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Experimental Investigation of Influence of Process Parameters on Surface Roughness during WEDM of AA 6063A

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Abstract—*Wire cut electrical discharge machining (WEDM) is a specialized thermoelectric machining process which is capable of machining parts with high accuracy and varying hardness or complex shapes. WEDM can be used for machining such parts which have sharp edges and are very difficult to be machined by the conventional machining processes. The principle of WEDM process is based on the conventional EDM sparking phenomenon. Since the introduction of the process, WEDM has evolved from a simple means of making tools and dies to the best alternative of producing micro-scale parts with the highest degree of dimensional accuracy and surface finish quality. In this research work the effect of various parameters of WEDM like pulse on time (T_{on}), pulse off time (T_{off}), Servo voltage (V_s) have been investigated to reveal their impact on output parameter i.e., surface roughness of Aluminum alloy (AA 6063A) using response surface methodology. Experimental work is performed by standard RSM design called a BOX-BEHKEN DESIGN. The optimal set of process parameter has also been predicted to maximize the surface finish. It was found experimentally that on increasing the pulse-on time, the surface irregularity of Aluminum alloy (AA 6063A) increases and increasing the pulse-off time the surface irregularity decreases. Similarly increasing the servo voltage the surface irregularity decreases. In case of peak current, on increasing the peak current, surface roughness firstly decreases gradually and then increases.*

Keywords: ANOVA, RSM, SN Ratio, WEDM, Box- Behnken Design

1. Introduction

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. This practical technology of the WEDM process is based on the conventional EDM sparking phenomenon utilizing the widely accepted non-contact technique of material removal. Since the introduction of the process, WEDM has evolved from a simple means of making tools and dies to the best alternative of producing micro-scale parts with the highest degree of dimensional accuracy and surface finish quality.

Wire Electrical discharge machining is a non-traditional, 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. These electrical discharges melt and vaporize minute amounts of the work material, which are then ejected and flushed away by the dielectric. A wire EDM generates spark discharges between a small wire electrode (usually less than 0.5 mm diameter) and a work piece 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. 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. In addition, the WEDM process is able to machine exotic and high strength and temperature resistive materials and eliminate the geometrical changes occurring in the machining of heat-treated steels. WEDM was first introduced to the manufacturing industry in the late 1960s. The development of the process was the result of seeking a technique to replace the machined electrode used in EDM.

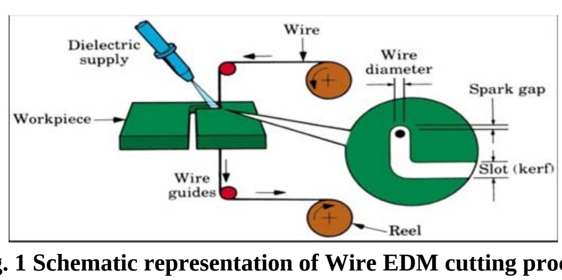

Fig. 1 Schematic representation of Wire EDM cutting process

1.1. Introduction to the RSM Method

Many experimental programs are designed with a two-fold purpose in mind. First, to quantify the relationship between the values of some measurable response variable and those of a set of experimental factors presumed to affect the response. And second, to find the values of the factors that produce the best value or values of the response. Response Surface Methodology (RSM) is a set of techniques designed to find the "best" value of the response. If the best value or values of the response is beyond the available resources of the experiment, then response surface methods are used to at least gain a better understanding of the overall response system.

1.2. Techniques of the Response Surface Methodology

Following are the three principal techniques of RSM.

- Setting up a series of experiments.
- Determining a mathematical model that best fits the data collected.
- Determining the optimal settings of the experimental factors that produce the optimum value of the response.

