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Optimization of Electrical Discharge Machining Process Parameters using JIS SCM420 low alloy steel by Response Surface Methodology

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Abstract
Electrical discharge machining is a nonconventional machining process which enables machining of complex and intricate shapes, hard materials that are precise and difficult to machine such as heat treated tool steels, composites, super alloys, ceramics, carbides, heat resistant steels etc. The process involves spark erosion in the presence of dielectric fluid. In this work SCM 420 low alloy steel material is used for the machining purpose with electrolyte copper as tool. The present work is concerned with analysis of Material removal rate (MRR) and surface roughness (R_a). Input parameters used for the study are peak current (I_P), pulse on time (T_{on}) and gap voltage (Vg). Response surface methodology is used for experimental design. Peak current found to be most significant parameter for output responses. The suggested model can be used in the different manufacturing firms by selecting right combination of process parameters to achieve optimal values of output responses.
Keywords- *Electrical discharge machining, Material removal rate, Peak current, Response surface methodology, Surface roughness*

1. Introduction

Among the many unconventional processing techniques, EDM has proved itself to be one among the effective tool in shaping such difficult to machine materials. Electrical discharge machining is used to make dies, punches and moulds. This process is best suitable for finishing automotive, aircraft and surgerical components. The surface of material is cut due to spark erosion by means of a formed electrode tool. This sparks occur across a small gap between tool and work surface. The EDM process is carried out in the presence of a dielectric fluid which creates a path for each spark as the fluid becomes ionized in the gap. The sparks are generated by a power supply connected to the work piece and the tool. The discharge occurs at the location where the two surfaces are close to each other and the dielectric fluid ionizes at this location. The work surface is suddenly melted and removed due to generation of extreme high temperature. The flowing dielectric then flushes away the removed particles of material [1]. Recently several research works related to different aspects of EDM on different work piece and tool material have been done. It is noticed that Milan Kumar Das *et. al*. observed the effect of process parameters on MRR and R_a. Electrical discharge machining of EN31 tool steel was done using artificial bee colony (ABC) algorithm. Response surface methodology was used for experimental design. It was seen that MRR and Ra were proportional to pulse on time and discharge current [2]. Mehdi 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. Conclusion was made that current and pulse on time is the most significant factors on MRR [3]. S. Gopalakannan *et. al.* studied the effect of process variables on MRR, EW and R_a. The newly engineered metal matrix composite of aluminium 7075 reinforced with 10wt% of B4C particles were prepared by stir casting method. Experiments were carried out by response surface methodology. They found two main significant factors that affect the MRR and R_a are pulse current and pulse on time [4].The influence of operating parameters on the EDM of WPS DIN 1.2379/AISI D2 tool steel using the copper electrode material was studied by S. B. Chikalthankar, *et. al.* Design of experiment was conducted with L9 orthogonal array and Multi- objective Optimization was carried out with the help of Response surface methodology to optimize both the responses They concluded that current followed by a pulse-on time, gap voltage and pulse-off time were the influencing factors for surface roughness[5]. The investigation for the Effect of the process parameters on MRR was done by Md. Ashikur Rahman Khan. Analysis and modeling was carried out using design of experiment and response surface methodology. They concluded that, high ampere combined with short off time and low servo voltage yield maximum MRR [6]. The feasibility of machining Ti6Al4V with a bundled electrode was studied by Lin Gu, LeiLi *et. al.* and its effect on EDM performance was compared experimentally using a solid die-sinking electrode. They observed that, compared with a solid die-sinking electrode, bundled electrodes can endure a much higher peak current which results in higher MRR and a lower TWR[7]. Ko-Ta Chiang has studied the effects of machining parameters on the performance characteristics in the EDM process of Al2O3+TiC mixed ceramic. Mathematical models were developed using the response surface methodology to explain the influences of machining parameters [8]. Mr. Kurri Rohan Ramesh and Jagtap Shrikant Tukaram have studied the effect of process parameters on R_a. The work piece material was alloy steel (EN-31).From the analysis of response surface methodology they concluded that peak current was the most significant factor for surface roughness. Whereas gap voltage found to be least significant factor for roughness. They prepared mathematical models using the response surface methodology (RSM) to correlate dominant machining parameters [9]. Optimization of MRR and TWR was done on EDM by Suresh Kumar Gurjar and Rajeev Kumar by using Taguchi and ANOVA. They attempted for finding feasibility of machining die steel H13 work piece using circular copper electrode and dielectric flushing. They observed that current have the statistical significance on MRR whereas TWR is influenced by current, feed and pulse on time [10]. Experiments were conducted for three different work piece materials to find the effect of work piece material variation by P. Sahoo *et. al.* by using RSM. Influence of machining parameters was studied on the quality of surface produced in EDM. Five roughness parameters, such as centre line average roughness, root mean square roughness, skewness, kurtosis and mean line peak spacing have been considered. They found that, pulse current has the maximum influence on the roughness parameters [11].

