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Effect of machining parameters on surface roughness in EDM of AISI H 13 steel

Saket Mishra [1], Pavan Agarwal[2], Brajesh Kumar Lodhi[3]

[1]P.G. Student, MED, Vickrant Institute of Technology & Management, Gwalior, saket.sonu@gmail.com
[2]Associate Professor, MED, Vickrant Institute of Technology & Management, Gwalior, me_pavan@vitm.edu.in
[3]Brajesh Kumar Lodhi, MED, Bundelkhand Institute of Engineering & Technology, Jhansi, brajeshlodhi@gmail.com

Abstract — *Electrical discharge machining (EDM) is a non-traditional manufacturing technique that has been widely used in the production of precision engineering components throughout the world in recent years. The most important performance measure in EDM is the surface roughness. In this study, the experimental studies were conducted under varying pulse on time, current and gap voltage. The numbers of experiments were reduced by* L_9 *array of Taguchi's method of DOE. Signal-to-noise (S/N) ratio was employed to determine the most influencing levels of parameters that affect the surface roughness in the EDM of AISI H13 Steel. To validate the study, confirmation experiment has been carried out at optimum set of parameters and predicted results have been found to be in good agreement with experimental findings.*

Keywords- *EDM, Taguchi method, Surface roughness, ANOVA*

I. INTRODUCTION

Electrical discharge machining is an earliest non-traditional machining process, where material is removed by a sequence of electrical discharges occurring between an electrode and a work-piece. EDM is generally used for machining hard metals and alloys used in aerospace, automotive and die industries, the only limitation is that they must be conductive. In this process material is removed in the form of debris, with repetitive electrical discharge between tool called electrode and the work material in the existence of dielectric fluid. In this machining process tool is cathode and work piece is anode [1].

Khan investigated electrode wear and material removal rate during EDM of aluminium and mild steel using copper and brass electrodes and concluded that electrode wear is more during machining along their cross section than along its length. EWR is increases with increases of current and Gap voltage and MRR is sharply increases with increases of current [2]. Bhattacharya et al performed an experiment to see the Performance of ZrB2–Cu composite as an EDM electrode as the low wear resistance of electrodes like Cu, Cu alloys and graphite is a major problem for electrical discharge machining (EDM) operation [3]. George et al optimize the machining parameters in the EDM machining of C–C composite using Taguchi method. The process variables affects electrode wear rate and MRR, according to their relative significance, are *V*g, *I*p and Ton, respectively [4]. Tanimura et al reported that near-dry EDM utilizes gas and liquid mixture as dielectric medium. Liquid phase in the dielectric medium enhances debris flushing and eliminates debris reattachment. This results in the better surface finish and increases process efficiency in the near-dry EDM [5]. Marafona Conclude that the black layer composition varies with an interaction of electrical discharge machining (EDM) input parameters, which affects the electrode wear ratio (EWR), using the Taguchi methodology [6]. Lin and Lin examined the performance characteristics of the EDM process such as material removal rate, surface roughness, and electrode wear ratio are improved together by using Gary relation analysis and Taguchi analysis [7]. Kiyak et al the experimental study of the EDM of 40CrMnNiMo864 tool steel (AISI P20) tool steel they Examine machining parameters on surface roughness in EDM of tool steel [8].

The literature review reveals that EDM has the merit in finishing operation than conventional EDM. In this investigation, EDM oil were used as the dielectric medium. Experiments were designed using Taguchi' method. Three process parameters (pulse on time, peak Current, and gap voltage) were selected for experimentation. The experiments were conducted on AISI H13 steel as work material. Surface roughness were taken as results of experimentation and analyzed to determine the significant process parameters.

II. EXPERIMENTAL WORK

The material used for this work is AISI H13 steel plate of size 100 mm × 80 mm × 20 mm. The chemical composition of the select work material is shown in Table 1. The experiments were carried out using EDM machine model EMS-5535 EZNC manufactured by Electronica pune. The electrode used is electrolytic cooper 2 mm diameter (99.97% pure) of 8930 kgm^{-3} density with melting point of 1083^0C. EDM oil 40 is used as a dielectric fluid during the operation which is a fully synthetic EDM fluid. The photographic view of Experimental setup and machined work-piece has been shown Figure 1 and Figure 2 respectively. The surface roughness measured by with Talusurf-6 on the work-piece after machining.

Table 1 Composition of AISI H13 steel

Elements	C	Si	M	Ni	Cr	Mo
Weights %	0.40	0.25	0.70	1.85	0.80	0.25

2.1 Design of Experiment based on Taguchi Method

This paper uses Taguchi method, which is very effective to deal with responses influenced by multi-variables. Taguchi method has become a power full tool for improving productivity during research and development so that high quality products can be produced quickly and at low cost. This is in contrast to the traditional method for controlling the source of the variation (variation of environmental conditions and other noise factors) at low cost.

