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Analysis of WEDM Parameters Using Taguchi Method

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Abstract: ***A multi parameter analysis of Metal removal rate imparted to WC-Co by wire electro-discharge machining (WEDM) is presented. Wire Electrical discharge machining (WEDM) is a nontraditional, thermoelectric process which erodes material from the work piece by a series of discrete sparks between a work and tool electrode immersed in a liquid dielectric medium). This paper presents a detailed model of a WEDM. The structure includes in the model, are three parameters such as pulse on time, pulse off time, peak current. We analyzed the effect of this three parameters on material removal rate .The detailed mathematical model is simulated by Minitab14 and simulation results fit experiment data very well this shows that the model can be used to forecast the performance of WEDM when design. In this investigation, an effective approach based on Taguchi method, analysis of variance (ANOVA), multivariable linear regression (MVLR), has been developed to determine the optimum conditions leading to higher MRR. Experiments were conducted by varying pulse on time, pulse off time, peak current using L9 orthogonal array of Taguchi method. The present work aims at optimizing process parameters to achieve high MMR. Experimental results from the orthogonal array were used as the training data for the MVLR model to map the relationship between process parameters and MMR the experiment was conducted on WEDM. From the investigation It concludes that pulse on is most influencing parameter followed by pulse off time and peak current on MRR.***

Keywords: ANOVA, WEDM, MVLR analysis, MMR

1. Introduction

Wire electrical discharge machining (WEDM) technology has grown tremendously since it was first applied more than 30 years ago. At the present time, EDM is a widespread technique used in industry for high-precision machining of all types of conductive materials such as metals, metallic alloys, graphite, or even some ceramic materials [1]. WEDM has tremendous potential in its applicability in the present day metal cutting industry for achieving a considerable dimensional accuracy, surface finish and contour generation features of products or parts these electrical discharges melt and vaporize minute amounts of the work material, which are then ejected and flushed away by the dielectric. Electrical discharge machining (EDM) has been used effectively in machining hard, high-strength, and temperature resistant materials. Material is removed by means of rapid and repetitive spark discharges across the gap between the electrode and work piece [2]. The schematic representation of the WEDM cutting process is shown in Figure 1. Wire electrical discharge machining (WEDM) is a specialized thermal machining process capable of accurately machining parts with varying hardness or complex shapes, which have sharp edges that are very difficult to be machined by the main stream machining processes. At present, WEDM is a widespread technique used in industry for high-precision machining of all types of conductive materials such as metals, metallic alloys, graphite, or even some ceramic materials, of any hardness. Tungsten carbide and cobalt (WC–Co) composite is of special attention in producing cutting tools, dies and other special tools and components due to its very high hardness and excellent resistance to shock and wear. It is possible to machine this material with some conventional methods; however, high accuracy required in machining complex shapes cannot be achieved. Attempt has been made to machine this material with turning [3]. The major advantage of EDM is that the selection of machining parameters in a machining process significantly affects production rate and quality of machined components. The selection of these parameters in WEDM is primarily dependent on the operator's experience and machining parameter tables provided by the machine-tool manufacturers [4]. Pandey and Jilani [5] studied the effects of pulse parameters and the carbide composition on the MRR, electrode wear and crater shape and size. Lee & Li [6] investigated the machined work piece surface integrity, including the microstructures, surface topography, micro-cracks, composition and hardness at various machining conditions. They found no difference between the hardness of the EDMed surface and the original hardness of the work piece for all EDM conditions. C.Y. Ho and Z.C Lin [7] explained that for the optimal selection of process parameters, the Taguchi method has been extensively adopted in manufacturing to improve processes with single performance characteristic. However, traditional Taguchi method cannot solve multi-objective optimization problem. To overcome this, the Taguchi method coupled with Grey relational analysis has a wide area of application in manufacturing processes.

