Investigation on Optimization of Machining Parameters in Wire EDM using Taguchi Technique

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Abstract—In this paper, the parameters used in the cutting of Cemented Tungsten Carbide using wire electrical discharge machining (WEDM) with a Brass electrode was optimized using Taguchi method. Taguchi method is used to formulate the experimental layout and to analyze the effect of each parameter on the machining characteristics. Also it is used to predict the optimal choice for each parameter such as peak current, voltage, and pulse duration and interval time. It was found that these parameters have significant influence on machining characteristics such as Metal Removal Rate (MRR) and Surface Roughness (SR). The result of the work reveals that, the peak current significantly affects the Surface Roughness (SR) and the pulse duration mainly affects the Metal Removal Rate (MRR).

Key words: Taguchi method, Cemented Tungsten Carbide, Metal Removal Rate, Surface Roughness, Wire EDM.

I. INTRODUCTION

In recent years, the technology of wire electrical discharge machining (WEDM) has been improved significantly to meet the requirements in various manufacturing fields, especially in the precision die industry. WEDM is a thermo electrical process in which material is eroded from the work piece by a series of discrete sparks between the work piece and the wire electrode (tool) separated by a thin film of dielectric fluid (deionized water) that is continuously fed to the machining zone to flush away the eroded particles. The movement of wire is controlled numerically to achieve the desired three-dimensional shape and accuracy of the work piece. The schematic diagram of WEDM is shown in Fig. 1 along with dielectric flow, power supply, working table and other control devices.

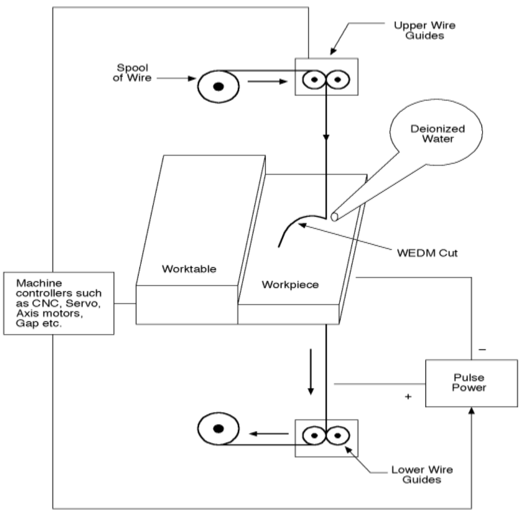

Fig. 1: Schematic Diagram of WEDM

Cemented Tungsten Carbide is a high quality material with high tensile strength, shock resistance, good ductility and resistance to wear. Tungsten Carbide is renowned for its wear resistance properties and also very high strength properties are required. It is very difficult to machine Tungsten Carbide by conventional machining processes and moreover, by conventionally used tool materials. Of late, modern machining techniques such as Wire Electrical Discharge Machining (WEDM) are increasingly being used for machining such hard materials. Hence, this study focused on machining of Tungsten Carbide using WEDM, in order to satisfy production and quality requirement.

The selection of optimum machining parameters in WEDM is an important step. Improperly selected parameters may result in serious problems like short-circuiting of wire, wire breakage and work surface damage which is imposing certain limits on the production schedule and also reducing productivity. As Material Removal Rate (MRR) and Surface Roughness (Ra) are most important responses in WEDM; various investigations have been carried out by several researchers for improving the MRR and Surface Finish. However, the problem of selection of machining parameters is not fully depending on machine controls rather material dependent.

For the optimal selection of process parameters, the Taguchi method has been extensively adopted in manufacturing to improve processes with single performance characteristic to achieve higher Material Removal Rate (MRR) and lower surface roughness (Ra).

II. MATERIALS AND METHODS

A. *Taguchi Method*

The Taguchi method is a traditional approach for robust experimental design that seeks to obtain a best combination set of factors/levels with the lowest societal cost solution to achieve customer requirements. In the Taguchi design method the design parameters (factors which can be controlled) and noise factors (factors which cannot be controlled, e.g. environmental), which influence product quality, are considered. Therefore, in the Taguchi design method, the objective is to select the levels of design parameters such that the performance of product or process is insensitive to noise factors. That is, parameter settings should be determined with the intention that the product response (quality characteristic) has minimum variation while its mean is close to the desired target. Nevertheless, until now the Taguchi method can only be used for a single response problem; it cannot be used to optimize a multiresponse problem. But, in practice more than one quality characteristic may have to be considered for optimizing the quality of product or process.

B. Work Material

Tungsten carbide (WC) is an inorganic chemical compound containing equal parts of tungsten and carbon atoms. Colloquially, tungsten carbide is often simply called carbide. In its most basic form, it is a fine gray powder, but it can be pressed and formed into shapes for use in industrial machinery, tools, abrasives, as well as jewelry. Tungsten carbide is approximately three times stiffer than steel, with a Young's modulus of approximately 550 GPa, and is much denser than steel or titanium. It is comparable with corundum (α-Al2O3 or sapphire) in hardness and can only be polished and finished with abrasives of superior hardness such as silicon carbide, cubic boron nitride and diamond. The density of the material is 15.8g/cm^3.

C. Machine Description

The experiments were carried out on a Four-axes ELECTRONICA MAXICUT WEDM machine. The electrode material used was a 0.25 mm diameter brass wire. A small gap of 0.025 mm to 0.05 mm is maintained in between the wire and work-piece. The high energy density erodes material from both the wire and work piece by local melting and vaporizing. The di-electric fluid (de-ionized water) is continuously flashed through the gap along the wire, to the sparking area to remove the debris produced during the erosion. A collection tank is located at the bottom to collect the used wire erosions and then is discarded. The wires once used cannot be reused again, due to the variation in dimensional accuracy.