Figure 1Experimental setup

Figure 2 Machined work-piece

To evaluate the effects of machining parameters of EDM process in terms of machining Performance characteristics such as Surface Roughness a Taguchi method used here to model the EDM process. In this study, Taguchi method, a powerful tool for parameter design of performance characteristics, for the purpose of designing and improving the product quality [9]. In the Taguchi method, process parameters which influence the products are separated into two main groups: control factors and noise factors. The control factors are used to select the best conditions for stability in design or manufacturing process, whereas the noise factors denote all factors that cause variation.

According to Taguchi based methodology, the characteristic that the smaller value indicates the better machining performance, such as Surface roughness is addressed as the-smaller-the-better type of problem. The S/N Ratio, i.e. η, can be calculated as shown below:

$$\eta = -10log\left(\frac{1}{n}\sum_{i=1}^{n} y_{Ra}^{2}\right) \qquad (1)$$

The process parameters chosen for experiments are: pulse on time (T_{on}), peak current (I_p) and Gap voltage (V_g) while the response function are surface roughness. According to the capability of commercial EDM machine available and general recommendations of machining conditions for AISI H13 steel the range and the numbers of levels of the parameters are selected as given Table 2.

Table 2 Setting of levels for process parameters

Parameters	Unit	Symbol	Level		
			I	II	III
Pulse on time	µs	T_{on}	50	75	100
Peak current	A	I_p	1	3	5
Gap Voltage	µs	V_g	30	40	50

***Table 3* Experimental design using L_9 orthogonal array**

Exp.No	Factor Assignment			R_a	S/N Ratio (db)
	T_{on} (µs)	V_g (V)	I_p (A)		
1.	1	1	1	1.14	-2.984
2.	1	2	2	1.88	-5.483
3.	1	3	3	2.20	-6.848
4.	2	1	2	2.21	-6.887
5.	2	2	3	3.10	-9.827
6.	2	3	1	2.81	-8.974
7.	3	1	3	3.10	-9.827
8.	3	2	1	2.44	-7.747
9.	3	3	2	2.71	-8.659

III. RESULT AND DISCUSSION

The experimental results are collected for surface roughness and 9 experiments were conducted using Taguchi (L_9 orthogonal array) method and there are two replicates for each experiment to obtain S/N values. In the present study all the designs, plots and analysis have been carried out using Minitab-14 statistical software. Lower amount of surface roughness show the high productivity of EDM process. Therefore, small the better are applied to calculate the S/N ratio of surface roughness respectively. Regardless of category of the performance characteristics, a greater value corresponds to a better performance. Therefore, optimal level with the greatest value. By applying Eq. (1) the values for each experiment of L_9 (Table 3) was calculated Table (4). The optimal machining performance for R_a was obtained as 50 µs pulse-on time (Level 1) 30 V gap voltage (Level 1), and 1 A current (Level 1) settings that give the minimum R_a.

The main effect plot for means that with increase in gap voltage the surface roughness is increases similarly with increase in pulse on time and current the surface roughness is also increases from Figure 3. This is because if current is increase the electron flow will increase and due to this the temperature will increase so if more electrons will strike to the surface more will be the temperature of the surface and more melting and evaporation of the surface will take place and this will lead to increase surface roughness similarly with increase in pulse on time the pulse duration will increase due to which the discharge energy increases which tends to more temperature on the surface due to which more cracks generation on the surface takes place. So with the lower parameters we can get small surface roughness or we can say good quality surface.

Table 4 S/N ratio response table for R_a

Factors/Levels	Level 1	Level 2	Level 3	Delta	Rank
T_{on}	-5.105	-8.563	-8.745	3.639	1
V_g	-6.566	-7.686	-8.161	1.594	3
I_p	-6.569	-7.010	-8.874	2.266	2

A statistically analysis of variance (ANOVA) is performed to identify the process parameters that are statistically significant. A better feel for the relative effect of the different machining parameters on the R_a was obtained by decomposition of variances, which is called analysis of variance [10].The relative importance of the machining parameters with respect to the Ra was investigated to determine more accurately the optimum combinations of the machining parameters by using ANOVA. The results of ANOVA for the machining outputs are presented in Tables 5. Statistically, F-test provides a decision at some confidence level as to whether these estimates are significantly different. Larger F-value indicates that the variation of the process parameter makes a big change on the performance characteristics.

Table 5 Analysis of Variance for Mean data for Ra

Factors	DOF	SS	Variance	F-ratio	Percentage
T_{on}	2	1.6168	0.8084	10.82	63.038
V_g	2	0.1755	0.0877	1.17	6.8426
I_p	2	0.6230	0.3115	4.27	24.290
Error	2	0.1494	0.0747	-	5.829
Total	8	2.5648			100%

At least 90% confidence level

According to F-test analysis, the significant parameters on the R_a are pulse on time. Pulse on time is found to be the major factor affecting the Ra (63.038%). The percent contributions of gap voltage and peak current are 6.842 and 24.290%, respectively.

