Journal of Chemical and Pharmaceutical Sciences ISSN: 0974-2115

PARAMETRIC OPTIMIZATION OF INCREASING CORNER ACCURACY IN WEDM ON INCONEL625

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ABSTRACT

This paper deals with finding optimal control parameters viz. input voltage ,current ,wire feed , wire tension ,wire diameter ,pulse on/off time to maximize metal removal rate (MRR) and minimize surface roughness(SR).The Inconel 625 alloys are often employed in Aerospace industry components due to their outstanding mechanical properties. This work mainly focuses on the parameter optimization in WEDM. When cutting sharp corners the wire dwells longer by the inside radius causing a slight overcut on the outside radius and leaving a slight undercut in the inside radius. The main focus of this work is to optimize the Process Parameters in WEDM such as Surface roughness and Material Removal Rate pertaining to this corner cutting machining process using Taguchi Method. The Inconel 625 was machined in wire cut EDM with different optimal combination of control using Taguchi method algorithm.The optimal parameters were found to get higher metal removal rate, good surface finish and improved corner accuracy.

Keywords: Wire EDM, Taguchi Design of Experiments,ANOVA. Grey relational Analysis.

INTRODUCTION

A wire EDM generates spark discharges between a small wire electrode (usually less than O.l0mm diameter) and a workpiece with deionized water as the dielectric medium and erodes the work piece to produce complex two and three dimensional shapes according to a numerically controlled(NC) path. The wire cut EDM uses a very thin wire 0.2 to O.3mm in diameter an electrode and machines a work piece with electrical discharge like a band saw by moving either the work piece or wire, erosion of the metal utilizing the phenomenon of spark discharge that is the very same as in conventional WEDM. The prominent feature of a moving wire is that a complicated cut out can be easily machined without using a forming electrode. Rajurkar and William reported that wire electrical discharge machine (WEDM) manufacturers and users are to achieve higher machining rate with desired accuracy and minimum surface damage. The complex and random nature of the erosion process inWEDM requires the application of deterministic as well as stochastic techniques. Surface roughness profiles were studied with a stochastic modeling and analysis methodology to better understand the process mechanism. With the application pf scanning electron microscopic (SEM) important features of WED machined surfaces are found out. Kanlayasiri and Boonmung investigated the effects of machining parameters on the surface roughness of DC53 die steel on WEDM.

In this study, the machining variables investigated were pulse peak current, pulse-on time, pulseoff time, and wire tension. Analysis of variance (ANOVA) technique was used to find out the variables affecting the surface roughness. Material is removed from the work piece by a series of rapidly recurring current discharges between two electrodes, separated by a dielectric liquid and subject to an electric voltage. The most important performance characteristics for a WEDM process include material removal rate (MRR)/cutting speed, surface finish and kerf width. Discharge current, pulse time, pulse frequency, wire speed, wire tension, servo voltage and flushing pressure of dielectric fluid are the parameters which influence the performance of the process. Material removal rate, surface roughness and cutting width (kerf) were considered as a performance measures considered in this study. Titanium and its alloys provide excellent corrosion resistance, a high strength-to-weight ratio and good high temperature properties. Ti6Al4V, a titanium alloy commonly known as Ti64, is commonly used for space and aircraft applications, as well as high performance automotive and marine applications that require materials with high corrosion resistance and strength. Obara et al proposed a combination of power control with path correction in order to increase accuracyin corners at roughing stage. In this approach, power control is implemented to reduce wire bending, while the path regeneration is to compensate the errors. They claim that this method requires the least time for machining corners. In another investigation, Obara et al.investigated several controlling methods for reducing machining time in the corners and finally suggested a combinationof an increase in off-time pulse duration, control of servo voltage, and path compensation techniques. By using a computer-integrated system, based on practical and numerical simulation results, the machining errors were estimated, and the path for enhanced accuracy inthe corners was regenerated.