This study investigated the multi-response optimization of WEDM process for machining of WC-Co using combination of Regression analysis and Taguchi method to achieve higher Material Removal Rate (MRR), lower surface roughness (Ra). Finally, the analysis of variance (ANOVA) and necessary confirmation tests were conducted to validate the experimental results.

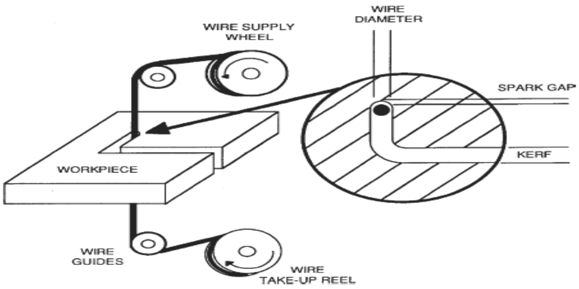

Figure 1: Schematic representation of Wire EDM cutting process

2. Experimental Details

2.1 Design of Experiments

Taguchi and Konishi had developed Taguchi techniques [15]. These techniques have been utilized widely in engineering analysis to optimize the performance characteristics within the combination of design parameters. Taguchi technique is also power tool for the design of high quality systems. It introduces an integrated approach that is simple and efficient to find the best range of designs for quality, performance, and computational cost [16]**.** In this study we have consider 3 factors which affect majorly on quality characteristic such as (A) pulse on time, (B) pulse off time, (C) peak current. The design of experiment was carried out by Taguchi methodology using Minitab 14 software. In this technique the main objective is to optimize MMR of WEDM that is influenced by various process parameters.

2.2 Selection of Control Factors

From the discussion with company peoples and on the basis of literature survey it is strongly felt that WEDM parameters viz. pulse on time, pulse off time, peak current etc bears a direct relationship with MMR. So that pulse on time, pulse off time, peak current selected as process parameters as they have most effect on response parameter.

2.3 Selection of Orthogonal Array

Since 3 controllable factors and three levels of each factor were considered L9 Orthogonal Array was selected for this study.

2.4 Experimental set up

A Series of experiment was conducted to evaluate the influence of parameters on MMR. The experiments were carried out on a wire-cut EDM machine (ELEKTRA SPRINTCUT 734) of Electronica Machine Tools The WEDM (Figure 2) has the following specifications:

Design	Fixed column, moving table
Table size	440 x 650 mm
Max. workpiece height	250 mm
Max. workpiece weight	168.66 g
Wire electrode diameter	0.25 mm (Standard)
Work Material	Wc-co sintered
Cutting Tool	Brass wire of dia. 0.25 mm
Conductivity of Dielectric	20mho
Work Piece Height	25 mm
Cutting fluid	Distilled water

Figure 2: Pictorial View of WEDM Machine Tool

2.5 Work Material

Work piece material for the present work is Tungsten Carbide Cobalt sintered composite.

Chemical composition:

Co (%)	10
WC (%)	90
Density (g/cm^3)	14.4
Hardness (HV30)	>1550
Transverse Rupture Strength	>3600 (N/mm^2)
Grain size	0.7 (microfine)
Size	Dia 10×325mm

2.6 Weight Measurement

MRR is the rate at which the material is removed from the workpiece. Electric sparks are produced between the tool and the workpiece during the machining process. Each spark produces a tiny crater and thus erosion of material is caused.

The MRR is defined as the ratio of the difference in weight of the workpiece before and after machining to the machining time.

3. Experimental Conditions

The experiments were carried out on WEDM for MMR there are three input controlling factors selected having three levels. Details of parameters and their levels used shown in the table 3 and other parameters kept constant.

