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Study of the parameters in electrical discharge machining through response surface methodology approach

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ABSTRACT

Whereas the efficiency of traditional cutting processes is limited by the mechanical properties of the processed material and the complexity of the workpiece geometry, electrical discharge machining (EDM) being a thermal erosion process, is subject to no such constraints. The lack of correlations between the cutting rate, the surface finish and the physical material parameters of this process made it difficult to use. This paper highlights the development of a comprehensive mathematical model for correlating the interactive and higher order influences of various electrical discharge machining parameters through response surface methodology (RSM), utilizing relevant experimental data as obtained through experimentation. The adequacy of the above the proposed models have been tested through the analysis of variance (ANOVA). Optimal combination of these parameters was obtained for achieving controlled EDM of the workpieces.

1. Introduction

In non-traditional machining processing, electrical discharge machining (EDM) has tremendous potential on account of the versatility of its applications and it is expected that it will be successfully and commercially utilized in modern industries. EDM is a process for producing holes, external shapes, profiles or cavities in an electrically conductive workpiece by means of the controlled application of high-frequency electrical discharges to vaporize or melt the workpiece material in a particular area. The electrical discharges are the result of controlled pulses of direct current and occur between the tool electrode (cathode) and the workpiece (anode) [1,2].

Some researchers studied EDM of composite materials and ceramics [3,4]. An attempt has been made to develop mathematical models for optimizing EDM characteristics such as material removal rate, tool wear rate and surface roughness. A three level full factorial design was chosen for experimentation and mathematical models with linear, quadratic and interactive effects of the parameters chosen were developed [5]. Warrier Ashish et al. [6] determined the optimal setting of the process parameters of EDM machine while machining carbon–carbon composites. The parameters considered are pulse current, gap voltage and pulse-on-time, whereas the responses are electrode wear rate and material removal rate. They used Taguchi method to determine the optimal setting of the EDM parameters.

Fattouh et al. [7] studied the modeling of the EDM process for the purpose of providing minimum cost and maximum production rate. They used the response surface methodology to establish mathematical relations between the principal process parameters and response parameters such as material removal rate, percentage electrode wear and surface finish of electrical discharge machined surfaces.

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The present paper emphasizes the development of mathematical models for correlating the various machining parameters, such as pulse on time, peak current, average gap voltage and the percent volume fraction of SiC present in the aluminum matrix on the most dominant machining criteria, i.e. the metal removal rate, electrode wear ratio, gap size and the surface finish, for achieving controlled EDM. Machining parameters optimization has been carried out through response surface methodology, utilizing the relevant experimental data as obtained through experimentation. The adequacy of the developed mathematical models has also been tested by the analysis of variance test. Also, optimal combination of these parameters was obtained for achieving controlled EDM of the workpieces.

2. Material and methods

For carrying out the experiments, a numerical control programming electrical discharge machine known as "R50-EZNC" was used. The EZNC has the provisions of programming in the *Z*-vertical axis-control and manually operating *X* and *Y* axes. In this work, conductive metal matrix composite Al/SiC was selected as the workpiece material. Four different volume fraction percentages (5, 10, 20 and 25) of silicon carbide in the aluminum matrix were chosen. Also, for studying the effect of SiC percentage in EDM performance aluminum workpieces without any percentage of SiC particles were selected for this work.

The present experiments have been performed using copper electrodes (99.7% Cu, 0.12% Zn, 0.02% Pb, 0.02% Sn) with positive polarity. The electrode used is 15 mm in diameter and 50 mm in height. Commercial kerosene was used as a dielectric fluid. The machining was generally carried out for a fixed time interval and the amount of metal removed was measured by taking the difference in weights of the workpiece before and after electrical discharge machining.

Material removal rate (MRR) in mm^3/min and electrode wear ratio (EWR) can be calculated by the following formulae:

$$\mathrm{MRR} = \frac{1000 \times w_w}{\rho_w \times T} \cdots, \tag{1}$$

$$\mathrm{VEW} = \frac{1000 \times w_e}{\rho_e \times T} \cdots, \tag{2}$$

$$\mathrm{EWR} = 100 \times \frac{\mathrm{VEW}}{\mathrm{MRR}} \cdots, \tag{3}$$

where VEW is the volumetric electrode wear in mm^3/min, w_w is the workpiece weight loss in gms, w_e is the electrode weight loss in gms, ρ_w is the workpiece material density in gm/cm^3, ρ_e is the electrode material density in gm/cm^3 and T is the machining time in min.

