for obtaining maximum GRG. Whereas remaining parameter has less significance

CONCLUSION

The following conclusion can be drawn from the grey relational analysis of Wire EDM of D3 steel tool. In this paper, an attempt was made to determine the important machining parameters for performance of WEDM viz MRR and Ra. The main goal is increase the accuracy and maximum MRR with the minimum surface roughness. Experimental results are analyzed for identifying the optimum parameters are Pulse on Time 5 μ s, Pulse off Time 50 μ s and Wire feed 30m/min, Wire tension 60 grams are the optimum parameters for obtaining minimum surface roughness and maximum MRR. The optimum parameters are used for conducting the confirmation experiment and also for predicting the surface roughness, MRR using Taguchi Design of Experiments.

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