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Research Article

Multi Response Optimization of Wire-EDM Process Parameters of Aluminium Alloy 6063 using Taguchi method

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Abstract

In the current investigation, a multi response optimization technique based on Taguchi method is planned for wire-EDM operations on aluminium alloy6063. Experiments have been performed with four machining variables: pulse-on time, pulse-off time, peak current and spark voltage. Experimentation has been planned as per Taguchi technique. Three performance characteristics namely material removal rate (MRR), surface roughness (SR) and gap current (GC) have been chosen for this study. Variation of performance measures with process variables was modeled by using response surface method.

Keywords: *Wire EDM, Taghuchi's Technique, ANOVA, MRR,SR.*

1. Introduction

Wire electrical discharge machining (WEDM) of aluminium alloy 6063 has been considered in this work which is having superior impact strength, corrosion resistance and low density. WEDM plays significant role in cutting conductive materials to produce intricate profiles and complex shapes. The material removal takes place due to melting and evaporation of work piece because of the heat produced by discharges. The wire cut electric discharge machine usually consists of a machine tool, a power supply unit and flushing unit. Wire travels through the work piece from upper and lower wire guides. In wire cut EDM process the spark is generated between continuously travelling wire and work piece . The most significant response variables in WEDM are material removal rate (MRR) surface roughness (SR) and gap current (GC) of work piece. Spark gap voltage, discharge current, pulse on time and pulse off time are the machining variables which influence the performance measures. The aim of this study is to examine the effects of process variables on MRR, GC and SR aluminium alloy 6063. MRR can be referred as degree of production whereas surface roughness (SR) represents the measure of surface quality. Gap current (GC) is taken as a pulse of current to initiate cutting. The peak current is the amount of power used in WEDM and measures in unit of amperage .Gap current specifies the supply current to be placed on the gap. The greater this value is, the greater the electric discharge energy becomes. Based on the literature survey, several pilot experiments were performed to select the influencing factors on performance characteristics. The chosen machining variables are: pulse on-time (TON), pulse off-time (TOFF), peak current (IP) and spark voltage (SV). The Taguchi technique is a dominant experimental planning tool, uses efficient and orderly approach for obtaining optimum process variables. It is difficult to select suitable process variables for every material in EDM, and depend greatly on operator's skill. With a view to lessen this complexity, a simple statistically planned experiments is recommended for examining the influence of different process variables on MRR, SR and gap current and estimate optimum machining variables. An appropriate orthogonal array is selected to conduct precise and accurate experiments. Confirmation experiments were then conducted based on statistical results.

2. Experimental details

2.1. *Material and methods*

The experiments were performed using CNC WEDM made Electronica Ezee Cut NXG , aluminium alloy 6063 (0.45% Si, 0.3% Fe,0.1% Mn, 0.5% Mg, 0.02% Zn, 0.02% Ti and Al remainder) with 240 mm X 80 mm X 30 mm size was used as cutting material. During the experiments 80 mm length was cut along the width of the work piece. The machining performance was evaluated by MRR, IG and SR. The MRR was determined by the wire feed rate and dimensions of

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the work piece. The surface roughness, usually expressed as an SR value in microns was measured by Taylor Hobson. The gap current (GC) is read on an ammeter, which is integral part of the machine, in amperes.

2.2. *Taguchi method*

Two aspects employed in Taguchi method are S/N ratio to estimate the quality and orthogonal arrays to accommodate many factors affecting simultaneously to evaluate the machining performances. Using Taguchi technique, an L18 orthogonal arrays table was chosen .In the present study all the designs, plots and analysis have been carried out using Minitab statistical software.

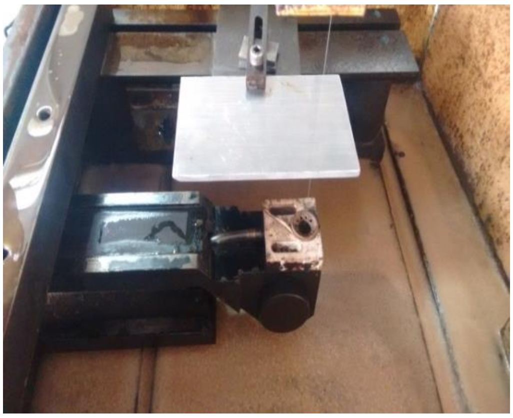
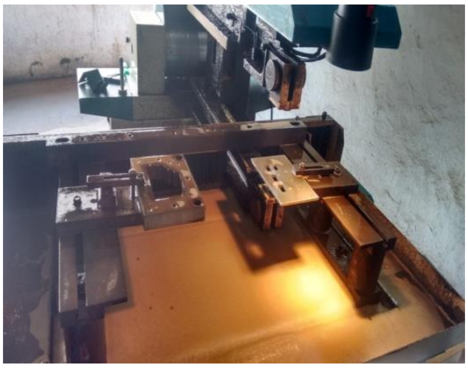


