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OPTIMIZATION OF PROCESS PARAMETERS ON ELECTRIC DISCHARGE MACHINING

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EDM is an important and efficient method of machining extremely tough and brittle electrically conductive materials. The present work deals with the features of electrical discharge machining of AISI 303 stainless steel. A second-order mathematical model, in terms of machining parameters, was developed for surface roughness and electrode wear rate (EWR) using response surface methodology (RSM). Based on the experimental design EDM process is followed and analyse the responses. Finally the responses have been optimized for a given machining condition by analysis of variance (ANOVA) analysis.

1. Introduction

Electrical Discharge Machining, commonly known as EDM [2] is a non-conventional machining method used to remove material by a number of repetitive electrical discharges of small duration and high current density between the workpiece and the tool. In EDM, since there is no direct contact between the workpiece and the electrode, hence there are no mechanical forces existing between them. Much conductive material can be machined using EDM irrespective of the hardness or toughness of the material. Material is removed in this process from the work-piece due to erosion caused by rapidly recurring electrical spark discharge between the work-piece and the tool electrode. Distance maintains between the tool and the work-piece is very small. The work-piece and tool both are submerged in dielectric fluid, commonly used are EDM oil, deionized water, and kerosene.

Fig. 1 Experimental setup

Wong and Noble (1986) [2] investigated the machining with cylindrical electrodes with microcomputer controllers. An oxygen assisted EDM system, which greatly improves the MRR was tested by supplying oxygen into the discharge gap by Kunieda et al. (1999) [3], besides MRR can be substantially improved with reduced TWR using a multi- electrode discharging system using without any improvement in surface roughness. A FEM model has been developed by Yadav et al. (2002)[4] to approximate the temperature field and thermal stresses due to Gaussian heat flux distribution of a spark during EDM of HSS material. A single spark produces significant compressive and tensile stresses beneath of the spark location and mostly the thermal stresses exceed the yield strength of the workpiece in an extremely thin zone near the spark. Marafona and Chousal (2006) [5] developed a thermal-electrical model using copper and iron as anode and cathode respectively. The TWR and MRR as well as surface roughness results agree reasonably well with them. Allen and Chen (2007) [6] reported a thermo-numerical model for material removal on molybdenum by a single spark. The effects of EDM parameters on the crater dimension and the tool wear percentage are studied. The tool wear is moderately analogous to the Material Removal Mechanism (MRM) in EDM. Mohri et al. [1995] [7] proved that tool wear is affected by the precipitation of turbostratic carbon from the hydrocarbon dielectric on the electrode surface during sparking. Bleys et al. [2002] [8] devised an online tool wear compensation method based on the pulse analysis and controlled the tool feed movement in real time. Kunieda and Kobayashi [2004] [9] clarifies the mechanism of determining tool electrode wear ratio in EDM by spectroscopic measurement of the vapour density of the tool electrode material Finally the literature presented research work under various in these areas in the last twenty years, along with possible future trends. The general direction of study relates to machining performance evaluation for instance MRR, TWR and surface integrity achieved after machining. However, many investigations were also directed towards monitoring and control of the process parameters. A second-order mathematical model, in terms of machining parameters, was developed for surface roughness and electrode wear rate (EWR) using response surface methodology (RSM).

2. Objective of present work

The present work deals with the features of electrical discharge machining of AISI 303 stainless steel. A second-order mathematical model, in terms of machining parameters, was developed for surface roughness and electrode wear rate (EWR) using response surface methodology (RSM). The experimental plan was based on the face centered, central composite design (CCD). The experimental results indicate that the proposed models could adequately describe the performance indicators within the limits of the factors that are being investigated.

3. Methods and Materials

The experiments were conducted using the Electric Discharge Machine, model ELECTRONICA -ELECTRAPLUS PS 50ZNC (die sinking type) the polarity of the electrode was set as positive while that of workpiece was negative. The dielectric fluid used was EDM oil (specific gravity-0.763). The EDM consists of the following parts:

i. Dielectric reservoir, pump and circulation system.
ii. Power generator and control unit.
iii. Working tank with work holding device.
iv. X-Y working table
v. The tool holder
vi. The servo system for feeding the tool.

