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Study of the Performance of Wire EDM on Titanium alloy using Taguchi Method

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Abstract: In this work, an experiment using wire electro-discharge machining to analyse titanium alloy is described (WEDM). The goal is to examine how various process factors affect a number of process performance indicators, including pulse width, servo reference voltage, pulse current, and wire tension (such as cutting speed, wire rupture and surface integrity).The Taguchi approach was used. Charmilles WEDM has been used in every trial. It was also shown that both peak current and pulse interval can speed up cutting. It has been demonstrated that surface roughness rises with pulse width and falls with pulse interval.

Keywords: Wedm, Pulse on Time, Pulse off Time, Pulse Current, Taguchi Method.

1. INTRODUCTION

One of the most popular non-conventional material removal techniques is wire electrical discharge machining. Researchers have successfully milled super alloys, composite materials, high-speed steel (HSS), conductive ceramics, etc. using the WEDM technique. It has a competitive advantage in the production of mould, die, and automotive, aircraft, and surgical components because to its unique ability to use heat energy to treat electrically conductive materials regardless of hardness. Using electrically conducting materials as the work piece electrode and the tool electrode, both of which are enclosed in a dielectric fluid and separated by a tiny gap, WEDM is a technique for eroding and removing material.Erosion is mostly produced by local thermal activity brought on by an electric discharge. The material is removed from the work piece by ionisation that occurs inside the discharge column between the electrode and the work piece. This ionisation results in a localised high temperature and extremely high energy density. The EDM process eliminates material as a result of thermal erosion caused by melting and vaporisation. Figure 1 depicts the wire EDM technique approximately. Wire-EDM is currently widely employed in the aerospace and automotive

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sectors after developing into a well-known non-traditional machining technique in recent years. a tiny space and separated by a dielectric fluid.Even with the most sophisticated CNC wire-EDM machines, selecting the cutting settings to enable better cutting efficiency or precision has not yet been fully addressed. The intricate wire-EDM stochastic process mechanisms are mostly to blame for this. The correlations between the cutting parameters and cutting performance are therefore difficult to pinpoint with accuracy. The Material Removal Rate (MRR), which is calculated as the rate at which material is removed from surfaces, is one of the most significant performance indicators (results) of the WEDM process. Wire feed, wire tension, spark gap voltage, servo feed, corner servo voltage, flushing pressure, pulse-on-time, and pulse-off time are some of these factors. The only approach to enhance the performance of the WEDM process is to set the optimal values for certain process parameters.

Experiment Details

Optimization Techniques

Taguchi suggested a sturdy design that was based on an experimental design. The best tool for performance characteristic parameter design is provided by this technique. The design of the experiment entails choosing the proper orthogonal array and assigning the components and interactions to the proper column. By adopting an orthogonal array, the Taguchi technique lowers the number of tests, which eases the burden of extensive testing. By reducing variability around the target value, Taguchi's resilient design technique aims to attain a goal value. Taguchi employs the SN ratio as a performance indicator when a characteristic deviates from its intended value and simulates quality degradation using a quadratic function. The key difference between SN ratio and other techniques is that it analyses mean and variance as separate performance metrics, whereas other approaches consider a response variable's location and dispersion as a single performance parameter.The response variables were often divided into three categories by Taguchi (Phadke, 1989): smaller-the-better (STB), larger-the-better (LTB), and nominal-the-best (NTB). The following are the formulas for determining the SN ratio (ij) for the jth response corresponding to the ith trial (i = 1, 2... m; j = 1, 2... p), which vary depending on the kind of response variable used:The HTB response variable is

$$S/N\ Ratio = 10 \log_{10} (1/n) \sum_{i=1}^{n} \frac{1}{y_{ij}^{2}} \qquad (1)$$

For STB response variable

$$S/N\ Ratio = 10 \log_{10} (1/n) \sum_{i=1}^{n} y_{ij}^{2} \qquad (2)$$

In order to determine the percentage contribution of each parameter to the output parameter against a given degree of confidence, the Analysis of Variance (ANOVA) is used to the results of experiments. This study investigated the effects of eight input factors, such as the timing of the pulse on and off, the corner servo voltage, the flushing pressure of the dielectricfluid, the wire feed, the wire tension, the spark gap voltage, and the servo feed, using an L20 orthogonal array.

