

A Parametric Experimental Design Study of EDM Process Parameters in Machining of Titanium Grade 2

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ABSTRACT

Electric discharge machining (EDM) is one of the widely used non-traditional machining processes especially used for producing intricate or complex geometry on difficult-to-machine materials. The surface integrity is one of the important performance attributes of EDM process. With upcoming worldwide applications of Titanium grade-2, machining has become an important issue which needs to be investigated in details.

Based on the design of experiment (DOE), a well-designed experiment was conducted with L18 Orthogonal Array (OA). The present study investigates the effect of process parameters such as Peak Current (I_p), Pulse on Time (T_{on}), Duty Cycle (%) and Voltage Gap (volt) on performance characteristics such as surface roughness (SR). In this research work, Regression analysis was used to find out the optimal level of the parameters

Keywords

Electric Discharge Machining (EDM), Titanium grade-2, Design of Experiment (DOE), Minitab 17, Regression Analysis, ANOVA, Surface Roughness (SR)

1. INTRODUCTION

Electric Discharge Machining (EDM) is an electro-thermal non-traditional machining Process, where electrical energy is used to generate electrical spark and material removal mainly occurs due to thermal energy of the spark.

EDM is mainly used to machine difficult-to machine materials and high strength temperature resistant alloys. EDM can be used to machine difficult geometries in small batches or even on job-shop basis. Work material to be machined by EDM has to be electrically conductive. This technique has been developed in the late 1940s where the process is based on removing material from a part by means of a series of repeated electrical discharges between tool called the electrode and the work piece in the presence of a dielectric fluid. The electrode is moved toward the work piece until the gap is small enough so that the impressed voltage is great enough to ionize the dielectric. Short duration discharges are generated in a liquid dielectric gap, which separates tool and work piece. The material is removed with the erosive effect of the electrical discharges from tool and work piece. EDM does not make direct contact between the electrode and the work piece where it can eliminate mechanical stresses chatter and vibration

problems during machining. Materials of any hardness can be cut as long as the material can conduct electricity.

2. EXPERIMENTAL DETAILS

2.1 Experimental Setup

All the experiments were carried out on the EDM setup (Model: Electronica xpert 1 ePULSE 50 CNC), the photograph of which is shown in Figure 1. It mainly consists of three parts: machining chamber (Figure 2), control unit (Figure 3), and dielectric circulation system. The machining takes place in the chamber while various process parameters are regulated through control unit. Dielectric fluid is pumped through the reservoir where dielectric flow rate can also be varied.



Fig 1: EDM setup



Fig 2: Machining Chamber

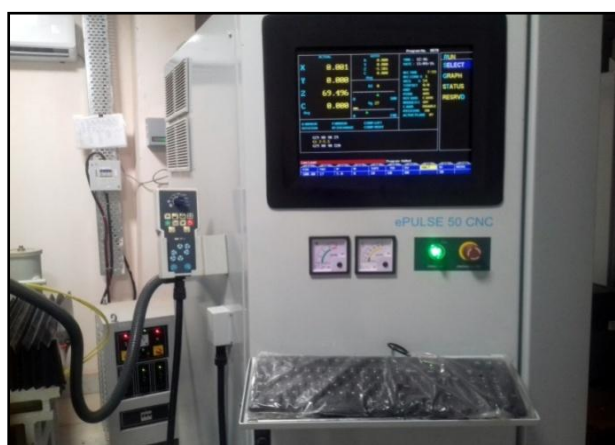


Fig 3: Control Unit

2.2 Selection Of Work Piece, Tool Material And Dielectric Fluid

Cube of 20 mm length, 20 mm breadth and 10 mm thickness of Titanium grade-2 was selected as workpiece. The tool made up of copper with circular cross section was selected as anode. Commercial grade EDM oil (specific gravity= 0.763, freezing point= 94°C) was taken as dielectric fluid for coolant medium of workpiece and tool during the process of erosion.

2.3 Machining Parameters And Response

The machining efficiency depends largely on machining parameters. So the judicious selections of parameters are of prime importance. From the literature review the process parameters like Peak Current (I_p), Pulse Time On (Ton), Duty Cycle (TAU) and Voltage Gap (V) have chosen for current study since they were found to have significant influence on surface roughness (SR).

Surface roughness is the variation or irregularity of a machined surface from its ideal atomic value. Arithmetic mean of surface roughness (R_a) which is the average of all the peaks and valleys height in a specified range was used as a measure of surface roughness. Surface roughness tester was used to measure SR (Model: TR110P).