2. Experimentation

2.1. Machine Setup

The experiments are carried out on a WEDM machine (ELEKTRA SPRINTCUT 734) of Electronica Machine Tools Ltd. installed at Advanced Manufacturing Laboratory of the Institute. The pictorial view of WEDM machine setup is shown in Figure . This machine setup consists of four major sub-elements namely power supply system, dielectric system, positioning system, and drive system. Power supply system contains DC high voltage transmission circuit, pulse main circuit and short protection circuit.

Dielectric system consists of de-ionized water reservoir, filtration system, deionization system, and water chiller unit. The positioning system is made of two computerized numerical control tables. It operates in an adaptive control mode so that in case wire reaches closer to the workpiece, or the gap is bridged by debris and causes a short circuit, the positioning system is capable to sense it. Instantaneously, it will move back to re-establish proper cutting condition in the gap. The drive system assists in continuously driving the fresh wire, and always keeping the wire under suitable tension so that it moves in the machining zone as a straight wire. Moreover, it helps in minimizing wire break, taper, streaks as well as vibration marks. On the way while moving to the machining zone, wire is guided by sapphire or diamond wire guides.

Figure 2.1: Pictorial view of WEDM machine tool

2.2. Selection of Workpiece Material

Aluminium 6063A alloy (AA6063A) has wide application areas including aerospace industry, medical implants, electronic industry, automobile industries, and architectural sections owing to its unique properties namely high strength to weight ratio, high wear resistance, improved stiffness, compatibility of operating at elevated temperature and low thermal expansion coefficient. Hence Aluminium 6063A alloy is selected as workpiece for this research work. In this study, a plate of AA6063 of dimension 150 mm × 50 mm × 15 mm has been used as workpiece. The chemical composition of the workpiece material is analysed using EDAX.

Table2.1: Chemical composition of AA6063A.

Constituent	% Composition
Al	97.51
Si	0.59
Fe	0.31
Cu	0.12
Mn	0.1
Mg	0.91
Cr	0.1
Zn	0.1
Ti	0.1
Other	0.17

2.3. Selection of Tool

In WEDM wire is used as tool. Different type of tool wires are available in market for WEDM process namely copper wire, brass wire, coated wire (copper/brass core), coated wire (steel core), diffusion annealed wire, etc. In the present study the tool wire used is made of brass and the diameter of the wire is 0.25 mm.

2.4. Experiment Design Method

For this experiment design we use the response surface method. The three factors are taken as input parameter (control factors) and three levels of each factor are considered in this experiment. Therefore, Box-Behnken Design of RSM is selected for the experiment.

2.5. Ranges and Levels of Input

The various input process parameters along with their three levels are taken for final experimentation as follows in the table 2.2

Table 2.2 Range and levels of Input

Parameters	Range	Level-1	Level-2	Level-3
Pulse-on time Ton	107-127 µs	107 µs	117 µs	127 µs
Pulse –off time Toff	40-60 µs	40 µs	50 µs	60 µs
Servo voltage SV	45-85 V	45 V	65 V	85V
Peak current (IP)	135-175 A	135 A	155 A	175A

2.6. Instruments used for Measuring Surface Roughness

One of the measurable output characteristics is surface Roughness. Instrument used in this work for measurement of surface Roughness is Surface Profilometer of Accretech Electronic Ltd. The workpiece is attached to the detector unit of Surface Profilometer will trace the minute irregularities of the workpiece surface. The vertical stylus displacement during the trace is processed and digitally displayed on the liquid crystal display of the Surface Profilometer. Another quality characteristic is MRR and it is calculated by the formula volume/time. The processing time of each cut will note down by the stop watch.

