

Parameter Optimization of Electro Discharge Machining of SCM 420 Low Alloy Steel by using RSM

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Abstract: The experimental investigation deals with Electrical Discharge machining (EDM) SCM 420 low alloy steel using electrolytic copper as an electrode. The effect on cutting parameters peak current (I_p), pulse on time (T_{on}), and gap voltage (V_g) on performance characteristics such as material removal rate (MRR) and surface roughness (R_a). Based on Response Surface Methodology, mathematical models were developed. Analysis of variance (ANOVA) was performed to check the adequacy of the mathematical model and its respective variables. The experimental data were analyzed to predict the optimal range of material removal rate and surface roughness. The result shows that peak current is the most significant parameter. An increase in peak current results in an increase in MRR and R_a .

Keywords- Surface roughness, Electrical discharge machining, Material removal rate, Peak current, Response surface methodology.

1. Introduction

Electric discharge machining finds applications in machining difficult to machine materials used in space industries, refractory metals, and heat-treated steels, etc. EDM is the method with higher material removal rate. Due to melting and evaporation surface finish is also better. In electrical discharge machining metal, removal takes place due to electrical erosion. Controlled erosion of the material takes place by repetitive electric sparks between the workpiece and tool. The tool and workpiece which is the conductor of electricity are immersed in a dielectric medium and separated by a gap. An electric field is established when the potential difference is applied between the tool and workpiece. In general, the tool is connected to the negative terminal, and the workpiece is connected to the positive terminal. Due to the establishment of electric field-free electrons would be emitted from the tool. The emission of electrons is known as cold emission. These free electrons from the tool are accelerated towards the workpiece. The collision between dielectric molecules and free electrons causes the ionization of dielectric molecules. This process results in the concentration of electrons and ions in the dielectric medium between the tool and workpiece. This results in the generation of spark. High-Speed electrons impinge on the workpiece and the kinetic energy of electrons and ions is converted to thermal energy. The extreme temperature rise leads to material removal [1].

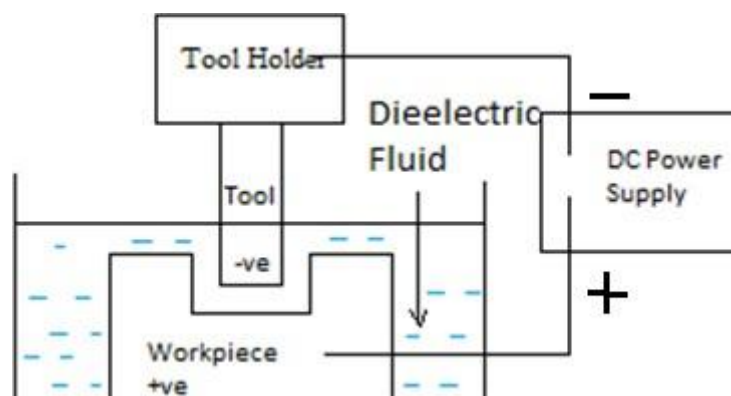


Fig. 1(a) Electrical discharge machining (EDM)

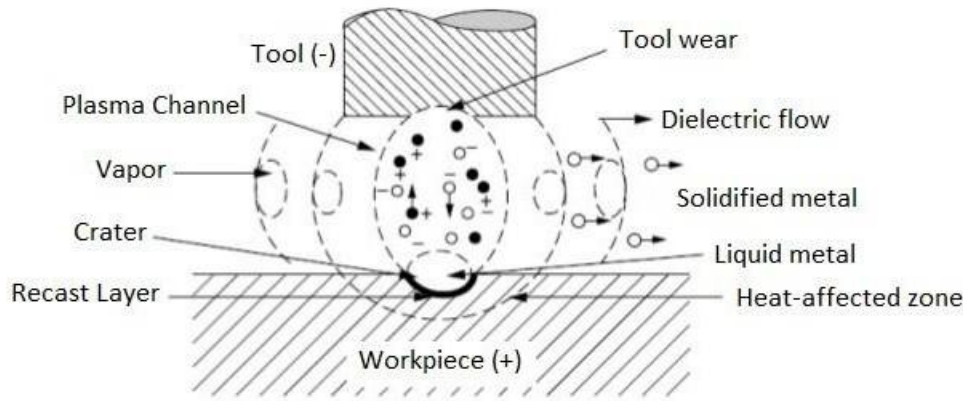


Fig. 1(b) Working principle of Electrical discharge machining (EDM)