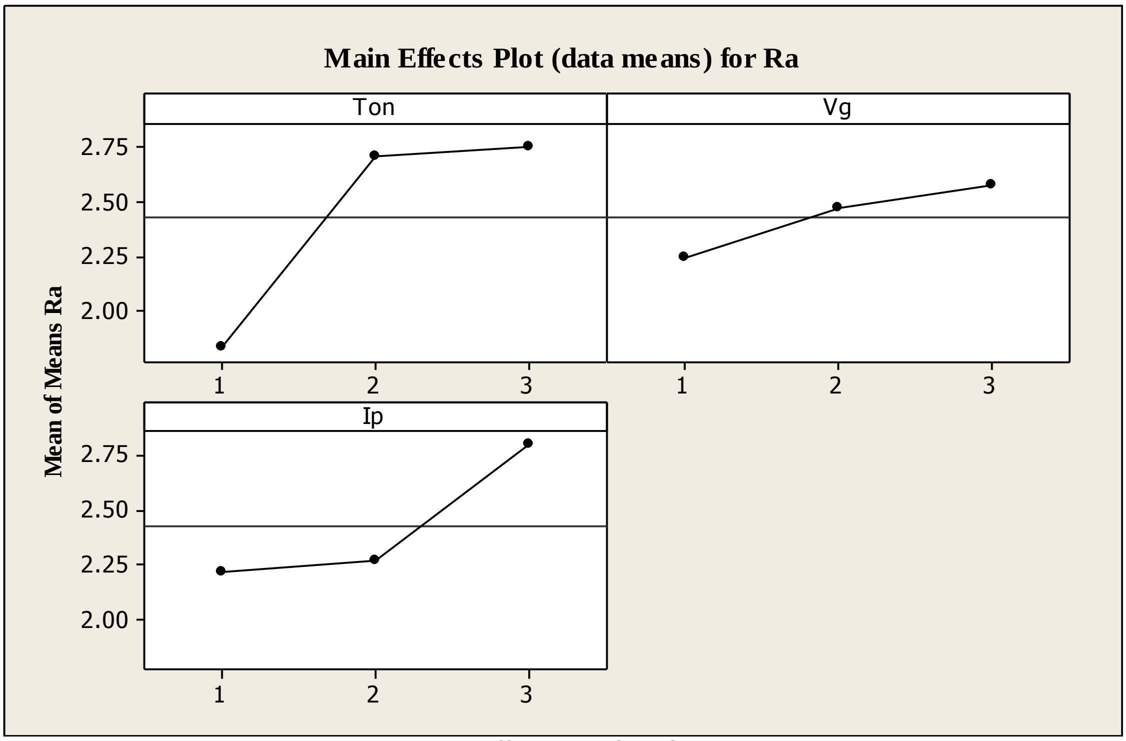

Figure 3 Main effect plot of Surface Roughness (Ra)

IV. CONFIRMATION EXPERIMENTS

The final step of the Taguchi's parameter design after selecting the optimal parameters is to be predict any verify the improvement of the performance characteristics with the selected optimal machining parameters [9]. The predicted S/N ratio using the optimal levels of the machining parameters can be calculated with the help of following prediction equation:

$$\eta_{opt} = \eta_m + \sum_{j=1}^{k} (\eta_j - \eta_m) \qquad (2)$$

Here, η_{opt} is the predicted optimal S/N ratio, η_m is the total mean of the S/N ratios, η_j is the mean S/N ratio of at optimal levels and k is the number of main design parameters that affect the quality characteristics.

Table 6 Results of confirmation experiments for Ra

Response	Factor	T_{on} (μs)	V_g (V)	I_p (A)	Predicted Value	Experimental Value
R_a	Level	1	1	1	1.43	1.48
	values	50	30	1		

V. CONCLUSION

The effect of EDM process parameters in terms of surface roughness of AISI H13 steel using Taguchi's L_9 orthogonal array. It is observed that the S/N Ratio with Taguchi's parameters design is a simple, systematic, reliable and more efficient tool for optimizing performance characteristics of EDM process parameters. Based on the experimental results and analysis, the following conclusions can be drawn:

- Surface roughness is increases with increase in current and voltage. This is due to higher current increases the discharge energy and the most influential factors were pulse on time.
- Optimal condition for lower surface roughness is Gap voltage at 30V, pulse on time at 50 μs, and current at 1A.
- Actual gain 1.48 for MRR is very close to the predicted 1.43. It shows very good reproducibility and confirms the success of the experiments.
- ANOVA found the significant parameters of pulse on time (63.038%) for Surface roughness.

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