Figure 2.2: photographic view of Surface Profilometer

2.7. Experimental Data for Surface Roughness

Table 2.3: Experimental data for surface roughness

Trial no	Level of input process parameters				Surface Roughness (µ meter)
	Pulse on Time (Ton) (µs)	Pulse off Time (Toff) (µs)	Peak Current(Ip) (A)	Servo Voltage(Vs) (V)	
1	107(-1)	40(-1)	155(0)	65(0)	1.38
2	107(-1)	60(+1	155(0)	65(0)	1.15
3	127(+1	40(-1)	155(0)	65(0)	3.85
4	127(+1	60(+1	155(0)	65(0)	3.34
5	117(0)	50(0)	135(-1)	45(-1)	2.82
6	117(0)	50(0)	135(-1)	85(+1	1.36
7	117(0)	50(0)	175(+1	45(-1)	3.880
8	117(0)	50(0)	175(+1	85(+1	1.81
9	107(-1)	50(0)	135(-1)	65(0)	1.40
10	107(-1)	50(0)	175(+1	65(0)	1.16
11	127(+1	50(0)	135(-1)	65(0)	3.26
12	127(+1	50(0)	175(+1	65(0)	3.93
13	117(0)	40(-1)	155(0)	45(-1)	4.15
14	117(0)	40(-1)	155(0)	85(+1	4.12
15	117(0)	60(+1	155(0)	45(-1)	3.03
16	117(0)	60(+1	155(0)	85(+1	2.91
17	107(-1)	50(0)	155(0)	45(-1)	1.35
18	107(-1)	50(0)	155(0)	85(+1	1.07
19	127(+1	50(0)	155(0)	45(-1)	3.50
20	127(+1	50(0)	155(0)	85(+1	3.25
21	117(0)	40(-1)	135(-1)	65(0)	3.85
22	117(0)	40(-1)	175(+1	65(0)	4.00
23	117(0)	60(+1	135(-1)	65(0)	1.55
24	117(0)	60(+1	175(+1	65(0)	2.74
25(C	117 (0)	50(0)	155(0)	65(0)	2.86
26(C	117 (0)	50(0)	155(0)	65(0)	3.20
27(C	117 (0)	50(0)	155(0)	65(0)	3.2
28(C	117 (0)	50(0)	155(0)	65(0)	2.91
29(C	117 (0)	50(0)	155(0)	65(0)	2.86

3. Results and Discussion

3.1. Description of the Experiment with Results

The influences of the T_{on}, T_{off}, Ip and SV on machined surface roughness in wire electrical discharge machining process have been examined. Experiments have been performed on Aluminium alloy (6063A) with brass wire of diameter 0.25 mm and the obtained data has been analyzed using Response Surface Methodology.

The results of the performed experiment show the effect of pulse on time (Ton), pulse off time (Toff), Ip and the servo voltage (SV) on surface roughness.

3.2. Effects of Process Parameters

The process performance characteristics are plotted against the input process parameters to explore the influence of input process parameters on measures of process performance and are illustrated in figure 3.1 to figure 3.7. The effect of input parameters on process performance characteristics is explained below.

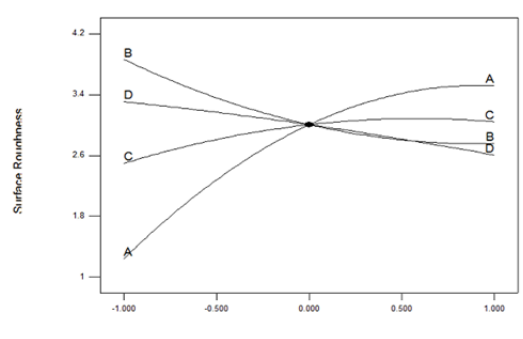

Figure 3.1 Effects of Process Parameters

3.2.1. Effect of Pulse on Time

It is found from Figure that surface roughness is increasing with the increase of pulse on time. Because discharge energy increases with increase in pulse on time and larger discharge energy produces a larger crater which causes a larger surface roughness value on the work piece.

3.2.2. Effect of Pulse off Time

From figure, it is found that surface roughness have a decreasing trend with the increase of pulse off time. As the pulse off time increases, the number of discharges within a given period becomes less which leads to less cutting rate. Because of low cutting rate the crater size is small which causes a lower surface roughness.