SCM 420 is low alloy steel which has high fatigue strength is used to make all kinds of fasteners; high pressure pipe and more advanced carburized parts, such as gear, shaft, crankpin etc. SCM420 low alloy steel is a novel material and there is no research found addressing the effects of EDM parameters (peak current, pulse on time and gap voltage) on this material. High MRR and low surface roughness are important in the roughing step of the EDM process. Therefore, developing a mathematical model and simultaneously evaluating the optimal machining parameters for MRR and R_a during the EDM process of SCM420 low alloy steel material are some of the goals of the current research. Another aim is to observe the effects of EDM parameters on the output responses MRR and R_a. For this purpose Central composite design of response surface methodology is used.

2. Experimental set up

The experiments were carried out on an Electrapuls PS 50 ZNC electrical discharge machine on round bars of SCM420 material (55 to 57 HRC) which has diameter 38 mm with electrolyte copper as electrode (tool of 20 mm diameter). The polarity of the electrode was positive and EDM oil (mixture of paraffin, kerosene and deionized water) was used as dielectric fluid. For experimentation purpose and for each run same tool was used and a circular cavity of 20 mm diameter and 2 mm depth was made centrally on face of each work piece by spark erosion on EDM. Pictorial view of experimental set up is shown in the Fig. 1

Fig. 1 Pictorial view of Electrapuls PS 50 ZNC electrical discharge machine

2.1 Work piece material

SCM420 low alloy steel is used as work piece material. (Φ38mm X 40mm) The chemical composition of material is shown in table 1

Table 1 Chemical composition

Element	Min	Max
C	0.18	0.23
Mn	0.60	0.90
Si	0.15	0.35
Ni	0.00	0.25
Mo	0.15	0.25
Cr	0.90	1.20
V	-	-
Cu	0.00	0.30
S	0.00	0.030
P	0.00	0.030

The mechanical properties of material are shown in table 2

Table 2 Mechanical Properties

Properties	Value
Young's modulus (MPa)	200000 – 200000
Tensile strength (MPa)	650 – 880
Elongation (%)	41876
Fatigue (MPa)	275 – 275
Yield strength (MPa)	350 – 550

2.2 Levels of process parameters

The process parameters chosen for the present 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 3

Table 3 Process parameters and their levels
(3 levels each for 3 factors)

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

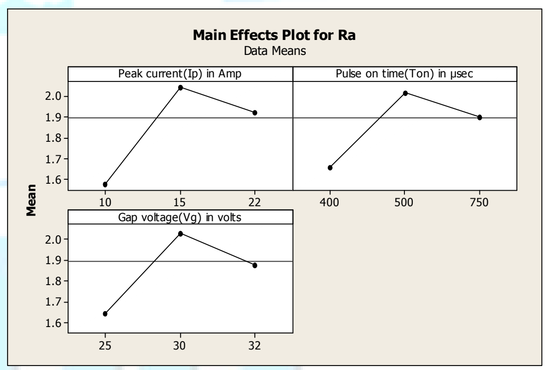
The result through experimental work is recorded as shown in table 4 Response surface methodology is used for design of experiments. Experimental data obtained for Surface Roughness (R_a) and Material Removal Rate (MRR) is analyzed and Mathematical modeling is done for both output responses.

