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"OPTIMIZATION OF PROCESS PARAMETERS IN ELECTRIC DISCHARGE MACHINING PROCESS"

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ABSTRACT

Electro Discharge Machining (EDM) is an extremely prominent machining process among newly developed non-traditional machining techniques for "difficult to machine" conducting materials such as heat treated tool steels, composites, super alloys, ceramics, hastelloys, nitralloy, nemonic alloys, carbides, heat resistant steels etc. In EDM, the material removal of the electrode is achieved through high frequency sparks between the tool and the work-piece immersed into the dielectric. The Material Removal Rate (MRR) is the important performance attributes of EDM process. The machining parameters that achieve the highest MRR strongly depend on the size of the machining surface i.e. the engaged electrode and work-piece surface. With upcoming worldwide applications of Titanium grade-2, machining has become an important issue which needs to be investigated in detail.

A well-designed experimental were conducted with L18 Orthogonal Array (OA) based on the design of experiment (DOE) with input factors like Peak Current (Ip), Pulse Time On (Ton), Duty Cycle (TAU) and Voltage Gap (V) was considered for investigation. The effect of the machining parameters on the responses such as MRR was investigated. In this research work, Regression analysis was used to find out the optimal levels of the parameters.

KEYWORDS: Electric Discharge Machining (EDM), Titanium Grade-2, Design of Experiment (DOE), Regression Analysis, Material Removal Rate

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. EDM techniques have developed in many areas.

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, control unit, 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.

Figure 1: EDM Setup

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 rectangular 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 Responses

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 (Ip), Pulse Time On (Ton), Duty Cycle (TAU) and Voltage Gap (V) have chosen for current study since they were find to have significant influence on MRR.

The MRR can be defined as rate of dissolution of material from the workpiece. MRR of Titanium grade-2 has been considered as one of the performance measures was calculated by following expression:

$$\text{MRR}= \frac{Initial\ weight - Final\ weight}{density * time}$$

Initial and final weights of the work piece were measured by electronic weighing balance machine of accuracy of 0.001 g.

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

Table 1: Taguchi L_{18} OA for MRR

Run	Ip (A)	Ton (µs)	TAU (%)	Voltage Gap (Volt)	MRR (mm^3/min)
1	8	50	10	60	0.4072431
2	8	100	12	70	0.5388026
3	8	150	15	80	0.5484109
4	12	50	10	70	0.6260162
5	12	100	12	80	0.7893569
6	12	150	15	60	1.1995565
7	16	50	12	60	0.8078344
8	16	100	15	70	1.0059127
9	16	150	10	80	1.0036954
10	8	50	15	80	0.5225424
11	8	100	10	60	0.7132298
12	8	150	12	70	0.8100517
13	12	50	12	80	0.5025868
14	12	100	15	60	1.001478
15	12	150	10	70	1.1005173
16	16	50	15	70	0.6910569
17	16	100	10	80	0.9874353
18	16	150	12	60	1.4161123

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 plots of each response are explained below:-

3.3 Material Removal Rate (MRR)

Although the material removal rate in EDM process is very low as compared to that of conventional machining but it's still a preferable option for machining of difficult-to-cut materials such as Nickel-based superalloy, Titanium alloy, Inconel 825 etc. The productivity of EDM can be determined through MRR, so it is necessary to know the influence of the machining parameters on the MRR during EDM of Titanium grade-2.

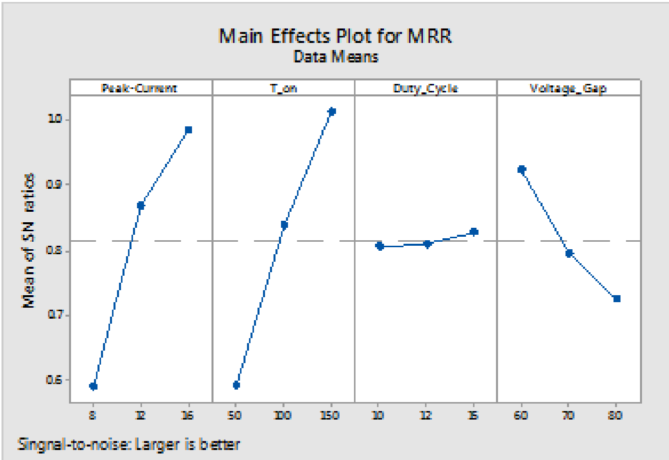

Figure 2: Main Effect Plots for S/N Ratios (MRR)