The surface roughness (R_a) of each machined workpiece was measured using the Mitutoyo Talysurf (SJ – 201). Each experiment was repeated three times for better results and the average was calculated. For measuring the gap size, the diameter of the resulted hole in the workpiece block was measured three times at different locations and the average was calculated. Profile projector 10 multiplied by magnification was used to measure these diameters. The gap size (GS) was then calculated by the difference between the radius of the average measured diameter and the radius of the electrode.

3. Theory of the experimental design

The main objective of experimental design is studying the relations between the response as a dependent variable and the various parameter levels. It provides an opportunity to study not only the individual effects of each factor but also their interactions. Design of experiments is a method used for minimizing the number of experiments to achieve the optimum conditions [8].

The design of experiments for exploring the influence of various predominant EDM process parameters (e.g. pulse on time, peak current, average gap voltage and the percent volume fraction of SiC present in the aluminium matrix) on the machining characteristics (e.g. the material removal rate, electrode wear ratio, gap size and the surface finish), were modelled. In the present work experiments were designed on the basis of experimental design technique using response surface design method.

In order to determine the equation of the response surface, experimental design has been developed with the attempt to approximate this equation using the smallest number of experiments possible. In this investigation, experimental design was established on the basis of 2^k factorial, where k is the number of variables, with central composite-second-order rotatable design to improve the reliability of results and to reduce the size of experimentation without loss of accuracy [9,10]. Thus, the minimum possible number of experiments (N) can be determined from the following equations:

$$N = n_c + n_a + n \cdots, \tag{4}$$

$$n_c = 2^k \cdots, \tag{5}$$

$$n_a = 2k \cdots, \tag{6}$$

where n_c parameter defines the number of factorial points or corner points. One central composite design consists of cube points at the corners of a unit cube that is the product of the intervals $[-1, 1]$. The n_a parameter defines the number of axial

Table 1
Coding levels of process parameters.

Level	T_{ON} (μs)	I_P (amp.)	V_G (volt)	P (%)
−2	50	10	30	0
−1	100	14	32	5
0	150	20	34	10
+1	200	24	36	20
+2	500	30	38	25

points or star points along the axes or outside the cube at a distance $\gamma = k^{1/2}$ from the centre point of the design to a star point and no parameter means the number of centre points at the origin and can be get from tables according to the number of independent variables [11].

In the present experimental investigation, the effects of EDM conditions such as pulse on time (T_{ON}), pulse peak current (I_P), average gap voltage (V_G) and percent volume fraction of SiC (P) on material removal rate, volumetric electrode wear, spark gap size and surface roughness were studied. In this case $k = 4$ and thus $n_c = 2^k = 16$ corner points at ±1 level, $n_a = 2^k = 8$ axial points at $\gamma = \pm 2$, and a centre point at zero level repeated 7 times (n_o). This involves a total of 31 experimental observations. The coded levels for all process parameters used are shown in Table 1.

4. Response surface modelling

In statistics, response surface methodology (RSM) explores the relationships between several explanatory variables and one or more response variables. The main idea of RSM is to use a set of designed experiments to obtain an optimal response. central composite design can be implemented to estimate a second-degree polynomial model, which is still only an approximation at best. In this work, response surface modelling (RSM) is utilized for determining the relations between the various EDM process parameters with the various machining criteria and exploring the effect of these process parameters on the responses, i.e. the material removal rate, electrode wear ratio, gap size and the surface finish. In order to study the effects of the EDM parameters on the above mentioned machining criteria, second order polynomial response surface mathematical models can be developed. In the general case, the response surface is described by an equation of the form:

$$Y_u = \beta_\circ + \sum_{i=1}^{S} \beta_i x_i + \sum_{i=1}^{S} \beta_{ii} x_i^2 + \sum_{i\rangle i}^{S} \beta_{ij} x_i x_j \cdots, \tag{7}$$

where, Y_u is the corresponding response, e.g. the MRR, TWR, GS and Ra produced by the various process variables of EDM and the x_i (1,2,...,S) are coded levels of S quantitative process variables, the terms β_0, β_i, β_{ii} and β_{ij} are the second order regression coefficients. The second term under the summation sign of this polynomial equation is attributable to linear effect, whereas the third term corresponds to the higher-order effects; the fourth term of the equation includes the interactive effects of the process parameters. In this work, Eq. (7) can be rewritten according to the four variables used as:

$$Y_u = \beta_\circ + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_{11} x_{12} + \beta_{22} x_{22} + \beta_{33} x_{32} + \beta_{44} x_{42} + \beta_{12} x_1 x_2 + \beta_{13} x_1 x_3 + \beta_{14} x_1 x_4 + \beta_{23} x_2 x_3 + \beta_{24} x_2 x_4 + \beta_{34} x_3 x_4 \cdots\cdots, \tag{8}$$

where: x_1, x_2, x_3 and x_4 are pulse on time, peak current, average gap voltage and percent volume fraction of SiC respectively.

