ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 2, Issue 1, January 2013

Spark Gap Optimization of WEDM Process on Ti6Al4V

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***Abstract*— WEDM is one of the important variants of electrical discharge machining (EDM) which uses the thermal energy generated between the electrodes for machining the electrically conductive materials. This method is successfully implemented in common materials like aluminum, stainless steel, etc. But its application in super alloys like Ti6Al4V, inconel 718, etc. is still under investigation. This study investigates the effect of voltage, dielectric pressure, pulse on-time and pulse off-time on spark gap of Ti6AL4V alloy. It has been found that pulse on time and pulse off time have the more impact on the spark gap. The minimum spark gap was obtained as 0.040407mm. The developed model agrees with the conformation results by less than 6%.**

***Index Terms*—EDM, Spark gap, Titanium, WEDM.**

I. INTRODUCTION

Electrical discharge machining (EDM) is an important non-traditional machining process which makes uses of precisely controlled electric sparks between the tool electrode and work piece for machining. A small portion of the work piece as well as the tool electrode are melted and vaporized by each spark. This melted portion of electrodes is ejected with the help of dielectric fluid and some portions of the melted electrodes are resolidified on the work piece. This re solidified portion is known as re cast layer [1]. S.S. Mahapatra et.al have optimized the WEDM parameters using Taguchi method and observed that combination of significant factors for each performance measure is different and developed mathematical model using non-linear regression method. Conformation experiments have shown less than 5% prediction error for each performance measures such as MRR, SF and kerf [2]. R.Ramakrishnan and L. Karunamoorthy have modeled and optimized inconel 718 on WEDM and established the effect of various machining parameters such as pulse on time, wire feed speed, delay time and ignition current. Pulse on time, delay time and ignition current were influenced more than wire feed on MRR [3]. U.Esme et.al observed that increase in pulse duration, voltage and wire speed increase the surface roughness whereas increase in flushing pressure of dielectric fluid decrease the surface roughness [4]. The investigations made by J.T Hung et.al revealed that pulse on time is one of the significant factors that influence surface roughness [5]. The previous researchers established that pulse duration, voltage, and dielectric pressure are the desired combination to control the surface finish [6]. From the literature reviewed it has been found that spark gap is an important response which decides the accuracy of the machined component in WEDM. Titanium alloys are nowadays increasingly being used in aero space, nuclear and automobile industries because of its attractive mechanical properties and corrosive resistance. The present work mainly concentrate on the effect of pulse on time, pulse off time, voltage and dielectric pressure on machining of Ti6Al4V.

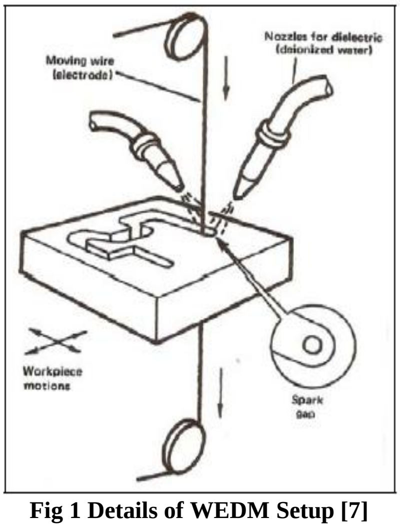

Fig 1 Details of WEDM Setup [7]

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II. EXPERIMENTAL SET UP

The experimental set up adopted for the present study is given in fig. 2. The WEDM experiments were conducted in Electronic ultra cut s1 machine using 0.25 mm brass wire as the tool electrode. 'Pulse on time', 'pulse off time', 'voltage' and 'dielectric pressure' are the four WEDM parameters that were selected for investigations. In this experimental study two level full factorial experiment is adopted because this gives all possible combinations of machine parameters. All other machine parameters were kept constant during the time of experiment.

III. EXPERIMENTAL DESIGN BASED ON DOE

Full factorial design of four factors with two levels each was conducted which consist of 16 runs plus two conformation tests which resulted in a total number of 18 trials. For the analysis of the experiments 10% confidence level is adopted.

Fig 2 Electronica Ultra cut S1 WEDM 5-Axes

ANNOVA table helped to find out the significant factors and to establish the mathematical relationship between the surface roughness and machining parameters. In this study, randomization of the run order to be carried out and analysis sequences were carried out according to the run order by Design Expert software.