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Work Material
Titanium alloy (Grade 12)
Chemical composition :- Ti – Balance , C – 0.08 , N – 0.03 , Ni – 0.06 to 0.09 , Fe – 0.30 , O – 0.25 , O – 0.25 , H – 0.015 , Mo – 0.2 to 0.4
Mechanical properties: - Hardness61HRB, Yield Strength 345 Mpa , Density 4.51g/cm^3

Experimental Procedure
On a CNC WEDM machine called the Ultra Cut 843/ULTRA CUT f2, the studies were conducted. All of the axes on this machine may be configured to operate in accordance with CNC code that is input through the control panel and are servo driven. Each of the three axes has 1 m accuracy. The electrode was made of brass wire that had a 0.25 mm diameter. The distance between the wire and work piece is extremely small—between 0.025 mm and 0.05 mm. The high energy density erodes material from the wire and the work piece by producing localised melting and vaporisation. To eliminate the debris created during the erosion, the dielectric fluid (deionized water) is constantly flashed through the gap along the wire and into the sparking region.The used wire erosions are collected in a tank at the bottom and then thrown away. Because of the variance in dimensional precision, the wires cannot be used again. Machining may be programmed using an NC code. In the current body of study, wire-cut electrical discharge machining of titanium alloy has been taken into account. A work piece with dimensions of 10 mm in width, 10 mm in length, and 15 mm in cut depth is used in the wire-cut EDM experiment. The experiment makes use of an L36 (21 X 37) mixed orthogonal array constructed utilising the Taguchi approach and resilient design.The three objectives while establishing machining parameters are to maximise MRR, minimise SR, and minimise gap width, especially in rough cutting operations. Typically, the manufacturer of the machine tool supplies a table of machining parameters that may be used to establish machining parameters. The operators' expertise is crucial to this operation. Due to the abundance of configurable machining factors, it is quite challenging to use a machine's best features in practise. A straightforward yet dependable technique based on statistically planned trials is used to analyse the effects of various process parameters on MRR, SR, and Gap width and to identify the best process settings.Data were gathered for the current study from a few experimental runs using factor combinations that were chosen at random. To pinpoint the process and create a rough relationship between the various process parameters and the response variables, a quadratic model has been fitted. These mathematical models were used to provide data in accordance with Taguchi design. The best process environment has been determined using the grey-based Taguchi approach. For optimality analysis during the machining of titanium alloy, three levels for the remaining seven control variables and two levels for one of the eight WEDM parameters (Pulse on time) are taken into consideration.
Experimental variables and their magnitudes for the process of WEDM

Parameter	Symbol	Level 1	Level 2
Corner servo	CS (volts)	60	70
Pulse On Time	T ON (μs)	110	116
Pulse Off Time	T OFF (μs)	55	60
Wire feed rate €	WF (m/min)	3	6
Wire tension	WT (Kg-f)	8	9

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Flushing pressure	WP (Kg/cm^2)	7	9
Servo Feed	SF (mm/min)	1000	1200
Spark Gap Voltage	SV (volts)	18	23

2. EXPERIMENTAL RESULTS

Exp. No.	T ON	T OFF	CS	WP	WF	WT	SV	SF	MRR
1	1	2	2	2	1	1	1	1	119.2
2	1	2	2	2	2	3	3	3	133.1
3	1	3	3	3	3	2	2	3	174.1
4	1	2	2	3	1	2	2	2	118.2
5	1	2	2	2	2	3	3	3	129.5
6	1	1	2	3	3	1	1	1	182.5
7	1	1	1	2	3	1	2	3	109.3
8	1	1	3	3	1	2	3	1	139.3
9	1	3	3	3	3	1	1	2	189.5
10	2	2	1	3	2	1	3	2	110.3
11	1	2	2	1	3	3	2	3	150.8
12	1	2	3	2	1	3	2	1	200.2
13	1	1	2	3	1	3	2	1	112.6
14	1	2	3	1	3	1	2	2	119.1
15	1	3	1	2	3	2	1	3	139.1
16	1	1	2	3	2	1	1	3	125.7
17	1	2	3	1	2	3	2	1	129.8
18	1	3	1	2	1	3	3	2	188.5
19	2	1	2	3	2	3	3	1	368.1