4.1. Mathematical modelling for MRR

Based on Eq. (8), the effects of the above mentioned process variables on the magnitude of the material removal rate have been evaluated by computing the values of the different constants of Eq. (8) using a curve fitting computer software "Oakdale Engineering (DataFit) version 8.2" [12] and utilizing the relevant data from Table 2. The mathematical relation for correlating the MRR and the considered process variables was obtained as follows:

$$\begin{aligned} Y_u(\mathrm{MRR}) = {} & 618.55993 - 7.50416E-03x_1 - 6.56817x_2 - 30.09905x_3 - 2.59182x_4 - 1.74368E-05x_{12} \\ & + 0.12973x_{22} + 0.39257x_{32} + 6.68543E-02x_{42} + 2.4234E-04x_1x_2 + 2.49988E-04x_1x_3 \\ & + 7.51773E-05x_1x_4 + 0.10008x_2x_3 - 2.99715E-02x_2x_4 + 0.02686x_3x_4. \end{aligned} \tag{9}$$

4.2. Mathematical modelling for EWR

A comprehensive model based on Eq. (8) has been developed to correlate the effects of the previously mentioned process parameters on the EWR criteria, utilizing the relevant experimental data as observed (Table 2) during the course of machin-

Table 2
Plan for central composite rotatable second-order design: different controlling parameters and results.

Experiment no.	x_1	x_2	x_3	x_4	Y_u (MRR)	Y_u (TWR)	Y_u (GS)	Y_u (R_a)
1	−1	−1	−1	−1	26.85641	2.685203	0.077407	4.987676
2	1	−1	−1	−1	26.75971	0.26545	0.087656	6.533458
3	−1	1	−1	−1	41.23893	5.463038	0.081256	5.399229
4	1	1	−1	−1	41.38458	1.926901	0.092652	7.216182
5	−1	−1	1	−1	19.48187	1.959431	0.06661	4.285287
6	1	−1	1	−1	19.48517	0.144678	0.07686	5.606111
7	−1	1	1	−1	37.8675	4.689346	0.071531	4.905782
8	1	1	1	−1	38.11314	1.758209	0.082928	6.497777
9	−1	−1	−1	1	19.76019	1.908296	0.069564	6.984586
10	1	−1	−1	1	19.77626	0.352515	0.078902	8.838425
11	−1	1	−1	1	29.647	4.211718	0.071538	7.642892
12	1	1	−1	1	29.90541	1.539553	0.082023	9.767901
13	−1	−1	1	1	13.99715	1.23239	0.059648	6.05741
14	1	−1	1	1	14.11321	0.281609	0.068986	7.686291
15	−1	1	1	1	27.88706	3.487892	0.062694	6.924657
16	1	1	1	1	28.24546	1.420727	0.073179	8.824709
17	−2	0	0	0	21.77827	4.672185	0.067841	4.588056
18	2	0	0	0	20.42996	0.624578	0.09382	8.107539
19	0	−2	0	0	17.4603	0.199092	0.071672	5.579863
20	0	2	0	0	52.66266	4.625881	0.078132	6.877754
21	0	0	−2	0	32.75563	2.617032	0.08518	7.724869
22	0	0	2	0	23.98461	1.746228	0.065461	6.196005
23	0	0	0	−2	38.07143	2.876037	0.085747	5.004775
24	0	0	0	2	23.18556	1.868311	0.070775	8.649102
25	0	0	0	0	22.08894	1.533243	0.08042	6.653381
26	0	0	0	0	22.08894	1.533243	0.08042	6.653381
27	0	0	0	0	22.08894	1.533243	0.08042	6.653381
28	0	0	0	0	22.08894	1.533243	0.08042	6.653381
29	0	0	0	0	22.08894	1.533243	0.08042	6.653381
30	0	0	0	0	22.08894	1.533243	0.08042	6.653381
31	0	0	0	0	22.08894	1.533243	0.08042	6.653381

ing for such purposes as varying parametric combinations. The mathematical relations thus obtained for analyzing the influences of the various dominant machining parameters on the TWR criteria is given by:

$$\begin{aligned} Y_u(\mathrm{EWR}) = {} & 61.76541 - 7.90436E - 02x_1 + 0.10946x_2 - 3.07572x_3 - 0.24833x_4 + 6.3985E - 05x_{12} \\ & + 8.79244E - 03x_{22} + 4.05242E - 02x_{32} + 6.26469E - 03x_{42} - 1.11638E - 03x_1x_2 - 1.5125E \\ & - 03x_1x_3 + 5.75982E - 04x_1x_4 - 1.19799E - 03x_2x_3 - 3.16275E - 03x_2x_4 + 8.311E \\ & - 04x_3x_4 \cdots\cdots. \end{aligned} \tag{10}$$