Table 4 Experimental result

Exp. run	I_p (A)	T_{on} (µs)	V_g (V)	MRR (mm^3/s)	Ra (µm)
1	10	400	25	2.5	1.4
2	22	400	25	4.1	1.5
3	10	750	25	2.3	1.7
4	22	750	25	5.2	2
5	10	400	32	2.8	1.59
6	22	400	32	4.1	2
7	10	750	32	3	1.8
8	22	750	32	4.9	2
9	10	500	30	4	1.4
10	22	500	30	5.1	2.1
11	15	400	30	4	1.8
12	15	750	30	3.2	2
13	15	500	25	3.3	1.63
14	15	500	32	3.2	2
15	15	500	30	2.7	1.9
16	15	500	30	2.9	1.9
17	15	500	30	3	2.2
18	15	500	30	3.1	2.3
19	15	500	30	3.2	2.3
20	15	500	30	3.3	2.4

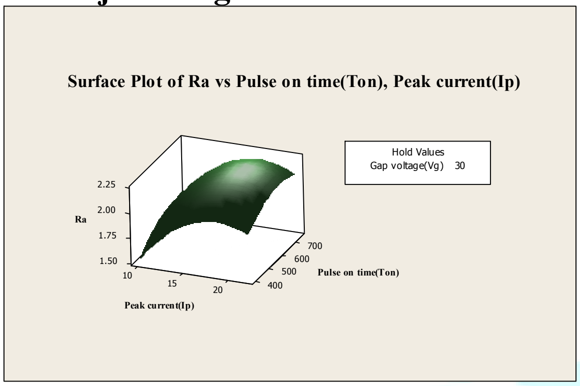
3.2 Discussion

Comparing the p-value to a commonly used α-level = 0.05, it is found that if the p-value is less than or equal to α, it can be concluded that the effect is significant. This clearly indicates that R_a and MRR are greatly influenced by the peak current followed by pulse on time and gap voltage. It can be observed from graph 1 that peak current has a huge impact on roughness value R_a. Graph shows peak current, pulse on time and gap voltage at low level gives low R_a value and peak current at high level gives high R_a value but after reaching the middle level R_a value goes on decreasing.



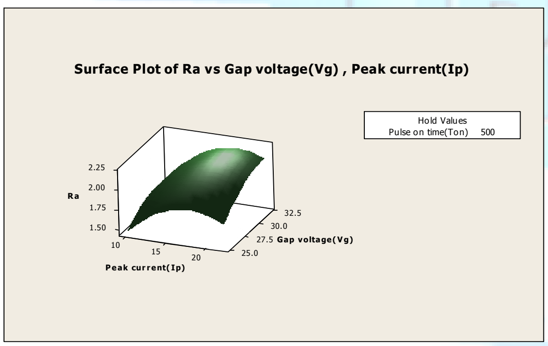
Graph 1 Main effects plot for R_a

The surface plot between peak current and pulse on time (graph 2) shows that increase of both these parameters results increase in surface roughness. The reason for this is that sparks discharge energy increases to facilitate action of melting and vaporization and advancing the large impulsive force in the spark gap. Therefore larger current causes deep craters with increase in surface roughness.



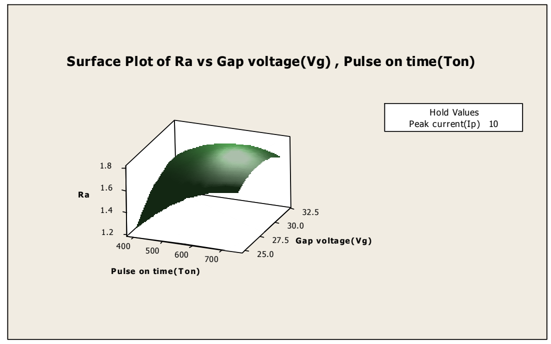
Graph 2 Surface plot representing effect of Ip and T_{on} on Ra

The surface plot between peak current and gap voltage for R_a (graph 3) shows that with the increase of current and gap voltage R_a increases. This is due to increase in sparks discharge energy.



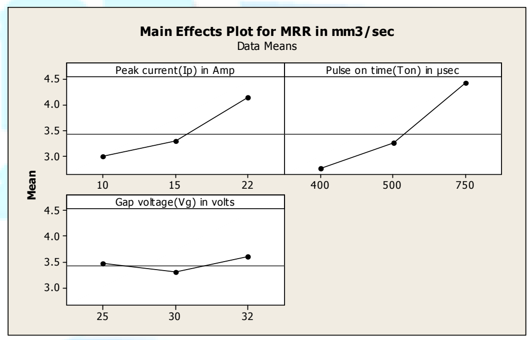
Graph 3Surface plot representing effect of V_g and I_p on R_a

The surface plot between gap voltage and pulse on time (graph 4) shows that R_a increases with increase in Gap voltage. Whereas with increase of pulse on time R_a increases to some extent but further increase of pulse on time causes reduction in R_a. As the voltage increases, spark also increases and due to this larger but sallower craters are formed. This is due to expansion of the plasma channel in the discharge gap.