Table 1: Process parameters and levels

A	Pulse on time (µs)	110	120	130
B	Pulse off time (µs)	30	35	40
C	Peak current (A)	190	210	230

Table 2: Layout for Experimental Design according to L9 Array

Sr. No	*Ton*	*Toff*	*IP*
1	110	30	190
2	110	35	210
3	110	40	230
4	120	30	210
5	120	35	230
6	120	40	190
7	130	30	230
8	130	35	190
9	130	40	210

4. Results and Discussion

4.1 S/N Ratio Analysis

In the Taguchi method, the term ‘signal’ represents the desirable value (mean) for the output characteristic and the term ‘noise’ represents the undesirable value for the output characteristic. Taguchi uses the S/N ratio to measure the quality characteristic deviating from the desired value. There are several S/N ratios available depending on type of characteristic: lower is better (LB), nominal is best (NB), or larger is better (LB). Larger is better S/N ratio used here. Larger the better quality characteristic was implemented and introduced in this study.

Larger the better characteristic

S/N = -10 log10 (MSD)

Where MSD= Mean Squared Division

$$MSD = (1/Y_1^2 + 1/Y_2^2 + 1/Y_3^2 + \cdots\cdots\cdots)/n$$

Where Y1, Y2, Y3 are the responses and n is the number of tests in a trial and m is the target value of the result. The level of a factor with the highest S/N ratio was the optimum level for responses measured. Table 4 and Chart 2 depict the factor effect on MRR. The higher the signal to noise ratio, the more favorable is the effect of the input variable on the output.

Table 3: Summary Report for Different trials conducted during Experimentation

Trail no.	*Ton*	*Toff*	*IP*	*MRR*	*SN Ratio*
1	110	30	190	0.00046	-66.7448
2	110	35	210	0.00047	-66.5580
3	110	40	230	0.00049	-66.1961
4	120	30	210	0.00066	-63.6091
5	120	35	230	0.00099	-60.0873
6	120	40	190	0.0012	-58.4164
7	130	30	230	0.00162	-55.8097
8	130	35	190	0.00152	-56.3631
9	130	40	210	0.00146	-56.7129

Table 4: Estimated Model Coefficients for SN ratios

Term	*Coef*	*SE Coef*	*T*	*P*
Constant	-61.1664	0.5182	-118.047	0.000
Ton 110	-5.3333	0.7328	-7.278	0.018
Ton 120	0.4621	0.7328	0.631	0.593
Toff 30	-0.8882	0.7328	-1.212	0.349
Toff 35	0.1636	0.7328	0.223	0.844
IP 190	0.6583	0.7328	0.898	0.464
IP 210	-1.1270	0.7328	-1.538	0.264

Summary of Model
S = 1.554 R-Sq = 97.2% R-Sq(adj) = 88.7%

Table 5: Response Table for Signal to Noise Ratios Larger is better

Level	*Ton*	*Toff*	*Ip*
1	-66.50	-62.05	-60.51
2	-60.70	-61.00	-62.29
3	-56.30	-60.44	-60.70
Delta	10.20	1.61	1.79
Rank	1	3	2

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From the Table 4 and chart 1 it is clear that, the optimum value levels for higher MMR are at a Ton (130 µs), Toff (30 µs), and IP (230 µs). Also, for MMR, from it can be seen that, the most significant factor is Ton (A), followed by Toff (B), and IP (C).

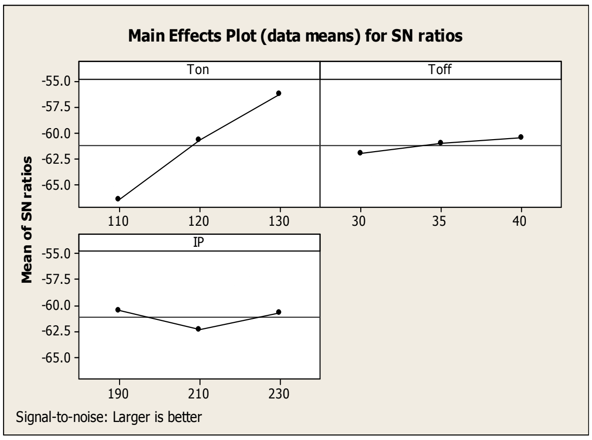

Chart 1: Effect of process parameters on S/N Ratio

4.2 Analysis of Variance (ANOVA)

Analysis of variance is a standard statistical technique to interpret experimental results. It is extensively used to detect differences in average performance of groups of items under investigation. It breaks down the variation in the experimental result into accountable sources and thus finds the parameters whose contribution to total variation is significant. Thus analysis of variance is used to study the relative influences of multiple variables, and their significance.