Material Selection: INCONEL 625 steel of 100 x 300 x 5 mm was selected as work piece material and brass wire of 0.25 mm and 0.2 mm was chosen as cutting tool material. Materials have been selected based on their properties, cost and application. Its composition is as follows Nickel, 58% Chromium, 20-23%
Molybdenum, 8-10% Iron, 5% Niobium, 3.15-4.15% others, balance

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.

Figure.1.Photograph of ECOCUT – CNC wire EDM

Figure.2.Surface Roughness Testers

Surface roughness of the machined component was measured using surface roughness tester (Surfcorder SE 3500) and was shown in Figure 2

DESIGN AND ANALYSIS OF EXPERIMENTS

Plan of Experiments: The experiment is designed significantly contributes towards the accurate characterization and optimization of the process. The experiments were developed to achieve higher MRR and reduced $R_a$to improve the corner accuracy. The increase in MRR and reduction in Ra is required to increase productivity, dimensional stability and improvement in geometrical accuracy. The process parameters and their levels are shown in Table 1

Table.1.Process Parameters and their Levels

Parameter number	Parameters	Level 1	Level 2
A	Gap volt(v)	35	40
B	Ton(μs)	8	9
C	Toff(μs)	16	17
D	Wire feed(mm/min)	40	45
E	Wire tension(N/mm^2)	1400	1600
F	Peak Current (Amps)	7	8
G	wire dia(mm)	0.2	0.25

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_8, a mixed type of Orthogonal array (OA) is used to conduct the experiments. In L_8 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_8 orthogonal array was chosen and shown in Table 2.

Table.2.Experimental Design Using L_8 Orthogonal Array

Gap vol (vols)	Ton(μs)	Toff(μs)	Wire feed(mm/min)	Wire tension(N/mm²)	Peak current(amps)	Wire thickness(mm)
35	8	16	40	1400	7	0.2
35	8	16	45	1600	8	0.25
35	9	17	40	1400	8	0.25
35	9	17	45	1600	7	0.2
40	8	17	40	1600	7	0.25
40	8	17	45	1400	8	0.2
40	9	16	40	1600	8	0.2
40	9	16	45	1400	7	0.25

Grey Relational Analysis: Grey theory is one of the important theories and can be used for analyzing the uncertainty, multi-input and discrete data. A grey system has a level of information between black and white. The grey relational analysis is a measurement of the absolute value of the data difference between sequences, and is also used to measure an approximate correlation between sequences. It is an effective means of analyzing the relationship between the sequences with less data and can analyze many factors. Grey relational analysis uses a specific concept of information. It defines situations with no information as black, and those with perfect information as white. However, neither of these idealized situations ever occurs in world problems. In fact, situations between these extremes are described as being grey. Grey analysis does not attempt to find the best solution, but does provide techniques for determining a good solution, an appropriate solution for real world problems. Steps in Grey relational analysis are

Step 1.Normalizing the experimental results of each performance characteristic.
Step 2.Calculating the grey relational coefficient.
Step 3.Calculating the grey relational grade by the mean value of grey relational coefficient.
Step 4.Performing the response table and response graph for each level of the parameters.
Step 5.Selecting the optimal levels of machining parameter.
Step 6. Confirmation test and verifies the optimal levels of machining parameter.

Analysis approach: The experiments were conducted according to Taguchi's L_8 orthogonal array using 8 different experiments. For GRA, these 8 experiments became 8 subsystems. The influence of these subsystems on the response variables were analyzed by using GRA. The WEDM experiments (system) were assessed by conducting 8 experiments (subsystems) and each experiment was termed as comparability sequence. The parametric conditions corresponding to the highest weighted GRG gave maximum values of MRR and minimum values of surface roughness. In this manner, the multi-objective problem was converted into single objective optimization using GRA technique.

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.