3.2.3. Effect of Peak Current

It is found that initially surface roughness increases to the mid value of peak current and after that decreases. When we increase peak current, cutting speed increases. Due to high cutting speed material removed from workpiece is more and this causes increase in surface roughness.

3.2.4. Effect of Servo Voltage

It is found from Figure that MRR is decreasing with the increase of servo voltage. With increase in servo voltage, the average discharge gap gets widened resulting into a lower cutting speed which causes smaller crater size. Due to this smaller crater size, surface roughness is lower.

3.3. Three-Dimensional view of all Graphs

Three dimensional graphs show the variation of output parameter i.e. surface finish with respect to two input parameters.

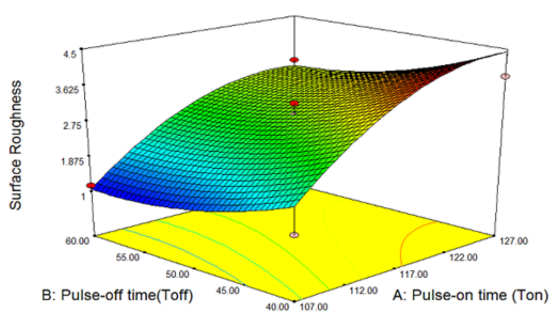

Figure 3.2 Effects of A &B on SR

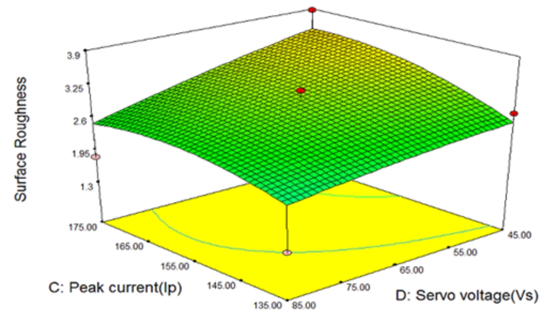

Figure 3.3 Effects of C & D on SR

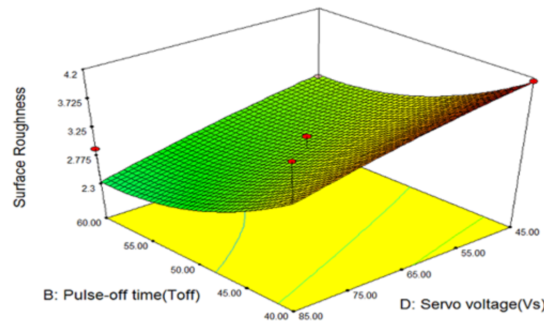

Figure 3.4 Effects of B & D on SR

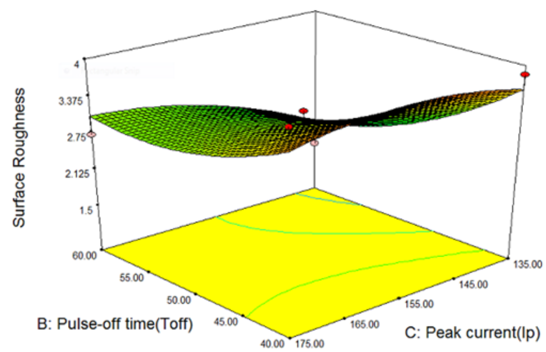

Figure 3.5 Effects of B & C on SR

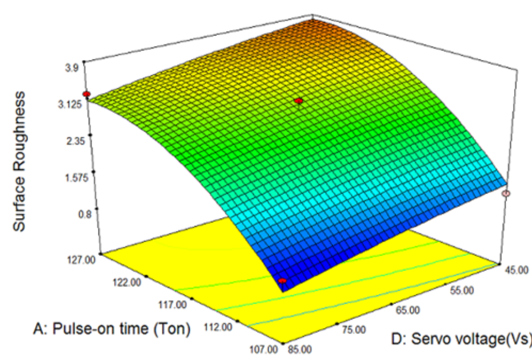

Figure 3.6 Effects of A & D on SR

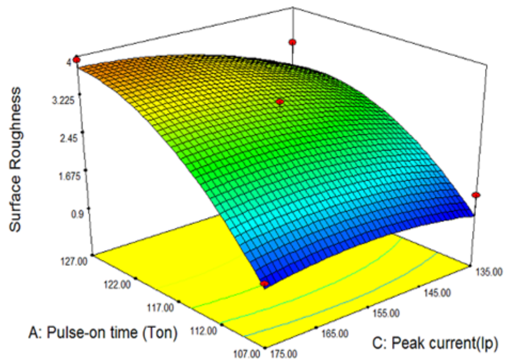

Figure 3.7 Effects of A & C on SR

The experiment was carried out as per the experimental plan and Analysis of Variance (ANOVA) is achieved by design expert software.

Table 3.1: ANOVA table for Surface Roughness

Source	Sum of squares	D .o.f	Mean square	F Value	P-Value Prob>F	% of cont.
Model	26.06	14	1.86	6.15	0.0008	
A	15.44	1	15.44	51.03	<0.0001	51.46%
B	3.66	1	3.66	12.10	0.0037	13.9%
C	0.90	1	0.90	2.96	0.1072	1.8%
D	1.48	1	1.48	4.11	0.0439	7.15%
AB	0.020	1	0.020	0.065	0.8028	