Fig.1 (a) Experimental setup



(b) Machinng zone

3. Result and discussions

The results of performance measures MRR, SR and Gap current are obtained for 18 experimental trials of WEDM and given in Table 1 . The ANOVA results are presented in Table 3 a-c , Taguchi method is adopted to study the effect of different machining variables viz., TON, TOFF, IP, and SV on MRR. MRR is directly proportional to the power supplied during this pulse-on time (TON). As the pulse-off time (TOFF) is decreased, more sparks will be generated. It is attributed to higher thermal power with increase in TON leading to a faster cutting rate. This led to improvement in MRR. It is observed that the pulse on time and peak current have strong effect on MRR. It is suggested to apply the parameters TON and IP at levels 2 and 3 respectively for achieving maximum MRR. Similarly, it is recommended to use the parameters TON and IP at levels 1 and 1 respectively for obtaining minimum SR.

Table 1 Input process parameters and their levels

Sr. No	Parameter	Symbol	Units	Levels		
				L1	L2	L3
1	Pulse on time	TON	µs	0.85	1.35	
2	Pulse off time	TOFF	µs	18	36	56
3	Peak current	IP	A	10	13	16
4	Spark voltage	SV	Volt	10	15	20

Table 2 Experimental design using L18 orthogonal array

Expt.No	T_{ON}	T_{OFF}	IP	SV	MRR	SR	GC
1	0.85	18	10	10	12.42	1.84	2.1
2	0.85	18	13	15	13.87	2.31	2.9
3	0.85	18	16	20	14.45	2.79	3.4
4	0.85	36	10	10	11.21	1.75	3.1
5	0.85	36	13	15	12.95	1.98	2.4
6	0.85	36	16	20	14.17	2.89	1.8
7	0.85	56	10	15	13.54	1.54	2.3
8	0.85	56	13	20	13.74	2.47	2.6
9	0.85	56	16	10	13.48	2.61	2.8
10	1.35	18	10	20	13.11	1.94	3.2
11	1.35	18	13	10	13.27	3.21	2.7
12	1.35	18	16	15	15.47	3.64	3.6
13	1.35	36	10	15	14.19	2.76	2.9
14	1.35	36	13	20	14.91	2.87	3.1
15	1.35	36	16	10	15.12	3.04	3.5
16	1.35	56	10	20	13.47	1.39	2.5
17	1.35	56	13	10	13.97	3.29	3.4
18	1.35	56	16	15	14.42	3.85	3.1

Table 3a: Analysis of Variance for MRR

Source	DF	Adj SS	Adj MS	F-value	P-value
TON	1	1.17556	1.17886	4.69	0.056
T OFF	2	0.14778	0.07389	0.29	0.751
IP	2	0.36778	0.18389	0.73	0.505
SV	2	0.08444	0.04222	0.17	0.847
Error	10	2.50889	0.25089		
Total	17	4.28444			

Table 3b : Analysis of Variance Gap current

Source	DF	Adj SS	Adj MS	F-value	P-value
TON	1	1.87534	1.87534	12.06	0.006
T OFF	2	0.03053	0.01527	0.10	0.907
IP	2	4.95023	2.47512	15.91	0.001
SV	2	0.28003	0.14002	0.90	0.437
Error	10	1.55531	0.15553		
Total	17	8.69145			

Table 3c : Analysis of Variance for SR

Source	DF	Adj SS	AdjMS	F-value	P-value
TON	1	3.645	3.645	8.82	0.014
T OFF	2	0.0004	0.00021	0.00	1.000
IP	2	7.0112	3.50561	8.49	0.007
SV	2	2.4574	1.22871	2.97	0.097
Error	10	4.1308	0.41308		
Total	17	17.2448			

The response function indicating each of the four responses can be expressed as follows:

$Y = f(T_{ON}, T_{OFF}, IP, SV)$

Here Y is response characteristic.