4.3. Mathematical modelling for GS

As mentioned in Eq. (8), a developed model has been evaluated to correlate between the response gap size (GS) and the EDM conditions employed in this work. An empirical mathematical relation can be determined as follows:

$$\begin{aligned} Y_u(GS) = {} & -0.22445 + 1.47807E - 04x_1 + 1.57185E - 03x_2 + 1.85221E - 02x_3 - 6.4621E - 04x_4 - 1.94435E \\ & - 07x_{12} - 5.5177E - 05x_{22} - 3.18672E - 04x_{32} - 4.40999E - 06x_{42} + 1.14697E - 06x_1x_2 + 6.90315E \\ & - 11x_1x_3 - 6.07739E - 07x_1x_4 + 2.67992E - 05x_2x_3 - 1.24999E - 05x_2x_4 + 1.46688E - 05x_3x_4 \cdots\cdots. \end{aligned} \tag{11}$$

4.4. Mathematical modelling for Ra

According to Eq. (8), a proposed mathematical model between surface roughness (Ra) and the independent variables such as pulse peak current, pulse on time, average gap voltage and percent volume of SiC can be given as:

$$\begin{aligned} Y_u(R_a) = {} & 28.17869 + 3.96302E - 02x_1 - 2.44761E - 06x_2 - 1.47874x_3 + 0.24126x_4 - 3.66634E - 05x_{12} \\ & - 4.24572E - 03x_{22} + 1.9191E - 02x_{32} - 1.2725E - 03x_{42} + 2.71171E - 04x_1x_2 - 5.62393E - 04x_1x_3 \\ & + 2.05371E - 04x_1x_4 + 5.22354E - 03x_2x_3 + 1.64502E - 03x_2x_4 - 3.74646E - 03x_3x_4 \cdots\cdots. \end{aligned} \tag{12}$$

Table 3
Analysis of variance test results for Eqs. (9)–(12).

Source of variation		Regression	Error	Total
Degrees of freedom		14	16	30
Sum of squares	Eq. (9)	2380.141	305.534	2685.675
	Eq. (10)	62.001	12.756	74.757
	Eq. (11)	0.002042	0.000182	0.00222
	Eq. (12)	51.829	1.42	53.249
Mean squares	Eq. (9)	170.01	19.096	
	Eq. (10)	4.429	0.797	
	Eq. (11)	0.0001459	0.00001137	
	Eq. (12)	3.702	0.08877	
F-ratio	Eq. (9)	8.903		
	Eq. (10)	5.555		
	Eq. (11)	12.825		
	Eq. (12)	41.704		

The correlation coefficients for equations from (9)–(12) are 0.933, 0.872, 0.962 and 0.917 respectively. The adequacy of the above four proposed models have been tested through the analysis of variance (ANOVA). The variance is the mean of the squared deviations about the mean or the sum of the squared deviations about the mean divided by the degrees of freedom. The fundamental technique is a partitioning of the total sum of squares and mean squares into components such as data regression and its error. The number of degrees of freedom can also be partitioned in a similar way as discussed in Table 3. The usual method for testing the adequacy of a model is carried out by computing the F-ratio of the lack of fit to the pure error and comparing it with the standard value. If the F-ratio calculated is less than the standard values, the postulated model is adequate [8,10]. The results of the analysis justifying the closeness of fit of the mathematical models have been enumerated. It is concluded that the evolved models given by Eqs. (9)–(12) are quite adequate and demonstrate the independent, quadratic and interactive effects of the different machining parameters on the MRR, TWR, GS and the Ra criteria values.

5. Results and discussion

In order to study the machined surface by EDM process of Al–SiC workpieces, some micrographs were taken as shown in Fig. 1.

5.1. EDM parametric influence on the MRR

Metal removal rate in EDM is an important factor to estimate the time of finishing the machined part. In this work MRR values are relatively smaller probably due to the decrease in the conductivity of the work material with refractory dispersions.