D. Process Parameters and Design

Input process parameters such as Pulse-on time (A), Pulse-off-time (B), and Wire Feed (C) used in this study are shown in Table 1. Each factor is investigated at two levels to determine the optimum settings for the WEDM process. These parameters and their levels were chosen based on the review of literature, experience, significance and their relevance as per the few preliminary pilot investigations. The smallest standard 3-level OA L_9 (3^3) is chosen for this case.

Factor notation	Control Factors	Level 1	Level 2	Level 3
A	Pulse on time (μs)	2	2	3
B	Pulse off time (μs)	4	4	4
C	Wire feed (m/min)	6	6	5

Table. 1: Factors and Levels

III. RESULTS AND DISCUSSIONS

Experiments were conducted as per the L_9 (3^3) orthogonal array. After individual experiments for a set of values were conducted on Tungsten Carbide for a size of 45×40×6 mm^3, their surface roughness values were measured in surface roughness tester to determine the surface finish.

In this study most important output performances in WEDM such as Material Removal Rate (MRR) and Surface Roughness (Ra) were considered for optimizing machining parameters. The surface finish value (in μm) was obtained by measuring the mean absolute deviation, Ra (surface roughness) from the average surface level using a Computer controlled surface roughness tester. The Material Removal Rate (MRR) is calculated as

$$MRR = v_f\, h\, \delta\, b$$

Where,

v_f → cutting speed of wire into the work piece in mm/min,

h → work piece thickness or height in mm,

δ → density of the material in g/mm^3,

b → Kerf given by : $b = d_w + 2s$

where,

d_w → wire diameter in mm,

s → gap between work piece & tool.

Exp No.	Pulse On time (μs)	Pulse Off time (μs)	Wire Feed (m/min)	MRR (g/min)	Surface Roughness, Ra (Mm)
1	2	2	3	0.03513	3.2354
2	2	4	4	0.03384	3.4628
3	2	6	5	0.03287	2.6842
4	4	2	4	0.03835	3.8170
5	4	4	5	0.03739	3.2202
6	4	6	3	0.03642	3.6702
7	6	2	5	0.04190	4.1022
8	6	4	3	0.04093	3.8518
9	6	6	4	0.03964	3.5348

Table. 2: L_9 (3^3) Orthogonal Array with Responses

A. S/N ratio calculation

The characteristics that lower value represent better machining performance such as surface roughness is called "lower is better (LB)" in quality engineering. The equation for calculating the S/N ratio is

$$S/N_{LB} = -10\log_{10}\left[\sum \frac{{y_i}^2}{n}\right]$$

The characteristic that higher values represent better machining performance such as material removal rate is called "higher is better (HB)" in quality engineering. The equation for calculating the S/N ratio is

$$S/N_{HB} = -10\log_{10}\left[\frac{1}{n}\sum \frac{1}{{y_i}^2}\right]$$

Exp. No.	Performance Measures		S/N Ratio	
	MRR (g/min)	Surface Roughness, Ra (μm)	MRR (db)	Surface Roughness, Ra (db)
1	0.03513	3.2354	- 29.086	- 10.198
2	0.03384	3.4628	- 29.411	- 10.788
3	0.03287	2.6842	- 29.664	- 8.576
4	0.03835	3.8170	- 28.325	- 11.634
5	0.03739	3.2202	- 28.545	- 10.158
6	0.03642	3.6702	- 28.773	- 11.294
7	0.04190	4.1022	- 27.556	- 12.260
8	0.04093	3.8518	- 27.759	- 11.713
9	0.03964	3.5348	- 28.037	- 10.967

Table. 3: Experimental Results with S/N Ratio

B. *Analysis of variance table*

ANOVA table is used to find the significant parameters which influence the performance measures.

Parameters	*Sum of Squares*	*Variance*	*Dof*	*F Test Values*	*Contribution %*
Pulse on time	4.9754	2.4877	2	2.9219	51.629
Pulse off time	1.7743	0.8872	2	1.0420	18.412
Wire feed	1.1842	0.5921	2	0.6954	12.288
Error	1.7029	0.8514	2		17.671
Total	9.6368		8		100

Table. 4: ANOVA table for surface roughness

Parameters	*Sum Of Squares*	*Variance*	*Dof*	*F Test Values*	*Contribution (%)*
Pulse on time	3.8572	1.9286	2	2571.46 7	90.927
Pulse off time	0.3782	0.1891	2	252.133	8.915
Wire feed	0.0052	0.0026	2	3.467	0.123
Error	0.0015	0.00075	2		0.035
Total	4.2421		8		

Table. 5: ANOVA table for Material Removal Rate

IV. CONCLUSION

This work is intended to study factors like pulse on time, pulse off time and wire feed for maximizations of MRR and minimization of surface roughness in WEDM process using Taguchi Method. The analysis of the results leads to conclude that pulse on time influences more on both MRR and surface roughness. In order to get better performance measures, factors at level A3 B1 C3 can be set for maximization of MRR. Similarly, the factors at levels A1 B3 C3 is recommended for minimization of Ra. For Tungsten Carbide, the experiments have been successfully carried out and practical results for the WEDM process have been obtained. The experimental results can be used in industry in order to select the best suitable parameter combination to get the required surface roughness values and MRR for the products. Based on the minimum number of trails conducted to arrive at the optimum cutting parameters, Taguchi method seems to be an efficient methodology to find the optimum cutting parameters.

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