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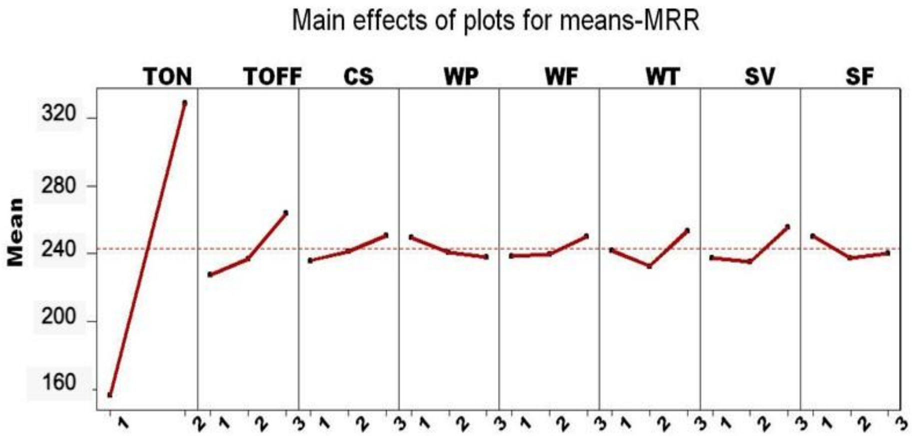
20	2	2	3	2	1	1	1	2	321.5

Using the statistical programme MINITAB 16, the experimental data generated by the Taguchi experimental design were statistically analysed. To ascertain how the input parameters impacted the output response variables, analysis of variance (ANOVA) was utilised.

Response values are calculated as the mean effect plot of material removal rate as corner servo voltage, dielectric fluid flushing pressure, wire feed, wire tension, spark gap voltage, and servo feed on MRR under the selected machining settings. Calculated response values are summarised in a table and displayed in a figure. Figure 2 for the raw data shows the typical material removal rates for each parameter at levels 1, 2, and 3. It shows that as the pulse on time grows, so does the rate of material removal.The corner servo voltage and time pulse hardly affect how quickly material is removed. There is a transient rise in pulse off time and corner servo voltage, which occurs after a little increase in MRR.



Parameter	Level1	Level 2
T ON	136.213	309.921
T OFF	226.566	215.632
CS	219.011	212.189
WP	223.401	223.552
WF	217.360	219.602
WT	215.762	212.654
SV	205.168	230.112
SF	222.272	211.557

Combination of optimal process parameters using Taguchi method

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S. No.	Response characteristics	Optimal Parameter Combination								Response characteristics values	
		TON	TOFF	CS	WP	WF	WT	SV	SF	OA	Experimental value
1	MRR (mm^3/min)	2	3	3	2	3	3	3	1	326.5	355.5

Experiment results

Response parameters	process parameters (Optimal)	
	Assumed value	Experimental value
MRR (mm^3/ min)	123.375	139.5

3. CONCLUSION

This work used the Taguchi technique, traditional utility analysis, and principal component analysis for weighting to offer the multi-objective optimization process parameters for WEDM of Titanium alloy. The statistical analysis (ANOVA) showed that the main machining parameter considered in this study enhances the WEDM method machining's performance. ANOVA was used to statistically validate the mathematical model that was provided for forecasting the ideal conditions of material removal rate, Spark Gap, and surface roughness.The findings of the ANOVA test demonstrate that the two machining parameters pulse on time (T ON) and wire tension have a significant impact on the rate of material removal during the WEDM process (WT). The wire feed, Spark Gap, and pulse on time all have a significant impact on surface roughness. Corner servo voltage (CS), wire feed rate (WF), and wire tension are the three machining variables that have the greatest impacts on spark gap (WT).

Future Scope

Even though WEDM machining for Titanium alloy Grade 12 has been fully studied, there is still need for more research. The following recommendations can be beneficial for upcoming work.

- It is important to look at how different machining parameters affect the overcut and recast layer thickness.
- In the WEDM process, electrodes made of brass or graphite may be utilised in place of copper electrodes.
- Only four machining parameters are selected for this investigation. A detailed study can be done, considering other parameters also.

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