Fig. 2 Dielectric reservoir [16]

Fig. 3 Control unit of EDM machine [16]

Selection of the workpiece

Most widely used materials in all industrial applications is AISI 304 Stainless Steel and accounts for approximately half of the world's stainless steel production and consumption. The aesthetic view in architecture, superior physical and mechanical properties, resistance against corrosion and chemicals, weldability, it has become the most preferred material over others. Very few non-conventional methods for machining AISI 304 stainless steel are available.

Tool Design

The tool material used in Electro Discharge Machining can be of a variety of metals like copper, brass, aluminium alloys, silver alloys etc. The material used in this experiment is copper. The tool electrode is in the shape of a cylinder having a diameter of 21mm.

Fig. 4 Machined workpiece and Tool

Mechanism and Evaluation of MRR and TWR

MRR is the rate at which tha material is removed the workpiece. Electric sparks are produced between the tool and the workpiece during the machining process. Each spark produces a tiny crater and thus erosion of material is caused.

The MRR is defined as the ratio of the difference in weight of the workpiece before and after machining to the density of the material and the machining time.

$$MRR = \frac{Wi - Wf}{t \times \rho}$$

Where W_i = initial weight before machining
W_f = final weight after machining
T = machining time
ρ is the density of AISI 303 stainless steel = 8000 kg/m^3

Mechanism of Tool wears-

Tool wear is an important factor because if affects dimensional accuracy and the shape produced. Tool wear is related to the melting point of the materials. Tool wear is affected by the precipitation of carbon from the hydrocarbon dielectric on the electrode surface during sparking. **By Mohri et al. [17]** Also the rapid wear on the electrode edge was because of the failure of carbon to precipitate at difficult to reach regions of the electrode.

Evaluation of tool wear rate

TWR is expressed as the ratio of the difference of weight of the tool before and after machining to the machining time. That can be explain this equations

$$TWR = \frac{Wtb - Wta}{t} \qquad \text{…………………(3.2)}$$

Whereas Wtb = Weight of the tool before machining.
Wta = Weight of the tool after machining.
t = Machining time.

Fig. 5 Weight balance

The graphical representations of these equations are called response surfaces, which can be used to describe the individual and cumulative effect of the test variables on the response and to determine the mutual interactions between the test variables and their subsequent effect on the response.

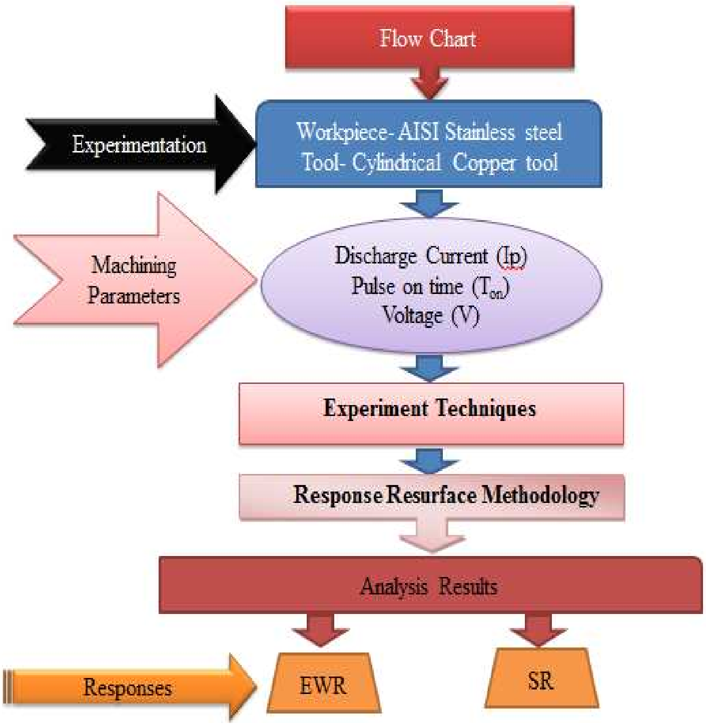

Fig. 6 Flow chart of the experiments

4. Experiment and Analysis

AISI 303 Stainless Steel is one of the most widely used materials in all industrial applications and accounts for approximately half of the world's stainless steel production and consumption. Because of its aesthetic view in architecture, superior physical and mechanical properties, resistance against corrosion and chemicals, weldability, it has become the most preferred material over others. Many conventional and non-conventional methods for machining AISI 303 stainless steel are available.