AC	0.21	1	0.21	0.68	0.4220	
AD	$1.000X10^{-4}$	1	$1.000X10^{-4}$	$3.306X10^{-4}$	0.9858	
BC	0.27	1	0.27	0.89	0.3605	
BD	$2.025X10^{-3}$	1	$2.025X10^{-3}$	$6.694X10^{-3}$	0.9359	
CD	0.093	1	0.093	0.31	0.5880	
A2	2.54	1	2.54	8.41	0.0116	
B2	0.60	1	0.60	1.98	0.1815	
C2	0.36	1	0.36	1.19	0.2947	
D2	0.016	1	0.016	0.054	0.8200	
Residual	4.23	14	0.30			
Lack of fit	4.11	10	0.41	12.93	0.0125	
Pure error	0.13	4	0.032			
Cor total	30.29	28				
Std. dev=0.55			R-Squared=0.8602			
Mean=2.75			Adj R-Squared= 0.7204			
C.V= 19.97%			Pred. R-Squared=0.2122			
Press= 23.86			Adeq. Precision=9.104			
A=Pulse on time (Ton) in micro second						
B=Pulse off time (Toff) in micro second						
C=Peak current (Ip) in A						
D=servo voltage (Vs) in V						

In case of analysis of variance of material removal rate, the model F-value of 11.65 implies the model is significant. There is only 0.01% chance that a "model F-value" this large could occur due to noise. Values of "prob> F" less than 0.0500 indicate model terms are significant. In this case A, B, D, A^2 are significant model terms. Values greater than 0.1000 indicate the model terms are not significant. In case of analysis of variance of surface roughness, the model F-value of 5.03 implies the model is significant. There is only a 0.23% chance that a "model F-value" this large could occur due to noise. Values of "prob> F" less than 0.0500 indicate model terms are significant. In this case A, B, D, A^2 are significant model terms. Values greater than 0.1000 indicate the model terms are not significant. If there are

Many insignificant model terms (not continuing those needed to support hierarchy)., model reduction map improve the model.