2. Literature Review

Kurri *et. al* have defined RSM model to study the effect of discharge current, pulse on time, duty factor, and open discharge voltage in the EDM process of EN-31 on R_a . They observed a reduction of R_a value with decreasing current and with the increase of open discharge voltage [2]. Gurjar and Kumar have investigated the input process parameter namely discharge current, pulse on time, and feed of the tool for improved MRR and less TWR on EDM. They have used Taguchi and ANOVA [3]. The results revealed that current has statistical significance on MRR. Where TWR is influenced by current, feed, and pulse on time [3]. Two different electrode materials cast copper and sintered powder metallurgy copper and EN8 and D3 steel was used as workpieces by Balasubramanian and Senthilvel so as to analyze the EDM process using RSM. The value of MRR for EN-8 material was high and the TWR value was low for the cast electrode compared with the sintered electrode. The R_a value was less for sintered electrode compared with the cast electrode. Whereas, the mean value of MRR was high and low TWR for steel (D3). The mean value for R_a was lower for a sintered electrode as compared to the cast electrode [4].

Mathew *et. al.*, have studied the effect of input parameters of EDM process i.e., electrode type, peak current, gap voltage, and duty cycle on material removal rate of H11 steel. Taguchi's method was used for experimental design. Conventional Copper (Cu) and powder metallurgy (PM) copper tungsten (CuW) was used as tool materials. They found that MRR increases at reverse polarity with the conventional copper electrode as compared to powder metallurgy electrode [5]. Hourmand *et. al.* used a copper electrode and oil-based dielectric fluid mixed with aluminum powder. Response surface methodology was used to analyze EDM. They illustrated the effect of input variables on MRR, EWR, and microstructure changes. The conclusion was made that current and pulse on time are the most significant factors on MRR [7]. Tzeng and Chen investigated the influence of process parameters on MRR, TWR, and R_a during the manufacture of SKD61 by EDM. A hybrid method including a back-propagation neural network (BPNN), a genetic algorithm (GA), and RSM were used. The conclusion was that the cutting parameter of the discharge current is the most significant factor for MRR whereas pulse on time is the most significant factor for R_a [8]. Horacio T. Sánchez *et. al.*, have developed an inversion model based on least-squares theory to establish EDM process parameters namely peak current level, pulse-on time, and pulse-off time. ANOVA and regression models were used to predict the EDM output performance characteristics material removal rate (MRR), electrode wear ratio (EWR) and surface roughness (SR). AISI 1045 steel was used as workpiece material [13]. This literature survey reveals several relevant studies, which shows restrictions of different investigations related to commonly used metal. Hence, to find optimum settings of different process parameters of SCM 420 low alloy steel in EDM is still a challenge.

3. Experimental set up

The machine tool "Electrapuls PS 50 ZNC" electrical discharge machine is as shown in Fig. 2. Was used to carry out experiments on round bars of SCM420 material (55 to 57 HRC). The workpiece has a diameter of 38 mm and electrolyte copper was used as an electrode with a diameter of 20mm. The polarity of the electrode was positive whereas it was negative for the workpiece. EDM oil was used as dielectric fluid. A circular cavity of 20 mm diameter and 2 mm depth was made centrally on the face of each workpiece on EDM.



Fig. 2 Electrapuls PS 50 ZNC electrical discharge machine

3.1 Work piece material

The chemical composition of the workpiece material is given below in Table 1. SCM420 low alloy steel is used as workpiece material (diameter $\Phi 38$ mm and length 40mm).

Table 1 Chemical composition

C	Mn	Si	Ni	Mo	Cr	V	Cu	S	P
0.23%	0.90%	0.35%	0.25%	0.25%	1.20%	-	0.30%	0.030%	0.030%

3.2 Levels of process parameters

The process parameters chosen for the experimental study are peak current (A), pulse on time (μs) and gap voltage (V). The selection of the values of the variables is limited by the capacity of the machine used in the experimentation as well as recommended combinations depending on work piece and tool material. Process parameters and their levels are shown in Table 2.