The second order response surface models for various performance measures are given as follow:

Regression Equation for GC

GC = 2.856 - 0.256 T ON_0.85 + 0.256 T ON_1.35 + 0.128 TOFF_18 - 0.056 TOFF_36 - 0.072 TOFF_56 - 0.172 IP_10 - 0.006 IP_13 + 0.178 IP_16 + 0.078 SV_10 + 0.011 SV_15 - 0.089 SV_20

Regression Equation for SR

SR = 2.5650 - 0.3228 T ON_0.85 + 0.3228 T ON_1.35 + 0.057 TOFF_18 - 0.017 TOFF_36 - 0.040 TOFF_56 - 0.695 IP_10 + 0.123 IP_13 + 0.572 IP_16 + 0.058 SV_10 + 0.115 SV_15 - 0.173 SV_20

Regression Equation for MRR

MRR = 13.764 - 0.450 T ON_0.85 + 0.450 T ON_1.35 + 0.001 TOFF_18 - 0.006 TOFF_36 + 0.006 TOFF_56 - 0.774 IP_10 + 0.021 IP_13 + 0.754 IP_16 - 0.519 SV_10 + 0.309 SV_15 + 0.211 SV_20

The response surface of MRR, varying the parameters of pulse on time, peak current and spark voltage. It is observed from the figure that MRR increases with higher TON and spark voltage levels. Also in the higher levels of peak current by raising the spark voltage levels, the MRR increases. At higher peak current, more discharge energy is induced which causes overcuts and produces larger chips. The higher the peak current, the smaller is the machining time, as the machining rate is proportional to peak current. MRR increases as the supplied energy increases. It directly depends on the number of sparks generated per second. Higher TON specifies the discharge energy induced for a longer time which results in large craters.