2.4 Design of Experiments

The experiment was planned as per 3 levels L18 Taguchi orthogonal array. The design was generated and analyzed by using MINITAB 17 statistical software. Four parameters at

three levels were considered for the experimentation. The L18 orthogonal array (OA) for the SR is represented by Table 1. The machining was carried out for fixed duration of 30 minutes for all the experimental run.

Table 1 Taguchi L₁₈ Orthogonal Array for SR

Run	I_p (A)	Ton (μ s)	TAU (%)	Voltage gap (Volt)	SR (μ m)
1	8	50	10	60	2.00
2	8	100	12	70	7.86
3	8	150	15	80	2.98
4	12	50	10	70	3.33
5	12	100	12	80	3.22
6	12	150	15	60	3.79
7	16	50	12	60	3.34
8	16	100	15	70	4.56
9	16	150	10	80	5.04
10	8	50	15	80	2.76
11	8	100	10	60	3.46
12	8	150	12	70	3.29
13	12	50	12	80	2.28
14	12	100	15	60	2.77
15	12	150	10	70	2.95
16	16	50	15	70	3.25
17	16	100	10	80	3.15
18	16	150	12	60	2.67

3 RESULTS AND DISCUSSIONS

3.1 Influence of Cutting Parameters on Responses Measured

Traditional Experimental design such as full factorial utilizes large number of experimental run when factors are more. Thus they are of much time consuming and complicated. But Taguchi design of experiment uses small number of runs to study the effect of process parameters by using orthogonal array in its design. Taguchi method mainly focuses on the average performance characteristics data close to the ideal target data rather than any other data within specified range, thereby improving the quality of product. Taguchi method is easy and time savvy, thus can be directly applied to any engineering situations. Taguchi design employs statistical tool called ANOVA (Analysis of variance) developed by Sir Ronald Fisher in order to determine significance and percentage contribution of individual process parameter on the performance characteristics or responses measured. The influence of different cutting parameters on different performance characteristics are explained in following section:-

3.2 Main Effect Plot

The main effect plot is the graph of the average or means of response at each level of the factor or input parameter. The main effect plot helps one to determine the influence of individual input parameters on the responses measured, by disregarding the effect of any other input parameter present. The main effect plot of response is explained below:-

3.3 Surface Roughness (SR)

The quality of the machined surface can be determined by its surface texture. During the EDM process the surface quality obtained is of high order such that no further finishing operation is required for the electric discharge machined surface.