The tool material used in Electro Discharge Machining can be of a variety of metals like copper, brass, aluminum alloys, silver alloys etc. The material used in this experiment is copper. The tool electrode is in the shape of a cylinder having a diameter of 10mm. Machining parameters and their levels are presented in Table 1.

Table 1 Machining parameters and their levels

Machining Parameter	Symbol	Unit	Levels		
			Low	Medium	High
Discharge current	(Ip)	A	2	4	8
Pulse on time	(T_{on})	µs	50	250	450
Voltage	(V)	V	40	45	50

Surface Roughness is the measure of the texture of the surface. It is measured in µm. If the value is high then the surface is rough and if low then the surface is smooth.

It is denoted by Ra. The values are measured using Portable style type profilometer, Talysurf (Model: Taylor Hobson, Surtronic 3+). The arithmetic mean of three readings is taken as the final value shown in table 2.

Table 2 Observation Table

Run Order	Pt Type	Blocks	Ip A	T_{on} µs	V	EWR (MRR/TWR) (mm^3/min)	SR µm
1	1	1	2	50	40	22.471	2.87
2	1	1	8	450	40	131.805	7.77
3	1	1	8	50	50	116.969	5.06
4	1	1	2	450	50	93.547	3.72
5	0	1	5	250	45	62.689	4.41
6	0	1	5	250	45	63.034	4.28
7	1	2	8	50	40	104.150	5.90
8	1	2	2	450	40	35.476	3.90
9	1	2	2	50	50	26.417	2.80
10	1	2	8	450	50	162.112	7.67
11	0	2	5	250	45	77.393	5.35
12	0	2	5	250	45	51.111	4.11
13	-1	3	2	250	45	59.953	3.56
14	-1	3	8	250	45	199.844	5.86
15	-1	3	5	50	45	23.383	4.84
16	-1	3	5	450	45	11.165	5.87
17	-1	3	5	250	40	53.705	2.50
18	-1	3	5	250	50	85.405	2.78
19	0	3	5	250	45	71.504	3.15
20	0	3	5	250	45	70.417	3.40

Analysis and Discussion of EWR

In Fig. 7 the main effect plots for EWR (electrode wear ratio). In this EWR increases as the discharge current is (Ip) increases throughout the entire range. In case of pulse on time, the EWR first slightly increases up to 250 µs and then also increasing in a similar fashion till 450 µs [5]. The EWR decrease linearly along with the increase in Voltage within the range but the magnitude of increase is not very large

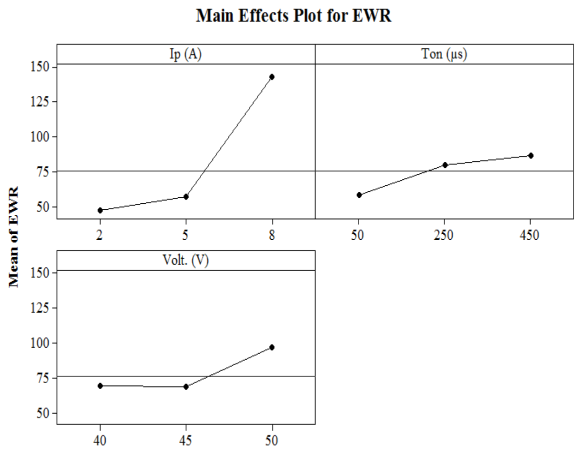

Fig. 7 Main effects plots for EWR

Analysis and Discussion of SR

The various machining parameter has given the significant effect on the SR, graphical representation of SR as shown in Fig. 8. This figure indicate that pulse current (Ip) is most effected as compare to pulse duration and other factor, because a higher pulse current may cause more frequently creaking of dielectric fluid, there is more frequent melt expansion resulting is a poor surface finish**.** The residual plot of SR is shown in Fig. 9. This layout is necessary to check whether the model meets the expectation of the analysis.