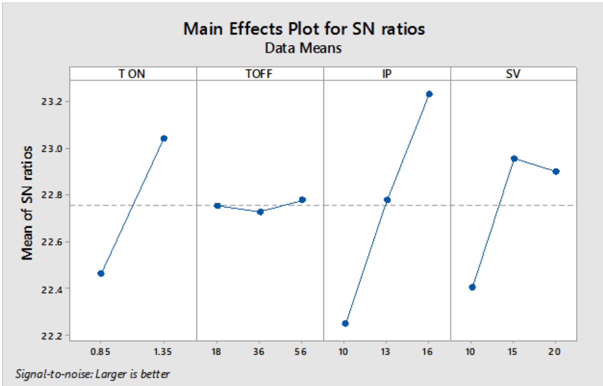


Fig 2 . Effect of processes parameters on S/N ratio

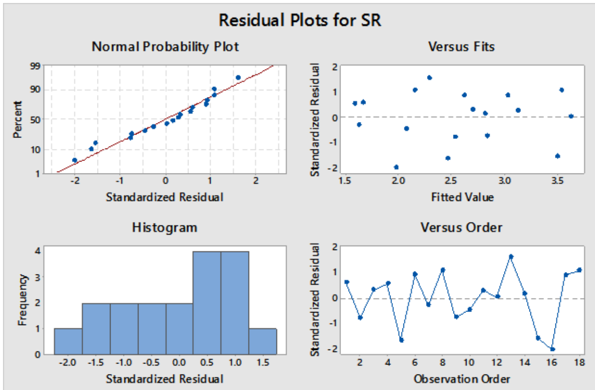


Fig3. Residual plots for Surface Roughness

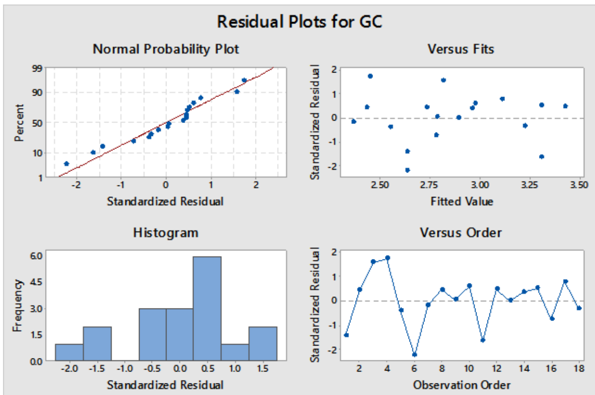


Fig4. Residual plots for Gap Current

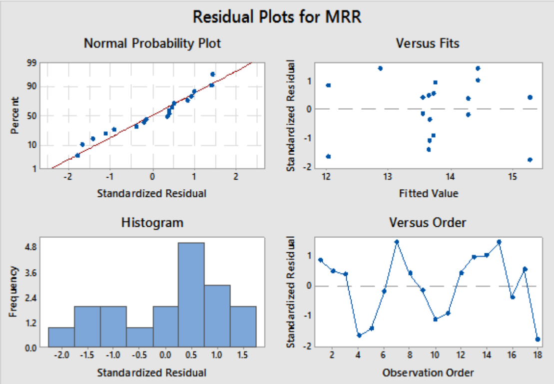


Fig5. Residual plots for MRR

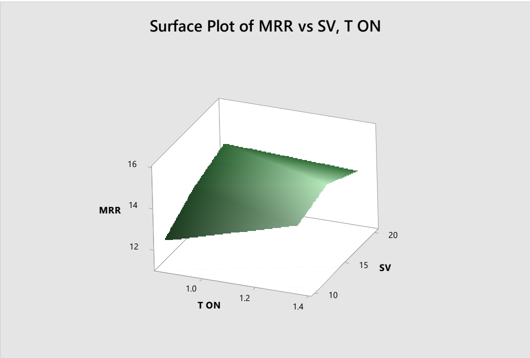


Fig 6. Response surface of MRR Vs pulse on time and spark voltage

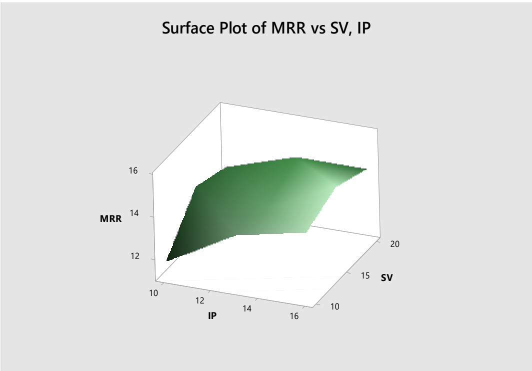


Fig 7. Response surface of MRR Vs peak current and spark voltage

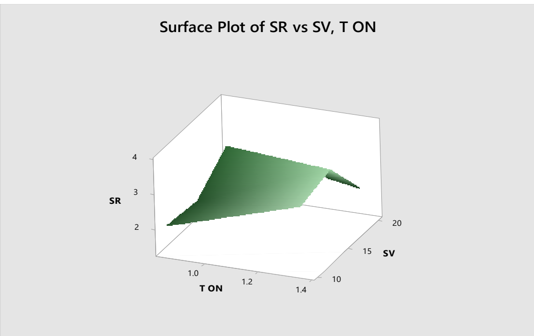


Fig 8. Response surface of SR Vs pulse on time and spark voltage

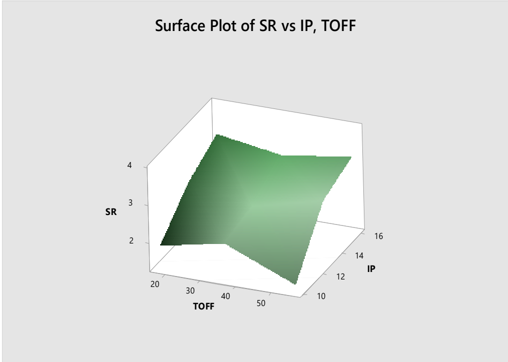


Fig 9. Response surface of SR Vs peak current and pulse off time

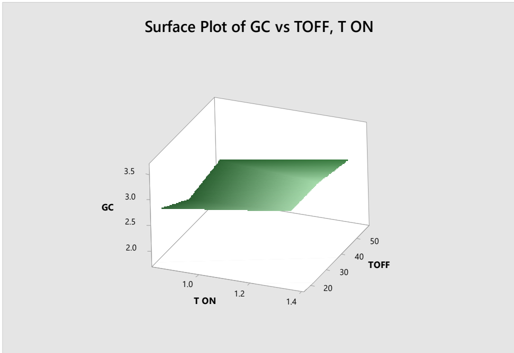


Fig 10. Response surface of IG Vs pulse off time and pulse on time

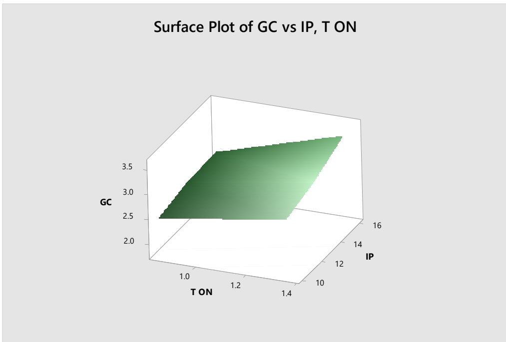


Fig 11. Response surface of IG Vs peak current and pulse on time

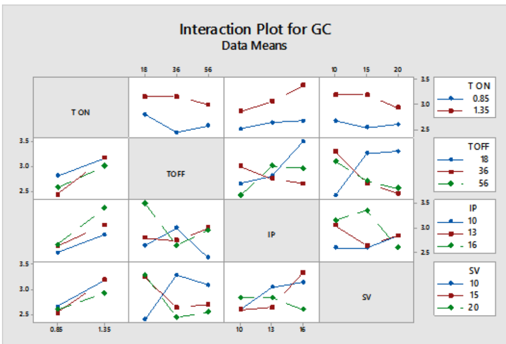


Fig 12. Interaction plots for GC

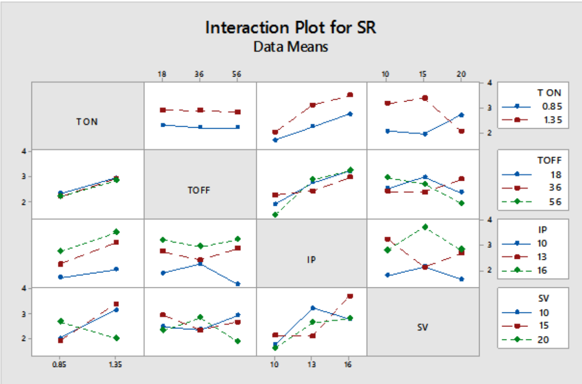


Fig 13. Interaction plots for SR

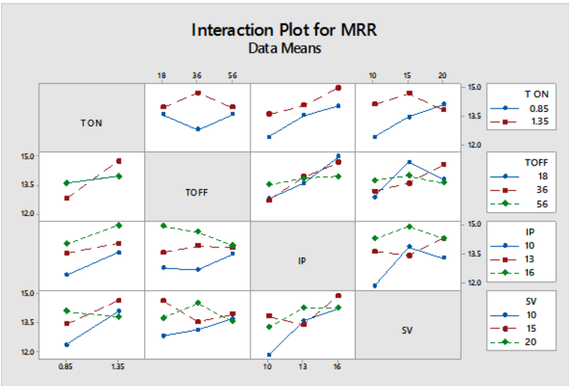


Fig 14. Interaction plots for MRR

Fig 8, 9 demonstrate the response surface of SR in function of the variables of SV, TON, IP and TOFF, while TOFF and SV remain stable in their middle values. It has been understood that by decreasing the TON and IP values, the SR minimizes. It has been noticed that at higher peak current, machined surface shows a higher SR due to uneven machined surface. On the other hand lower peak current produces little MRR and cause longer machining time. To achieve more MRR, higher TON and IP should be chosen. But, this will deteriorate the quality of the surface due to deeper and