The purpose of ANOVA is to investigate which process parameters significantly affect the quality characteristic. The analysis of the experimental data is carried out using the software MINITAB 14 specially used for design of experiment applications. In order to find out statistical Significance of various factors like pulse on time (A), pulse of time (B), and peak current (C), and their value on MMR, analysis of variance (ANOVA) is performed on experimental data. Table 4 shows the result of the ANOVA with the MMR. The last column of the table indicates p-value for the individual control factors. It is known that smaller the p-value, greater the significance of the factor. The ANOVA table for S/N ratio (Table 4) indicate that, the pulse on time (p=0.03), pulse off time (p= 0.697) and peak current (p=0.488) in this order, are significant control factors effecting MMR. It means, the pulse on time is the most significant factor and the pulse off time has less influence on the performance output.

Table -6: Analysis of Variance for SN ratios

Source	*DF*	*Seq SS*	*Adj SS*	*Adj MS*	*F*	*P*
Ton	2	0.00000	0.0000	0.0000	25.95	0.037
Toff	2	0.00000	0.0000	0.0000	0.43	0.697
IP	2	0.00000	0.0000	0.0000	1.05	0.488
Residual Error	2	0.00000	0.00000	0.0000		
Total	8	0.00000				

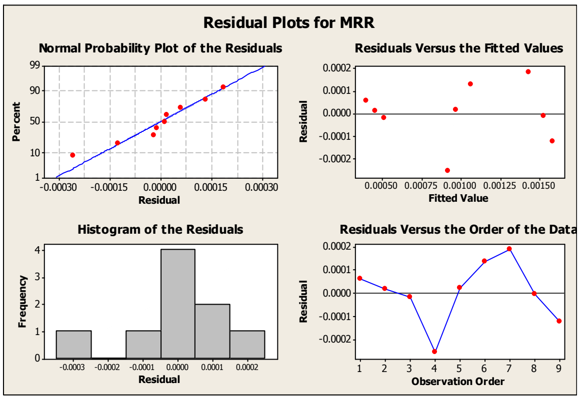

Chart 2: Residual Plots for MMR

4.3 Regression Analysis

Regression analysis is used for explaining or modeling the relationship between a single variable Y, called the response, output or dependent variable, and one or more predictor, input, independent or explanatory variables Mathematical models for process parameters such as pulse on time, pulse off time and peak current were obtained from regression analysis using MINITAB 14 statistical software to predict MMR.

The regression equation is

MRR = - 0.00571 + 0.000053 Ton + 0.000014 Toff - 0.000001 IP

S = 0.000166336 R-Sq = 92.5% R-Sq(adj) = 88.1%

Where,
Y = Response i.e. MRR
A = pulse on time (µs), B = pulse off time l (µs), C = peak current (Amp),

If we put optimum parameters which are drawn by ANOVA in equation 1 it will give optimum value of quality characteristic which will maximum MMR.

Yopt = - 0.00571 + 0.000053* A3 + 0.000014*B1 - 0.000001 *C3
Yopt = - 0.00571 + 0.000053* 130 + 0.000014*30 - 0.000001*230
Y opt = 0.0016 (Predicted by Regression Equation)

In multiple linear regression analysis, R2 is value of the correlation coefficient and should be between 0.8 and 1. In this study, results obtained from MMR in good agreement with regression models (R2>0.80).