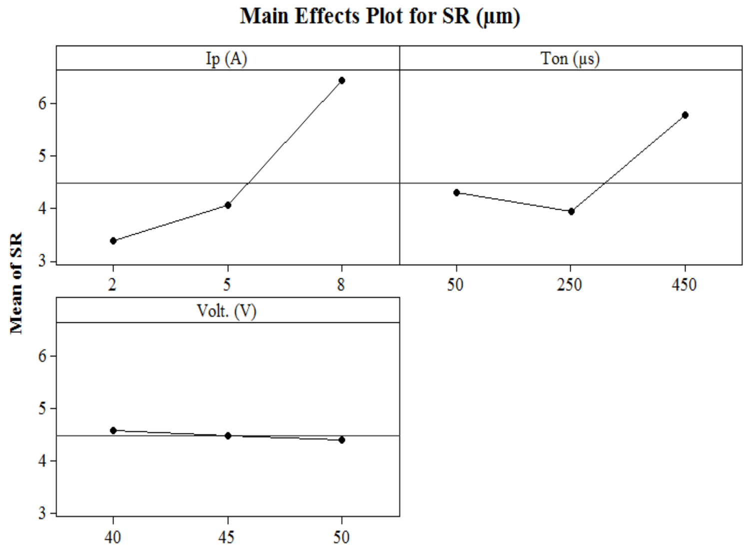

Fig. 8 Main effect plots for SR

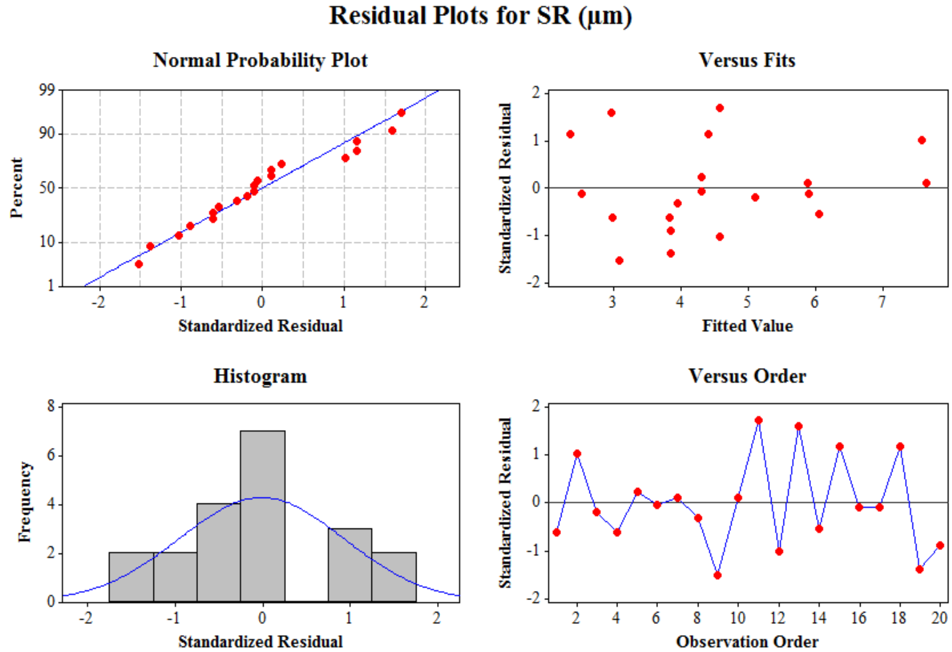

Fig. 9 Surface plots for SR

5. Conclusion

The tool material was taken as copper and the workpiece was chosen as AISI 303 stainless steel. Using the response surface methodology was created and the experiments were performed accordingly. The following conclusions were drawn:

1. For EWR the most significant factor was found to be peak current followed by pulse on time and the least significant was Voltage. The EWR increased nonlinearly with the increase in current. The optimized condition of the EWR is Ip = 8A, Ton = 450µs and V = 50 v.
2. For SR the most significant factor was again current followed by pulse on time and lastly the voltage. SR increased significantly with the increase in current in a nonlinear fashion. For increase in pulse on time SR increased up to 250 µs and then there was no significant increase. The optimized condition of the SR is Ip = 8A, Ton = 450µs and V = 50 v.

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