wider craters produced by sparks. Increasing TON from 0.85 to 1.35 ms generates more discharge energy, which results into formation of larger craters on the machined surface. Also, breakage of wire occurred at higher discharge energy levels due to more temperatures. Reduction of tensile strength at elevated temperature causes softening of wire. The wire breakage was prevented by setting low wire tension and high flushing pressure to enhance cutting efficiency.

Fig 10,11 show the response surface of GC of pulse off time, pulse on time and peak current. It has been observed that GC increases with increase in pulse on time and peak current.

Fig. 12 illustrates that the residuals follow an approximately straight line in normal probability plot. Residuals possess constant variance as they are scattered randomly around zero in residuals versus the fitted values. Since residuals exhibit no clear pattern, there is no error due to time or data collection order. The strongest interactions between various parameters can be observed from Fig. 13,14. The confirmation test is an essential step for validating conclusions drawn from the experimental results.

Conclusions

An application of Taguchi technique to optimize the input variables of WEDM on MRR, SR and GC of aluminium alloy 6063 has been studied. Optimization of the complex multi objective responses can be simplified through this technique.

The conclusions are as follows

Results confirm that TON, IP and SV are significant variables .Mathematical models were developed using response surface method for MRR, SR and IG to determine the relation between machine variables and performance measures. Optimum response characteristics such as MRR, SR and GC are improved with 6% error.

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