Table 1.Machining Parameters and Levels

Factor	**Parameters**	**Level 1**	**Level 2**
A	Pulse on time (µS)	20	25
B	Pluse off time (µS)	44	50
C	Voltage (V)	25	30
D	Dielectric pressure (kgf/cm^2)	10	15

IV. RESULTS AND DISCUSSIONS

This section discusses the influence of the process parameters on the spark gap. The main objective of this discussion is to assess the variation of spark gap with respect to the change in the process parameters. The various machining parameters in two levels and corresponding results of surface roughness (average of three readings) are tabulated in Table 2. All the measurements were taken using Zeiss Axiotech High Optical Microscope under 100 times magnification. The measurement were made three times at three different points along the kerf width left of the wire pass. The sparking gap was calculated using the following equation.

$$\text{Spark gap} = \frac{(\text{kerf width - wire diameter})}{2} \quad \text{mm}$$

Where,
kerf width was obtained from the measurements,
Wire diameter = 0.25 mm

The ANNOVA table of spark graph reveals that two individual factors and two interactions affect the spark gap. The probability values (Prob>F) are less than 0.05 for pulse on time, pulse off time , the interaction between the dielectric pressure and pulse off time and interaction between pulse on time and pulse off time . The most important factor which affects the spark gap is pulse off time. The relation between the various parameters and surface roughness are given in the main effect plot viz. fig. (3a), fig. (3b) ,fig. (3c) and fig. (3d).

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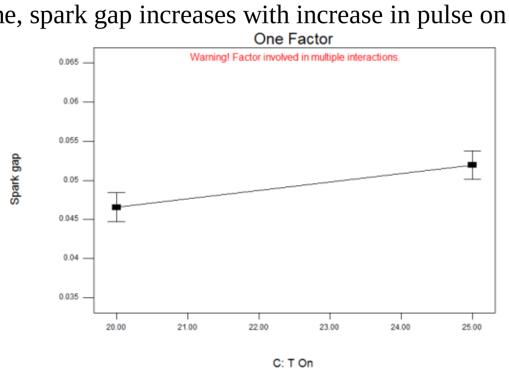
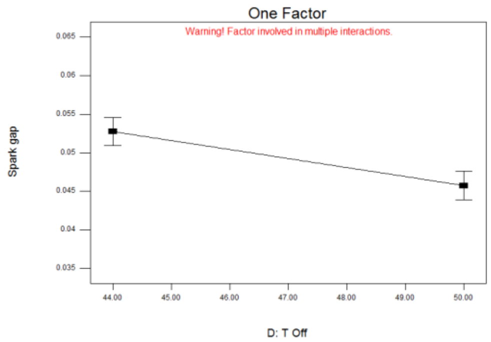
Table 2.Experimental Design and Results

Exp.No:	Servo voltage (V)	Dielectric Flushining pressure (kgf/cm^2)	T ON (µS)	T OFF (µS)	Spark Gap=(Kerf Gap- Wire Dia)/2 (mm)
1	25	10	20	44	0.0485
2	30	10	20	44	0.044
3	25	15	20	44	0.0495
4	30	15	20	44	0.0475
5	25	10	25	44	0.058
6	30	10	25	44	0.05
7	25	15	25	44	0.0595
8	30	15	25	44	0.065
9	25	10	20	50	0.0535
10	30	10	20	50	0.0455
11	25	15	20	50	0.0435
12	30	15	20	50	0.0405
13	25	10	25	50	0.051
14	30	10	25	50	0.047
15	25	15	25	50	0.042
16	30	15	25	50	0.043
17	28	13	23	47	0.05
18	26	11	21	45	0.0465

It is evident from fig. (3a) that the spark gap increases with increase in pulse on time, whereas fig. (3b) reveals that the spark gap decreases with increase in pulse off time. Fig. (3c) gives the variation of spark gap with dielectric pressure corresponding to minimum and maximum values of pulse off time. It can be noticed from the figure that corresponding to minimum value of pulse off time the spark gap decreases with increase in dielectric pressure, whereas the spark gap increases with increase in dielectric pressure corresponding to maximum value of pulse off time. Fig. (3d) shows the interaction effect of pulse on time and pulse off time on spark gap. For high value of pulse off time, spark gap increases with increase in pulse on time.



(a)



(b)

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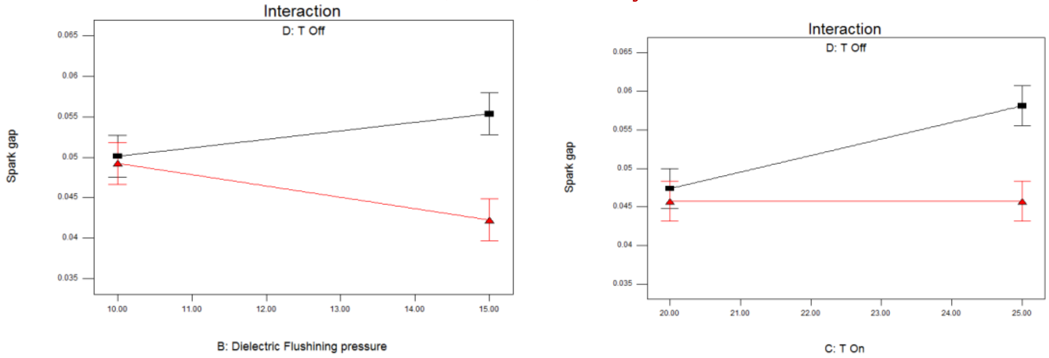