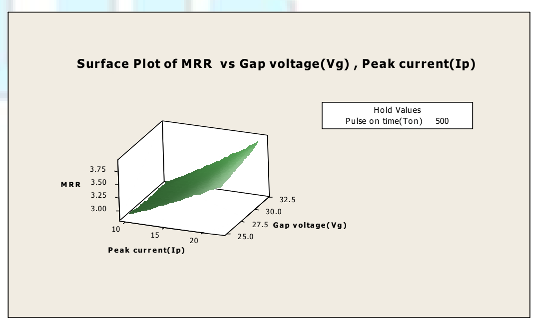
Graph 4 Surface plot representing effect of V_g and T_{on} on R_a

Graph 5 shows that peak current and pulse on time are the most significant parameters for MRR. MRR increases with increase of peak current and pulse on time. Whereas MRR slightly decreases up to middle level of gap voltage and then increases.



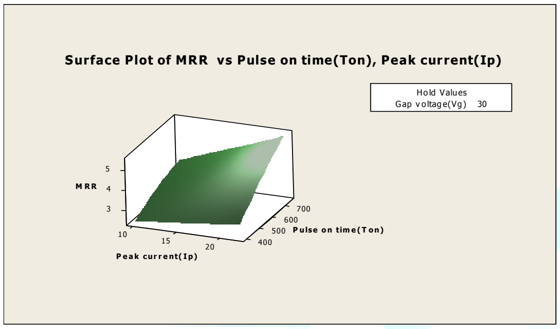
Graph 5 Main effects plot for MRR

The surface plot between peak current and gap voltage (graph 6) shows that increase of both these parameters results increase in MRR. Larger current causes deep craters with increase in MRR.



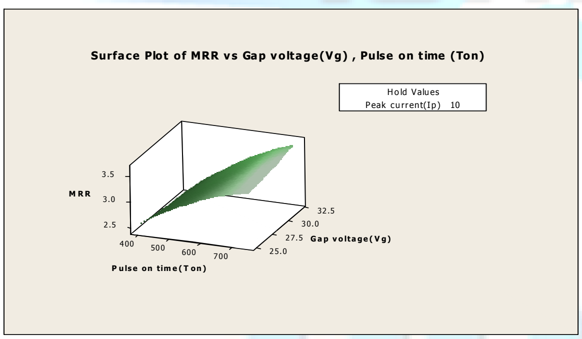
Graph 6 Surface plot representing effect of V_g and I_p on MRR

It can be concluded from graph 7 that with increase of peak current and pulse on time MRR increases. This is due to larger current which causes deep craters with increase in MRR and generation of large impulsive forces in spark gap.



Graph 7 Surface plot representing effect of Ip and T_{on} on MRR

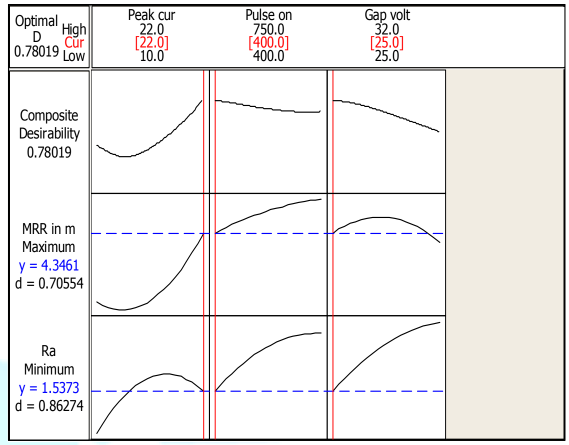
The surface plot between voltage and pulse on time (graph 8) shows that MRR increases with increase in pulse on time. Due to high pulse on time, maximum spark discharge energy causes high MRR.



Graph 8 Surface plot representing effect of V_g and T_{on} on MRR

3.3 Optimization Plot

Graph 9 shows the optimal set of condition with higher desirability function required for obtaining desired response characteristics under specified constraints. For MRR and Ra using MINITAB16 stastical software, the set of conditions possessing highest desirability value is selected as optimum condition for the desired responses. It shows optimum values of I_p, T_{on} and V_g are 22 A, 400 µs and 25 V respectively.