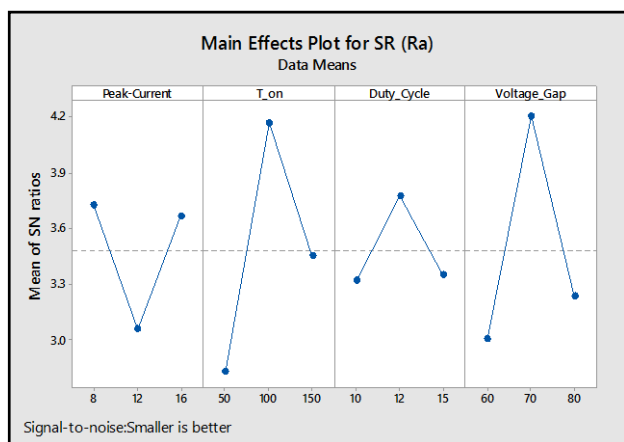


Fig 4: Main effect plot for SR

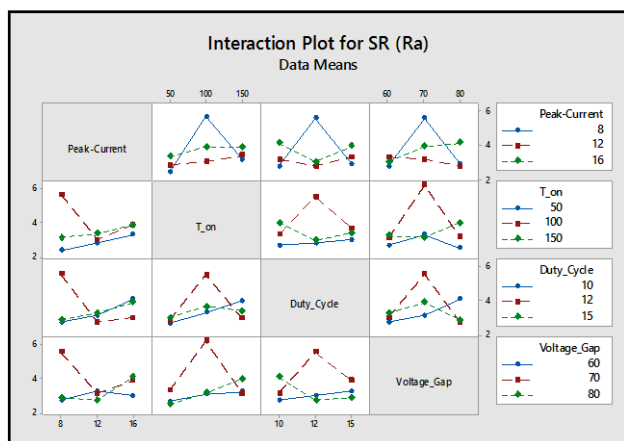


Fig 5: Interaction plot for SR

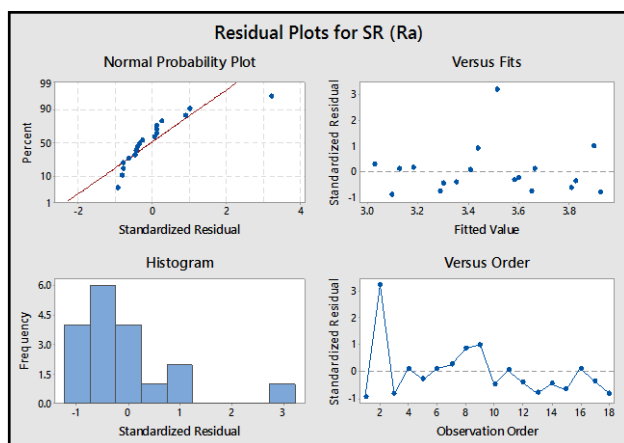


Fig 6: Residual plot for SR

During the process of EDM, the influence of various machining parameter like Ip, Ton, duty cycle and voltage gap has significant effect on SR, as shown in main effect plot for SR in Figure 4. Increasing in the peak current from 8A to 16A the SR is decreasing, but peak current in the range of 12A to 15A the SR is increasing. Because of Ip increases the pulse energy increases and thus more heat energy is produced between the

tool and work piece interface, leads to increase the melting and evaporation of the electrode. SR also increased with increases the Ton and then it decreases. Since SR having smaller is better characteristics, affecting lower Ip value would lead to better surface finish but higher values of Ton, duty cycle and voltage gap leads to better SR as shown in figure . The interaction plot of SR is shown in Figure 5, where each plot exhibits the interaction between four different machining parameters like Ip, Ton, duty cycle and voltage gap. This implies that the effect of one factor is dependent upon another factor. It is also confirmed by the ANOVA table (Table2). This implies that the effect of one factor is dependent upon another factor. The residual plot of SR is shown in Figure 6. This layout is useful to determine whether the model meets the assumptions of the analysis.

3.4 Analysis of Variance (ANOVA)

ANOVA developed by Sir Ronald Fisher is a very powerful statistical tool to determine the significance of the process parameters on the responses measured. The F-test in the table assesses which process factors are significant and insignificant. Generally a large F-value signifies the higher significance of the process parameters on the performance characteristics. Percentage of contribution of each factor can also be deducted from the ANOVA table which is calculated by following regression equation 1.

Regression Equation:

$$SR = 2.19 - 0.007 \text{ Peak-Current} + 0.00627 \text{ Ton} - 0.006 \text{ Duty Cycle} + 0.0117 \text{ Voltage Gap} \dots (1)$$

Table 2 ANOVA table for SR

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	4	1.3535	0.33838	0.16	0.955
Peak Current	1	0.0096	0.00963	0.00	0.947
Ton	1	1.1781	1.17813	0.55	0.470
Duty Cycle	1	0.0024	0.00243	0.00	0.974
Voltage gap	1	0.1633	0.16333	0.08	0.786
Residual Error	13	27.6747	2.12882		
Total	17	29.0282			

The analysis of variance for the factors is shown in Table 2 which is clearly indicates that the most significant factor contributing towards the SR is Ton and voltage gap with F-values of 0.55 and 0.08 respectively.

3.5 Response Table for Outputs

Response table can also indicate which process parameters has greater influence on the responses measured by giving the process parameter a rank. Also one can infer the optimal condition from the response table. The lowest value corresponding to the particular level in the response table is the optimal one for the SR.

Table 3 Response table for SR (smaller is better)

Level	Peak Current	Ton	Duty Cycle	Voltage gap
1	-10.559	-8.860	-10.110	-9.372
2	-9.597	-11.807	-10.762	-11.919

3	-11.073	-10.563	-10.357	-9.939
Delta	1.476	2.947	0.652	2.548
Rank	3	1	4	2

From the response table of SR (Table3) it can be also inferred that the Ton is the most influencing process parameter. The optimal condition was found at 16A peak current (level 3), 100 μ -sec Ton (level 2), 12% duty cycle (level 2) and 70v voltage gap (level 2).

4. MICROSTRUCTURE OF MACHINED SURFACES

Scanning electron microscope (SEM) is a powerful tool for the observation of surface structures with high spatial resolution. This technique is used for examining and analyzing elemental surface component of corrosion-related samples. The SEM examination provides information about the Titanium surface, especially with regard to the morphology and corrosion type.