Based on Eq. (3), as developed through experimental observations and response surface methodology, studies were carried out to analyze the effects of the various process variables on the MRR. The effect of variation of pulse on time and SiC percentage on EDM metal removal rate is shown in Fig. 2. It can be noticed that an increase of pulse on time causes an increase in the metal removal rate slightly until it reaches a point of 200 μs and then the material removal rate begins to decrease again. The increase in pulse on time means applying the same heating flux for a longer time. This will cause an increase of heat that is conducted into the workpiece as the plasma channel expands which will result in an increase in the MRR [13,14]. As the discharge duration increases, the pressure inside the plasma channel will be lower [15]. So, no more

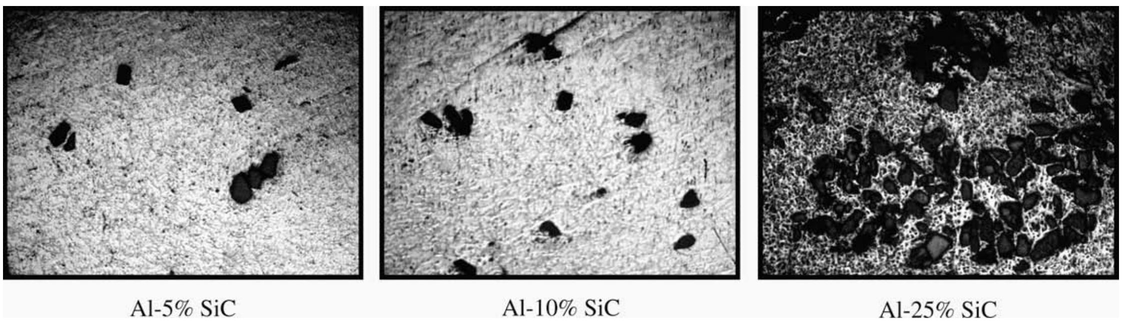

Fig. 1. Some micrograph of the machined samples (200×).

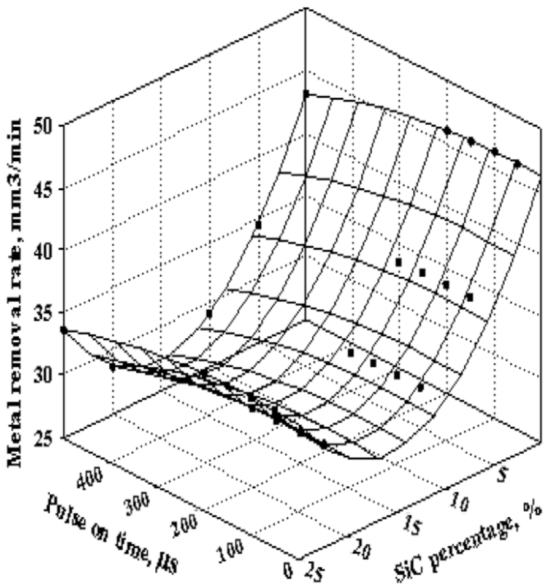

Fig. 2. Effect of pulse on time and SiC percentage on the MRR at peak current of 10 Amp. and gap voltage of 30 V.

increase in MRR since the molten metal volume does not change and further increase may be a cause to decrease MRR slightly.

The MRR values decrease with the increase of SiC percent amounts until it reaches to 15% and then begins to increase slightly again. The SiC ceramic particles were not melted during the machining process [16,17]. In this case the removal of the particle reinforced aluminium alloy matrix composite occurs through melting and vaporizing the aluminium matrix material around the SiC ceramic particles up to a point where the SiC particle becomes detached. The increase of MRR again at higher percentage of SiC is probably due to the more affected area of SiC particles with the EDM sparks energy.

Fig. 3 shows the variation of the MRR with respect to the peak current and gap voltage. The figure indicates that the metal removal rate increases with the increase of peak current for all values of gap voltages except at lower values of gap voltage, where it first decreases slightly and then begins to increase. The increase of peak current will increase the pulse discharge energy channel diameter and hence an increases in the crater diameter and depth which in turn can improve the metal removal rate [7]. The figure also demonstrates that the MRR decreases non-linearly with the increase of gap voltage, but after reaching a minimum value, it has a tendency to increase. Low values of gap voltage can give rise to increase in MRR. However, application of very low values has arcing tendency. Also, higher values of gap voltage can result in relatively lower metal removal rates.