Graph 9 Optimization plot for MRR and R_a

4. Conclusions

Basically this investigation is successful in achieving the objective with the acceptable outcome. This experiment evaluates the machining of JIS SCM 420 low alloy steel with a copper as electrode. Response surface methodology (RSM) has been utilized to investigate the influence of three important parameters - peak current (A), pulse on time (µs) and gap voltage (V) on two responses namely Surface Roughness (R_a) and Material Removal Rate (MRR). The analysis of experimental work is performed using MINITAB 16 statistical software and optimum values are calculated and confirmation tests are done. Confirmation test error is less than 5% which indicates the validation of the predicted models. The important conclusions from the present research work are summarized as follows.

a. Optimum values for process parameters are found to be peak current (22 A), pulse on time (400 µs) and gap voltage (25 V).
b. From statistical analysis, it is clear that peak current and pulse on time have significant effects on surface roughness and MRR values.
c. When peak current and pulse on time is increased, the MRR is increased. Gap voltage has less influence on MRR.
d. Value of R_a is less when peak current, pulse on time and gap voltage decreases.
e. In order to obtain high material removal rate in the case of SCM 420 steel, within the work interval considered in this study, one should use high values for peak current and gap voltage.
f. In order to obtain low values of surface roughness low values of pulse on time, current and gap voltage is to be used.

References

[1] Mikell P. Groover, Fundamentals of modern manufacturing (John Wiley and Sons Inc,2010).

[2] Milan Kumar Das, Kaushik Kumar, Tapan Kr. Barman and Prasanta Sahoo, "Application of Artificial bee Colony Algorithm for Optimization of MRR and Surface Roughness in EDM of EN31 tool steel", Elsevier, Procedia Materials Science, May 2014, pp. 741 – 751.

[3] Mehdi Hourmand, Saeed Farahany, Ahmed A. D. Sarhan and Mohd Yusof Noordin, "Investigating the Electrical Discharge Machining (EDM) Parameter effects on Al-Mg2Si Metal Matrix Composite (MMC) for high Material Removal Rate (MRR) and less EWR–RSM approach", Springer, International Journal of Advanced Manufacturing and Technology, October 2014.

[4] S. Gopalakannan, T. Sentjhilvelan and S. Ranganathan, "Modeling and Optimization of EDM Process Parameters on Machining of Al 7070-B_4C using RSM", Procedia Engineering, Volume 38, 2012, pp. 685-690.

[5] S. B. Chikalthankar, V. M. Nandedkar and S .V. Borde, "Experimental Investigations of EDM Parameters." International Journal of Engineering Research and Development, Volume 7, Issue 5, June 2013, pp. 31-34.

[6] Md. Ashikur Rahman Khan, M .M. Rahman, K. Kadirgama and A. R. Ismail, "RSM Model to evaluate Material Removal rate in EDM of Ti-5Al-2.5Sn using Graphite Electrode.", Materials Science and Engineering, Volume 36, 2012, pp. 1-9.

[7] Lin Gu, LeiLi, Wansheng Zhao and K. P. Rajurkar, "Electrical Discharge Machining of Ti6Al4V with a bundled Electrode", Elsevier, International Journal of Machine Tools & Manufacture, Volume 53, 2012, pp. 100–106.

[8] Ko Ta Chiang, "Modeling and analysis of the effects of Machining Parameters on the Performance characteristics in the EDM process of Al2O3+TiC mixed Ceramic.", International Journal of Advanced Manufacturing and Technology, Volume 37, 2008, pp. 523–533.

[9] Kurri Rohan Ramesh, Jagtap Shrikant Tukaram, "The effects of Machining Parameters on Surface Roughness of Material EN-31 in EDM using Copper Electrode.", International Journal of innovations in Engineering Research and Technology, Volume 2, Issue 9, September 2015, pp. 1-8.

[10] Suresh Kumar Gurjar and Rajeev Kumar, "Optimization of MRR and TWR on EDM by using Taghuchi's Method and ANOVA Die Steel H13.", International journal for Innovative Research in Science and Technology, Volume 2, Issue 3, August 2015, pp. 22-28.

[11] P. Sahoo, B .C. Routara and Bandyopadhyay, "Roughness modeling and optimization in EDM using Response Surface Method for different Work piece Materials." International Journal of Machining and Machinability of Materials, Volume 5, 2009, pp. 321-346.

[12] Nibu Mathew, Dinesh Kumar, Naveen Beri and Anil Kumar, "Study of Material Removal Rate of different Tool Materials during EDM OF H11 Steel at Reverse polarity", International Journal of Advanced Engineering Technology, Volume V, Issue II, April-June, 2014, pp. 25-30.