(c) (d)

Fig 3 Interactions of Various Factors with Spark Gap

When the pulse off time is maximum and the pulse on time increase from 20 µS to 25 µS, spark gap also increases. To achieve minimum spark gap, the pulse on time, pulse off time, voltage and dielectric pressure should be set at 20 µs, 50 µs, 30 V and 15 kgf / cm^2 respectively. The effect of these factors on spark gap is evident from the '3 D interaction graph' depicted in fig. (4). On the basis of the experimental investigations, an empirical relationship for surface roughness connecting voltage, dielectric pressure and pulse on time is established, which is given below

Spark gap = -0.44669-(3.27500E-003 X Servo Voltage)+(0.019017 X Dielectric Flushining pressure)+(0.014617X T On) + (0.012000 X T Off)+(1.20000E-004 X Servo Voltage X T On)-(4.08333E-004X Dielectric Flushining pressure X T Off-3.58333E-004 X T On X T Off).

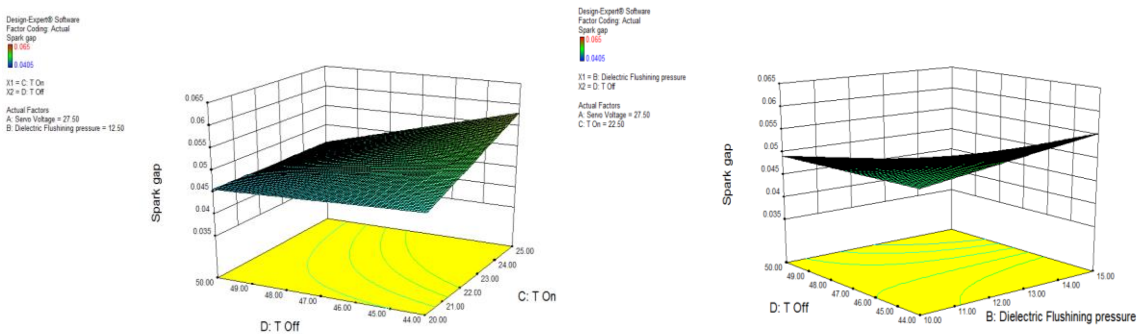

Fig 4 Surface Plot for Spark Gap

V. COMPARISON OF CONFORMATION TEST RESULTS WITH PREDICTED VALUES

Two conformation runs were conducted in order to measure the reliability of optimization solutions obtained from the analysis.The comparison of test results between the thoretical prediction and conformation test results were the final consideration that will determine whether the optimum parameters predicted are within the allowable range. The margin of error from prediction and experimental results was obtained below 6%. Table 3 shows the comparison of the test results with the predicted values.

Table 3. Comparison Of The Test Results With The Therotical Prediction.

No. of conformation Runs	Predicted values using the mathematical model (mm)	Conformation test results (mm)	% of Error
1	0.0494425	0.05	1.127
2	0.0490658	0.0465	5.102

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VI. CONCLUSION

This study evaluates the machining performance of grade-5 titanium alloy in wire electro discharge machining. The experiments were conducted using Electronica Ultra Cut S1 machine employing brass wire having a diameter of 0.25mm as the tool electrode. All the experiment trials, planning and analysis were executed using two-level full factorial experiment. Design of experiments was adopted in this study to determine the optimum condition of machining parameters and the significance of each parameters on the performance of machining characteristics. Altogether eighteen experiment trial runs were performed using randomized parameters obtained by Design expert software. The following conclusions were drawn based on the investigation.

1. The pulse on time , pulse off time , the interaction of dielctric pressure and pulse off time, and interaction of pulse on time and pulse off time are significant parameters which affect the spark gap of WEDM.
2. Minimum spark gap can be obtained by adopting a low value of pulse on time (20 µs) , a high value of dielectric pressure (15 kgf/cm^2), high value of pulse off time(50 µs) and voltage of 50V.
3. Improper setting of pulse on time and pulse off time can lead to wire breakage which in turn lead to increase in machining time.
4. A mathematical model is established to predict the value of surface roughness.
5. The marginal error obtained by the comparision of the predicted results with the conformation test was less than 6%.

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Volume 2, Issue 1, January 2013

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