Table 2 Levels of input process parameters

Process Parameters	Level		
	Low (-1)	Medium (0)	High (+1)
Peak current (A)	10	15	22
Pulse on time (μs)	400	500	750
Voltage gap (V)	25	30	32

3. Results and discussion

3.1 Experimental Results

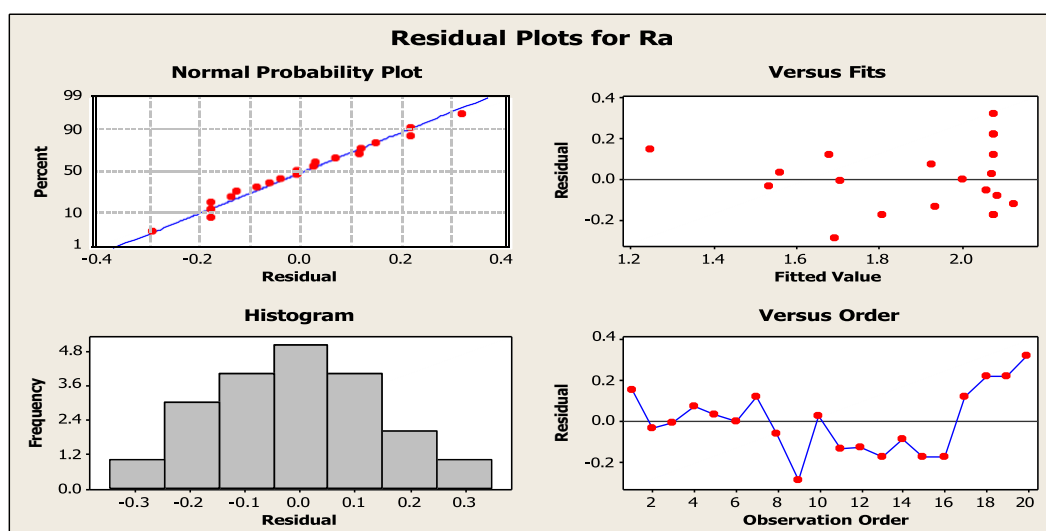
Response surface methodology is used for design of experiments. Experimental data obtained for surface roughness (R_a) and material removal rate (MRR) is analyzed and mathematical modeling is done for both output responses.

Table 3 Experimental results at different levels of process input parameters

Experimental run	I _p (A)	T _{on} (μs)	V _g (V)	MRR (mm ³ /s)	Ra (μm)
1	-1	-1	-1	2.5	1.4
2	+1	-1	-1	4.1	1.49
3	-1	+1	-1	2.3	1.71
4	+1	+1	-1	5.2	2
5	-1	-1	+1	2.8	1.59
6	+1	-1	+1	4.1	2
7	-1	+1	+1	3	1.8
8	+1	+1	+1	4.9	2
9	-1	0	0	4	1.4
10	+1	0	0	5.1	2.1
11	0	-1	0	4	1.79
12	0	+1	0	3.2	2
13	0	0	-1	3.3	1.63
14	0	0	+1	3.2	1.9
15	0	0	0	2.6	1.9
16	0	0	0	2.9	1.9
17	0	0	0	3	2.20
18	0	0	0	3.1	2.3
19	0	0	0	3.2	2.3
20	0	0	0	3.3	2.4

3.2 Discussion

The significance of effect is concluded from observed p-value by Comparing it to a commonly used α -level = 0.05. Figs. (3 and 4) reveals that the residuals generally fall on a straight line, implying that the errors are normally distributed. This implies that the models proposed for MRR and Ra are adequate, and there is no reason to suspect any violation of the independence or constant variance assumption.