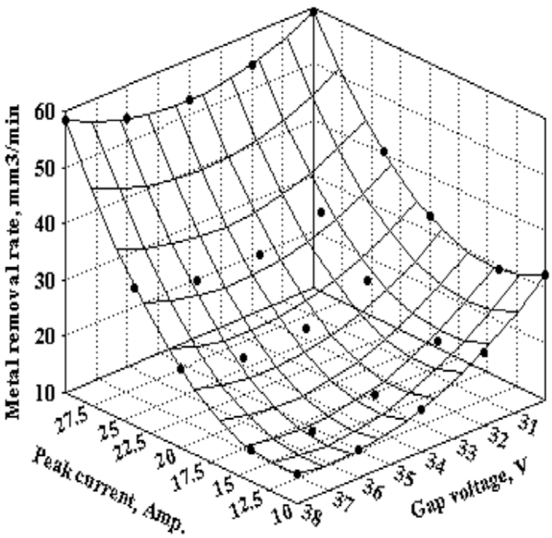

Fig. 3. Effect of peak current and gap voltage on the MRR at pulse on time of 150 MHz and SiC percentage of 10%.

5.2. EDM parametric influence on the EWR

Based on the mathematical model given by Eq. (4), the study of the effects of various machining parameters has been made in order to analyze the suitable parametric combinations that can be made for achieving controlled electrode wear ratio. Fig. 4 shows the effect of pulse on time and SiC percentage on EWR criteria. It can be seen that the electrode wear ratio values decrease as the pulse on time values increase for all SiC percentages for a preset peak current and gap voltage combination. With small values of pulse duration, a higher number of negatively charged particles in motion strike the positive tool electrode thus increasing the rate of melting in electrode material [7].

The electrode wear ratio values decrease with the increase of SiC percent amounts until it reaches to a minimum value at 15% and then begins to increase again. Since the VEW is proportional to the MRR, the presence of a large amount of abrasive particles in the debris causes excessive tool wear during flushing. After that as the material removal rate decreases, the electrode wear ratio also decreases [5].

Fig. 5 shows the influence of peak current and gap voltage on the electrode wear ratio for a preset pulse on time and SiC percent amount. The figure demonstrates that for each chosen gap voltage, the EWR increases with increase in the peak cur-

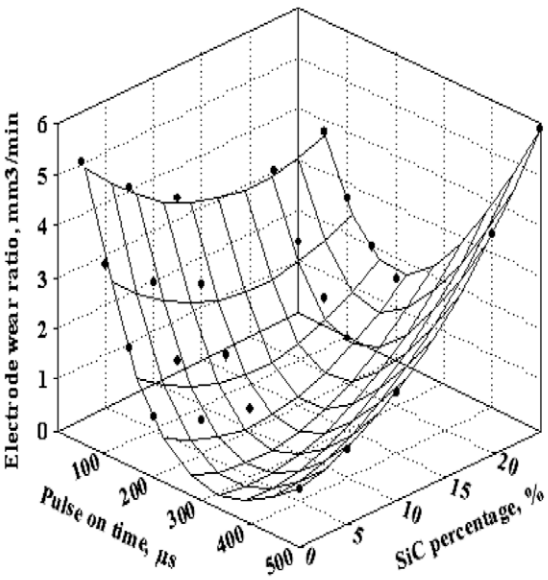

Fig. 4. Effect of pulse on time and SiC percentage on the EWR at peak current of 10 Amp. and gap voltage of 30 V.

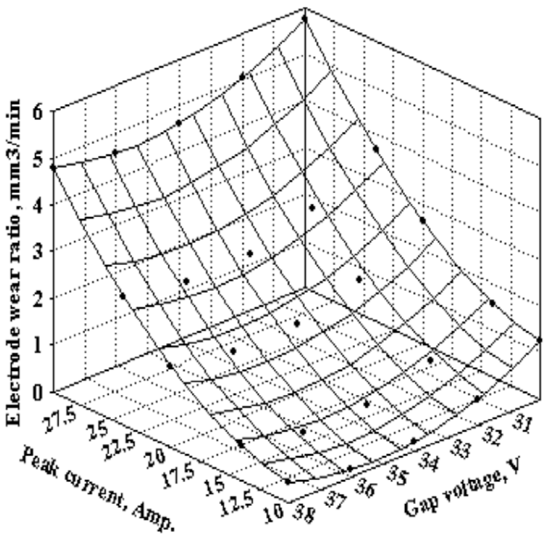

Fig. 5. Effect of peak current and gap voltage on the EWR at pulse on time of 150 MHz and SiC percentage of 10%.

rent in a parabolic fashion. Machining with higher values of discharge current means higher heat energy is subjected to both electrodes. The volume of the molten and ejected metal from both of them will increase.

5.3. EDM parametric influence on the GS

Studying effects of various machining parameters on the gap size has been made based on the mathematical model given by Eq. (5). Fig. 6 shows the effect of pulse on time and SiC percentage on the gap size for preset values of peak current and gap voltage. It can be noticed that the gap size values increase with the pulse-on-time increase for all SiC percentages. This may be due to that in EDM process the values of gap size are proportional to material removal rate. The gap size values decrease with the increase of SiC percent amounts. This is probably due to the decrease of metal removal rate.