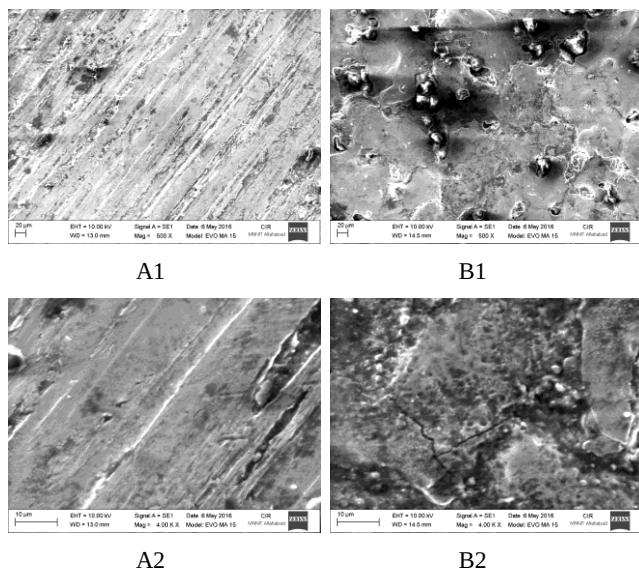


Fig 7: SEM images of Titanium grade-2 (A1-A2) before machining, (B1-B2) after machining

5. CONCLUSION

In the present study on the effect of machining response is SR of the Titanium grade-2 using the circular shaped copper tool has been investigated for EDM process. The experiments were conducted under various parameters setting of Peak Current (I_p), Pulse On-Time (Ton), Duty Cycle (TAU) and Voltage Gap (volt). L18 OA based on Taguchi design was performed for Minitab software 17 was used for analysis the result and theses responses were partially validated experimentally. Following was the conclusion:

The optimal condition for SR on Titanium grade-2 with copper electrode was 16A peak current, 100 μ - sec pulse time on, 12 % duty cycle and 70V voltage gap.

6. REFERENCES

- [1] Abdul kareem, S., Ali Khan, A., Zain, Z. M. (2011), "Experimental Investigation of Machining Parameters on Surface Roughness in Dry and Wet Wire-Electrical

Discharge Machining" Advanced Materials Research Vols. 264-265 pp. 831-836.

- [2] Aspinwall, D.K., Soo, S.L., Berrisford, A.E, Walder, G. (2008), Workpiece surface roughness and integrity after WEDM of Ti-6Al-4V and Inconel 718 using minimum damage generator technology, CIRP Annals – Manufacturing Technology Vol.57:pp. 187–190.
- [3] Curodeau, M. Richard, L. Frohn-Villeneuve, (2004), Models surface finishing with new EDM process in air with thermoplastic composite electrodes, Journal of Materials Processing Technology 149 (2004) 278–283.
- [4] H. Ramasawmy, L. Blunt, (2004), Effect of EDM process parameters on 3D surface topography, Journal of Materials Processing Technology 148 (2004) 155–164.
- [5] J.-P. Kruth, L. Stevens, L. Froyen, B. Lauwers, (1995), Study of the white layer of a surface machined by die-sinking electro-discharge machining, CIRP Annals—Manufacturing Technology 44 (1995) 169–172.
- [6] M.L. Jeswani, (1981), Effect of the addition of graphite powder to kerosene used as the dielectric fluid in electrical discharge machining, Wear 70 (1981) 133–139.
- [7] P. Pecas, E. Henriques, (2003), Influence of silicon powder-mixed dielectric on conventional electrical discharge machining, International Journal of Machine Tools & Manufacture 43 (2003) 1465–1471
- [8] Q.H. Zhang, J.H. Zhang, S.F. Ren, Z.W. Niu, X. Ai, (2005), a theoretical model of surface roughness in ultrasonic vibration assisted electrical discharge machining in gas, International Journal of Manufacturing Technology and Management 7 (2005) 381–390.
- [9] S.L. Chen, B.H. Yan, F.Y. Huang, (1999), Influence of kerosene and distilled water as dielectric on the electric discharge machining characteristics of Ti-6Al-4V, Journal of Materials Processing Technology 87 (1999) 107–111.
- [10] T. Yih-fong, C. Fu-chen, (2005), Investigation into some surface characteristics of electrical discharge machining SKD-11 using powder suspension dielectric oil, Materials Processing Technology 170 (2005) 385–391.