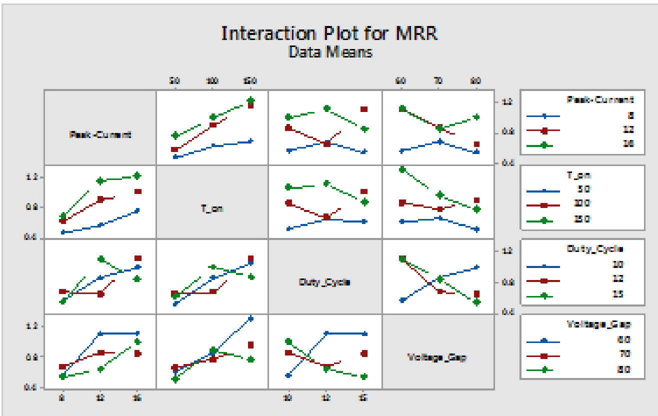

Figure 3: Interaction Plot for MRR

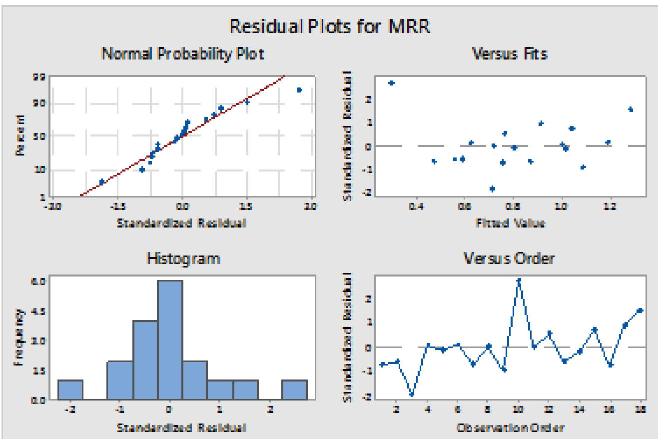

Figure 4: Residual Plots for MRR

During the process of Electrical discharge machining, the influence of various machining parameter like Ip, Ton, duty cycle and voltage gap has significant effect on MRR, as shown in main effect plot for S/N ratio of MRR in Figure 2.

The pulse time on (Ton) is directly proportional to MRR in the range of 50 µs to 100 µs. But, with increase in pulse time on from 100 µs to 150 µs MRR increases slightly. However, MRR increases monotonically with the increase in pulse time on. Besides this, other factor that influences MRR is peak current (Ip). The peak current (Ip) is directly proportional to MRR in the range of 8A to 12A. This is expected because an increase in peak current produces strong spark, which produces the higher temperature, causing more material to melt and erode from the work piece. But, with increase in peak current from 8A to 16A MRR increases slightly. However, MRR increases monotonically with the increase in peak current. Since MRR having larger is better characteristics, affecting higher Ip and Ton values would leads to higher MRR but higher value of voltage gap lead to lower MRR as shown. The duty cycle has very less effect on MRR. The interaction plot of MRR is shown in Figure 3, 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. The residual plot of MRR is shown in Figure 4. This layout is useful to determine whether the model meets the assumptions of the analysis.

3.5 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

MRR = 0.442 + 0.04941 Peak-Current + 0.004202 Ton + 0.0045 Duty Cycle - 0.00993 Voltage Gap… …. (1)

Table 2: ANOVA for S/N Ratios (MRR)

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	4	1.1182	0.27955	21.63	**0.000**
Peak Current	1	0.4687	0.46877	36.28	**0.000**
Ton	1	0.5296	0.52964	40.99	**0.000**
Duty Cycle	1	0.0015	0.00152	0.12	0.737
Voltage Gap	1	0.1182	0.11829	9.15	**0.010**
Residual Error	13	0.1679	0.01292		
Total	**17**	**1.2862**			

Table 2 here presents combined ANOVA table for all the response MRR. From the table 2 it can be observed that the most significant factor contributing towards the MRR is pulse time on and peak current with F-value of 40.99 and 36.28 respectively.

3.6 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 highest value corresponding to the particular level in the response table is the optimal one for the MRR.

Table 4: Response Table for S/N Ratios Larger is Better (MRR)

Level	Peak Current	Ton	Duty Cycle	Voltage Gap
1	-4.7992	-4.7580	-2.3421	**-1.3294**
2	-1.6122	-1.7345	-2.3438	-2.2660
3	**-0.3447**	**-0.2635**	**-2.0701**	-3.1606
Delta	4.4545	4.4944	0.2737	1.8311
Rank	2	1	4	3

From the response table of MRR (Table 4) it can be also inferred that the pulse time on is most influencing process parameter. The optimal condition was found at 150 µ-sec Ton (level 3), 16 Amp peak current (level 3), 60 volt voltage gap (level 1) and 15 % duty cycle (level 3).

6. CONCLUSIONS

In the present study on the effect of machining responses are MRR of the Titanium grade-2 using the rectangular shaped copper tool have been investigated for EDM process. The experiments were conducted under various parameters setting of Peak Current (Ip), Pulse On-Time (Ton), Duty Cycle and Voltage Gap (Volt). L18 OA based on Taguchi design was performed for Minitab 17 software was used for analysis the result and these responses were partially validated experimentally.

Following was the conclusion:

Optimal parameters for MRR on Titanium grade-2 with copper electrode were 12-amp peak current, 100-µ sec pulse time on, 15 % duty cycle and 60 volt voltage gap.

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