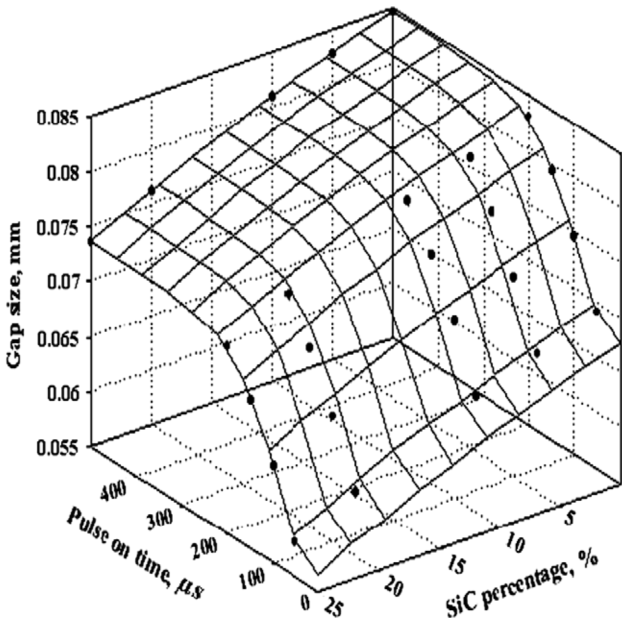

Fig. 6. Effect of pulse on time and SiC percentage on the GS at peak current of 10 Amp. and gap voltage of 30 V.

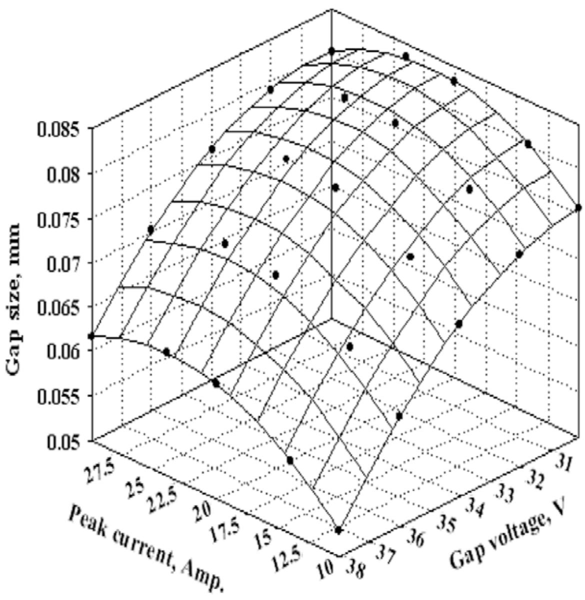

Fig. 7. Effect of peak current and gap voltage on the GS at pulse on time of 150 MHz and SiC percentage of 10%.

Fig. 7 shows the influence of both peak current and gap voltage on the gap size for a preset pulse on time and SiC percent amount. It can be seen that the gap size increases gradually with an increase in the both peak current and gap voltage. It can be seen also at a certain peak current the GS decreases with further increase of peak current.

5.4. EDM parametric influence on the Ra

Since the material removal in EDM is achieved through the formation of craters due to the sparks, it is obvious that larger crater sizes result in a rough surface. So, the crater size, which depends mainly on the energy per spark, controls the quality of the surface. Based on the mathematical model given by Eq. (6), the study of the effects of various machining parameters on surface roughness parameters has been made. The roughness of the machined surface increases as the energy of the pulse increases. In other words, at higher pulse energy the metal removal rate increases and the surface will be rough.

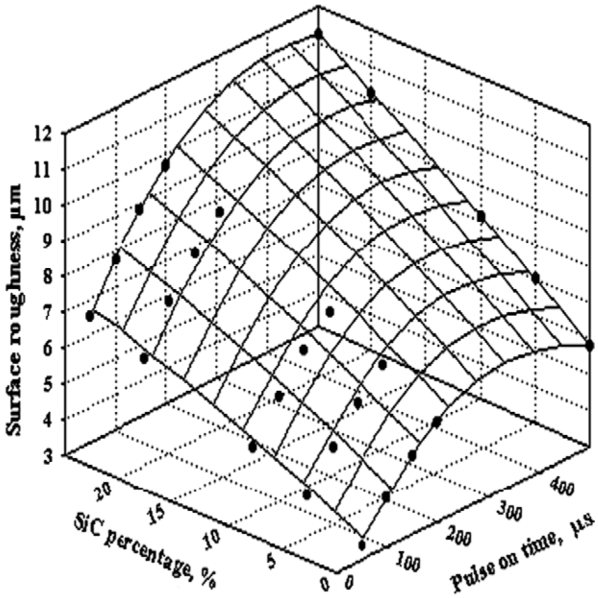

Fig. 8. Effect of pulse on time and SiC percentage on the Ra at peak current of 10 Amp. and gap voltage of 30 V.