Table.3.Experimental Results

S.No	MRR	Ra	GRC MRR	GRC Ra	GR Grade
1	5.35	3.695	0.43	1	0.715
2	6.36	3.834	0.677	0.778	0.728
3	6.81	4.026	0.909	0.636	0.481
4	4.55	3.715	0.333	0.538	0.436
5	6.93	3.98	1	0.467	0.734
6	4.89	3.518	0.368	0.412	0.39
7	5.65	3.784	0.482	0.368	0.425
8	6.25	3.794	0.636	0.333	0.485

Journal of Chemical and Pharmaceutical Sciences ISSN: 0974-2115

In this study all the designs, plots and analysis have been carried out using Minitab statistical software. Figure 3 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 3 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.

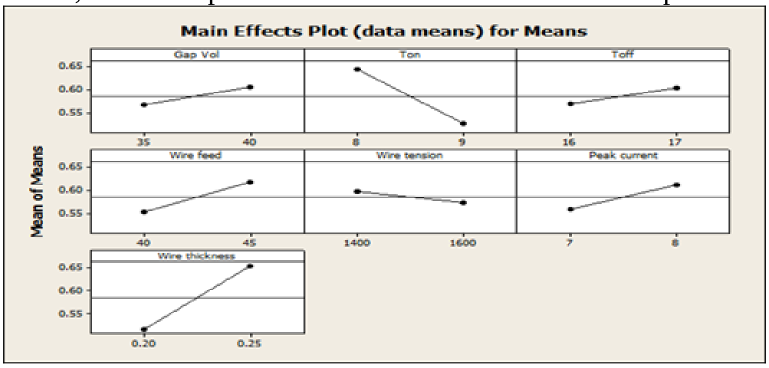

Figure.3.Response Graphs of GRG

Table.4.Response Table of GRG

S.NO	Gap vol (vols)	Ton(µs)	Toff(µs)	Wire feed(mm/min)	Wire tension(N/mm^2)	Peak current(amps)	Wire thickness(mm)
1	0.6630	0.6418	0.5883	0.6618	0.5908	0.5925	0.4915
2	0.5085	0.5298	0.5833	0.5098	0.5808	0.5790	0.6800
Delta	0.1545	0.1120	0.0050	0.1520	0.0100	0.0135	0.1885
Rank	2	4	7	3	6	5	1

In order to study the significance of the process variables towards GRG, ANOVA was performed. From ANOVA table 6 we see that gap voltage and wire dia were most influential for obtaining maximum GRG. Whereas remaining parameter has less significance.

Table.6.ANOVA of GRG

Source	DOF	Sequence of sum of square	Mean sum of square	Contribution %
Gap voltage	1	0.047741	0.0238705	25.03237782
Pulse on time	1	0.025088	0.012544	13.15456934
Pulse off time	1	0.00005	0.000025	0.026216855
Wire feed	1	0.046208	0.023104	24.22856903
Wire tension	1	0.0002	0.0001	0.104867421
Peak current	1	0.000365	0.0001825	0.191383044
Wire thickness	1	0.071065	0.0355325	37.2620165
Total	7	0.190717		100

Confirmation experiment: Experimental results are analyzed for identifying the optimum parameters. From Figure 3 and the response factors are Gap Voltage 35V, Pulse on Time 8µs, Pulse off Time17µs and Wire feed 40mm/min,Wire tension 1400 N/mm^2 ,Peak current 7amps and Wire thickness 0.25 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. The predicted GRG is 0.82075 and experimental value of GRG is 0.8324. The error is less than 5% so the optimization technique holds good for this study.

CONCLUSION

The following conclusion can be drawn from the grey relational analysis of Wire EDM of Inconel 625.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 to increase the corner accuracy and maximum MRR with the minimum surface roughness in setting machining parameters. Wiredia, Gap voltage and Wire tension have been found to play an important role in thjs experimental work. This outcome of result wilhelp in improve the quality and dimensional accuracy of Inconel 625 products as well as minimizing the machining cost.

Journal of Chemical and Pharmaceutical Sciences ISSN: 0974-2115

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