Final equation in the term of actual factors

$$S.R=-78.68+1.436XA-0.471B-0.0XD-6.26X10^{-3}A^2$$

With the help of this equation the optimal value of

With the help of this equation the optimal value

4. Conclusions

The findings of this study can be concluded as follows:

- The effects of the process parameters like pulse on time, pulse off time, servo voltage and peak current on response characteristics like surface roughness was studied.
- Box– Behnken Design of Response surface methodology (RSM) was applied for developing the mathematical models in the form of multiple regression equations correlating the dependent parameters with the independent parameters (pulse on time, pulse off time, servo voltage, peak current) in WEDM machining of Al 6063A alloy. To study the effects of process parameters on the performance characteristics the model equations are used and the response surfaces have been plotted. From the experimental data of RSM, empirical models were developed and the confirmation experiments were performed which were found within 95% confidence interval.
- .It was found experimentally that increasing the pulse-on time, the surface irregularity increases whereas increasing the pulse-off time, servo voltage decreases the surface irregularity.
- In the case of peak current, on increasing the peak current, surface roughness initially decreases gradually and then increases.

5. Acknowledgement

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References

[1]Aggarwal, V., Khangura, S. S., Garg, R. K. (2015), "Parametric modelling and optimiza tion for wire electrical discharge machining of Inconel 718 using response surface methodology", International Journal of Advanced Manufacturing Technology, 79:31–47

[2]Altug, M., Erdem, M., Ozay, C., (2015) "Experimental investigation of kerf of Ti6Al4V exposed to different heat treatment processes in WEDM and optimization of parameters using genetic algorithm", International Journal of Advanced Manufacturing Technology, 78:1573–1583.

[3]Bamberg E, Rakwal D., (2008), "Experimental investigation of wire electrical discharge machining of gallium-doped germanium", Journal of Materials Processing Technology, 197(1–3): 419–27.

[4]Benedict, G. F. (1987), "Electrical discharge machining (EDM), non-traditional manufacturing process", Marcel Dekker, Inc., New York & Basel, 231-232

[5]Box, G. and Behnken, D., "Some new three level designs for the study of quantitative variables", Techno metrics, Volume 2, 455-475, 1960.

[6]Chalisgaonkar, R., Kumar, J., (2013), "Optimization of WEDM process of pure titanium with multiple performance characteristics using Taguchi's DOE approach and utility concept", Front. Mech. Engg., 8(2): 201–214.

[7]Chiang, K. T., Chang, F. P. (2006), "Optimization of the WEDM process of particle reinforced material with multiple performance characteristics using grey relational analysis", Journal of Materials Processing Technology, 180, 96-101.

[8]Dabade, U. A., Karidkar, S. S., (2016), "Analysis of response variables in WEDM of Inconel 718 using Taguchi technique", Procedia CIRP 41, 886 – 891

[9]Das, A., Misra, J. P., (2012), "Experimental investigation on surface modification of Aluminium by Electric Discharge Coating Process using TiC/Cu green compact tool- electrode" Machining Science and Technology: An International journal. 16:4, 601-623

.

[10]Esme, U., Sagbas, A., Kahraman, F., (2009), "Prediction of Surface Roughness in Wire Electrical Discharge Machining using design of experiments and Neural Networks", Iranian Journal of Science & Technology, Vol. 33, No. B3, pp 24-34

[11]Fard, R. K., Afza, R. A., Teimouri, R., (2013), "Experimental investigation, intelligent Modelling and multi-characteristics optimization of dry WEDM process of Al–SiC metal Matrix composite", Journal of Manufacturing Processes 15, 483–494.

[12]Garg R., Singh K., Sachdeva A., Sharma V., Ojha K., Singh S., (2010), "Review of research work in sinking EDM and WEDM on metal matrix composite materials", International Journal of Advanced Manufacturing Technology, 50(5–8): 611–24.

[13] Gauri, S. K. and Chakraborty, S. (2009), "Multi-response optimization of WEDM process using principal component analysis", International Journal of Advanced Manufacturing Technology, 41, 741-748

[14]Ghosh, A and Mallik, A. K., "Manufacturing Science", Affiliated East-West Press Pvt. Ltd., New Delhi.

[15]Gupta, K., Jain, N. K., (2013), "On Micro-Geometry of Miniature Gears manufactured by Wire Electrical Discharge Machining", Materials and Manufacturing Processes, 28 (10), 1153-1159