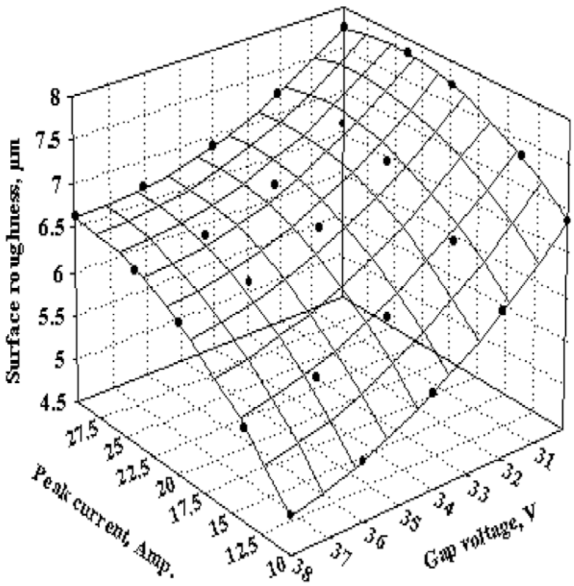

Fig. 9. Effect of peak current and gap voltage on the Ra at pulse on time of 150 MHz and SiC percentage of 10%.

Table 4
Optimal values of EDM parameters.

Process parameters	Value obtained			
	MRR	EWR	GS	Ra
Pulse on time, MHz	250	500	50	50
Peak current, Amp.	30	28	10	10
Gap voltage, V	30	36	28	38
SiC particles percentage, %	0	0	25	0

Fig. 8 indicates also that the surface roughness value increases with an increase in the SiC percentage. The SiC particles did not melt during the machining process thus the molten material is more viscous, which results in a decrease in removal efficiency. With an increase in the SiC percent amount, the voids left exposed on the surface by the SiC particles causing an increase in the surface roughness [5,17]. For a definite values of pulse on time and SiC percent amount, the surface roughness values increase with the increase of both of the peak current and gap voltage as shown in Fig. 9.

It is believed that the increase in peak current causes an increase in the discharge heat energy at the point where the discharge takes place. At this point, a pool of molten metal is formed and overheated. The molten metal evaporates and so forming gas bubbles that explode when the discharge takes place, taking the molten metal material away. Successive discharges will result in craters and pock marks, thus increasing the surface roughness [7].

6. Optimality search

For the purpose of achieving controlled electro-discharge machining, optimal combination of the various process-variable effects with the machining parameters such as the MRR, EWR, GS and Ra values, can be analyzed based on the developed mathematical models. The optimal search was formulated for the various process variable conditions based on maximizing the MRR, minimizing the EWR, GS and Ra values. The optimal combination of various process variables thus obtained within the bounds of the developed mathematical models. The optimal values resulted have been listed, as shown in Table 4.

7. Conclusions

The analysis of the experimental observations highlights that the metal removal rate, electrode wear ratio, gap size and surface roughness in electrical discharge machining are greatly influenced by the various dominant process parameters considered in the present study. In fact, the metal removal rate increases with an increase of pulse on time, peak current and relatively with gap voltage. Metal removal rate decreases with increase of SiC percentage. Electrode wear ratio increases with an increase of both pulse on time and peak current and decreases with increase of both of SiC percentage and gap voltage. The gap size decreases with the increase of SiC percentage and increases with the increase of pulse on time, peak current and gap voltage. Finally, the surface roughness increases with the increase of pulse on time, SiC percentage, peak current and gap voltage.

The mathematical models have been developed on the basis of RSM, utilizing the data from practical observable conditions of the electrical discharge machining of workpieces. Investigations were carried out for analysis of the control conditions needed for the control of the material removal rate, electrode wear ratio, gap size and surface roughness. The comprehensive models thus developed have been found to be quite unique, powerful and flexible. These models reflect the complex, interactive and higher order effects of the various predominant process parameters, e.g. the pulse on time, peak current, average gap voltage and SiC percentage on the respective material removal rate, electrode wear ratio, gap size and surface roughness criteria, as has been justified through the various experimental analyses and test results.

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