Fig. 3. Residual plots for R_a

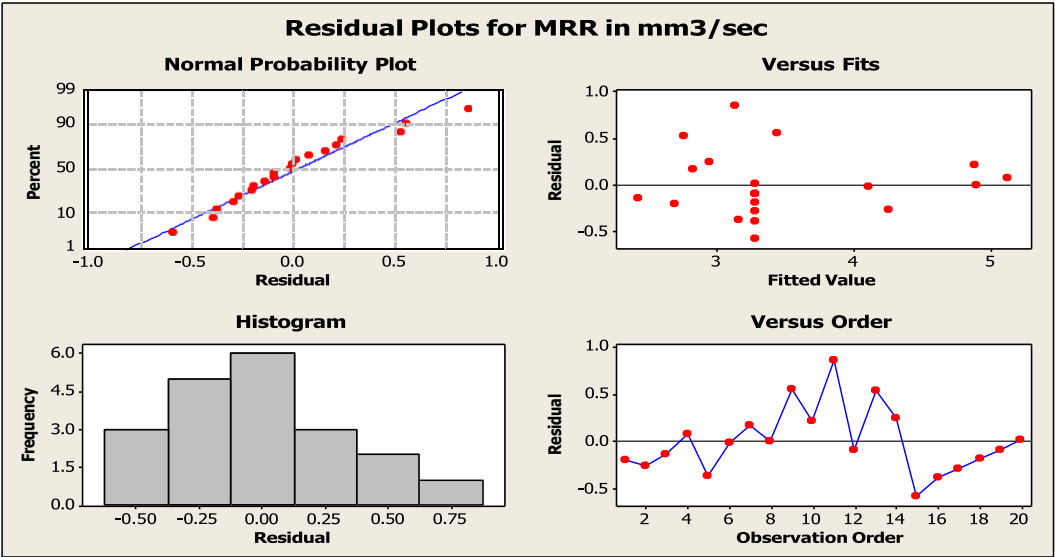


Fig. 4. Residual plots for MRR

The increase of current and pulse on-time MRR and Ra increases. Whereas, MRR is high at the higher level of gap voltage. This is due to the fact that sparks discharge energy increases to facilitate the action of melting and vaporization and advancing the large impulsive force in the spark gap. Therefore, a larger current causes deep craters with an increase in MRR and Ra.

The surface of material generated using EDM is composed of many microscopic craters associated with random spark discharge between the electrodes. The size of craters produced mainly on the workpiece surface depends mainly upon the energy of the discharge. As more energetic pulses usually lead to high material removal rate.

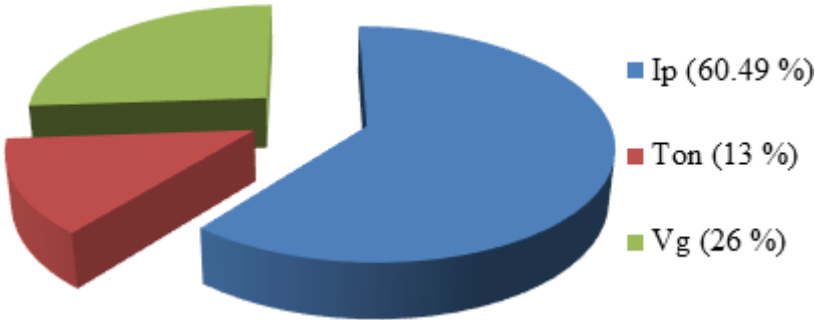


Fig. 5. Percentage Contribution of process parameters for Surface Roughness



Fig. 6. Percentage Contribution of process parameters for Material Removal Rate

4. Conclusions

The investigation is successful in achieving the optimization of EDM process parameters using RSM. This experiment evaluates the machining of SCM 420 low alloy steel with copper as the electrode. The analysis of experimental work is performed using MINITAB 16 statistical software and optimum values are calculated and confirmation tests are done. The important conclusions from the present experimental work are summarized as follows.

- a. Optimum values for process parameters are found to be peak current (22 A), pulse on time (400 μ s) and gap voltage (25 V).
- b. Peak current and pulse on-time found to be most significant on surface roughness and MRR values.
- c. Gap voltage found to be the least significant on MRR.
- d. Value of R_a decreases when current, pulse on time, and gap voltage decreases peak.
- e. So as to obtain high material removal rate in the case of SCM 420 steel, within the work interval considered in this study, high values for peak current and gap voltage should be used.
- f. So as to obtain low values of surface roughness low values of pulse on time, current and gap voltage is to be used.

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