Observation	Optimum Experimental value of MRR	Optimum Predicted Value	S/N Ratio
	0.00162	0.0016	-55.8097

5. Conclusions

The Taguchi method was applied to find an optimal setting of the material removal rate parameters process. The result from the Taguchi method chooses an optimal solution from combinations of factors if it gives maximized normalized combined S/N ratio of targeted outputs. The L-9 OA was used to accommodate three control factors and each with 3 levels for experimental plan selected process parameters are pulse on time (110,120,130 µs), pulse off time (30, 35, 40 µs), peak current (190, 210, 230 A). The results are summarized as follows:

- Among three process parameters pulse on time followed by pulse off time and peak current was most influencing parameters on MMR
- The Optimal level of process parameter were found to be **A3B1C3**
- The prediction made by Taguchi parameter design technique is in good agreement with confirmation results
- The result of present investigation are valid within specified range of process parameters
- Also the prediction made by Regression Analysis is in good agreement with
- The optimal levels of MMR process parameters for optimum MMR are:

Pulse On Time. (µs)	130
Pulse off Time l (µs)	45
Peak Current (Amp)	1

References

[1] Amir Ghaffari Bin Khalid, **“**Analysis Of The Influence Of Edm Parameters On Surface Quality, Mrr And Ew Of Wc–Co”
[2] Rohit Garg , Dr. Hari Singh “Effect Of Process Parameters On Performance Measures Of Wire Electrical Discharge Machining”
[3] R.A. Mahdavinejad , A. Mahdavinejad ,“ED machining of WC–Co” Mechanical Engineering Department, Faculty of Engineering, University of Tehran, Tehran, Ira
[4] M.Geetha, Bezawada Sreenivasulu, G. Harinath Gowd “Modeling & Analysis of performance characteristics of Wire EDM of SS304” ,
[5] Pandey PC, Jilani ST, "Electrical machining characteristics of cemented carbides", Wear 116, pp. 77–88, 1987
[6] Lee SH, Li XP, "Study of the surface integrity of the machined work piece in the EDM of WC", Journal of Materials Processing Technology 139, pp. 315–321, 2003.
[7] C.Y. Ho, and Z.C Lin, , “Analysis and application of grey relation and ANOVA in chemical mechanical polishing process parameters”, Int. J. Adv Manuf. Technol.,21, 10–14, (2003)
[8] J. A. McGeough, “Advanced Methods of Machining”, Chapman and Hall, New York, 1988
[9] S. S. Mahapatra & Amar Patnaiks “Optimization of wire electrical discharge machining (WEDM) process parameters using Taguchi method”
[10] F.R.M. Romlay and A. Mokhtar.,2008 “Machine Parameter Optimization for WEDM Machining”.
[11] Ahsan Ali Khan, Mohammad Yeakub Ali and Md. Mohafizul Haque, 2009 “A study of electrode shape configuration on the performance of die sinking EDM”
[12] Muhamad Haniffah Bin Ghafar Dec.2010 “ Surface integrity of mild steel in die-sinking electrical discharge machine (EDM)”
[13] Amir Ghaffari Bin Khalid., November 2008., “Analysis of the influence of EDM parameters on surface quality, MRR and EW of WC–CO”
[14] S.H.Tomadi, M.A.Hassan, Hamedon, IAENGR. Daud, A.G.Khalid (March 18 2009).,“Analysis of the Influence of EDM Parameters on Surface Quality, Material Removal Rate and Electrode Wear of Tungsten Carbide”.
[15] Taguchi G, Konishi S. “Taguchi methods, orthogonal arrays and linear graphs, tools for quality” American supplier institute. American Supplier Institute; 1987 [p. 8–35].
[16] “Taguchi G. Introduction to quality engineering”. New York: Mc Graw-Hill; 1990
[17] Mohd Amri Lajis, H.C.D. Mohd Radzi, A.K.M. Nurul Amin., 2009 “The Implementation of Taguchi Method on EDM Process of Tungsten Carbide”
[18] Chang-Ho Kim “Influence of the Electrical Conductivity of Dielectric on WEDM of Sintered Carbide”
[19] B. Puri, B. Bhattacharyya., 11 August 2004 “Modeling and analysis of white layer depth in a wire-cut EDM process through response surface methodology

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