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Investigation the Electrode Wear Rate and Metal Removal Rate in EDM Process using Taguchi and ANOVA Method

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K E Y W O R D S

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A B S T R A C T

The experimental work of this paper leads to electrical discharge machining (EDM). A system for machining in this process has been developed. Many parameters are studied such as current, pulse on-time, pulse off time of the machine. The main aim of this work is to calculate the metal removal rate (MRR) and electrode wear rate (EWR) using copper, electrodes when machining tool steel H13 specimens of a thickness (4mm).

Different current rates are used ranging from (30, 42, and 54) Amp, pulse on-time ranging from (75, 100, and 125) and pulse off time ranging from (25, 50, and 75) found that high current gives large electrode wear and metal removal rate and. The experiment design was by Taguchi Method. From an analysis of variance (ANOVA) the more active influence of input factors on the outputs is currently for metal removal rate (MRR) (58%) and electrode wear rate (EWR) (57).

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1. INTRODUCTION

The machining of electric discharge is known as spark erosion or EDM and one of the most vastly using non-conventional metal removal processes for machining of all material, can be electrically conductive, irrespective of its strength and hardness [1]. EDM technology is increasingly being used in a tool, die and mold making industries, for machining heat-treated tool steels and advanced materials (superalloys, ceramics, and metal matrix composites) requiring high precision, complex shapes, and high surface finish. The traditional machining technique is often based on the material removal using tool material harder than work material and is therefore unable to machine them economically. Heat-treated tool steel has proved to be extremely difficult-to-machine using traditional processes, due to rapid tool wear, low machining rates, inability to generate complex shapes and imparting better surface finish [2]. The production of the process scenarios contributes to electric discharge is for the manufacture of complex parts used in automotive, surgical, and aerospace components and high precision [3]. In 1943, the machining of electric discharge is developed by Lazarenko and Lazarenko. They could be to keep the width of the gap between the electrodes (tool and workpiece) constant by a simple servo controller and the discovery of the relaxation circuit [4]. A. K detects the electrode shape influence on the EWR and MRR of electric discharge for steel. The highest EWR is found in the electrode of a shaped diamond. And was conducting the simulation process and was found the distance between the electrode and workpiece (gap) and location of discharge that depending on the distribution of reported debris [5]. A. M et al studied CuW, Cu, and AgW for electrode metals in micro- electric discharge, which were produced by box electrode on Si_3N_4 coated with TiN for the workpiece. The properties of machining were estimated by the EWR and MRR. And were concluding the Cu electrode was given the highest EWR and MRR, followed by the AgW and CuW electrodes. [6]. B. L. studied the powder effect concentration on the metal removal rate through a mix dielectric fluid with powder. And were conducted the experimental at constant V, I, and T_{on} whereas the concentrations powder of Ti levels (5, 10, 15 and 20). The workpiece was made from steel H13 and electrode as graphite. Increased powder concentrations of Ti, is lead to a raise metal removal rate where the metal removal rate of the workpiece with a concentration of Ti 20 was 475.46% compared no powder [1]. M. R. studied the powder P.S. (10, 20, and 30) and P.C. effects (5, 10, and 15) for (SiC) on MR, EW, machining cost in the EDM process and machining time through mixing the powder with the fluid of kerosene dielectric. The outcomes indicate the process is capable of raising MR, decreasing TW, machining cost and machining time [7].

In this work is to calculate the electrode wear rate and metal removal rate using copper, electrodes when machining tool steel H13 specimens of the thickness (4mm).

2. METHOD of TAGUCHI

Taguchi is main to begin the design experimental work to find the best design of the experiments after that the values were determined for each output and to calculate the goal of its value (smaller is better, Larger is better).

3. VARIANCE ANALYSIS

It is also called **(ANOVA)** applied to analyze the difference between input and their related procedures like "variation". One-way variance analysis package program (Minitab) was used to find the contribution of all control parameters in the process.

4. EXPERIMENTAL WORK

I. Machine

In the work, all the experiments were performed with an electric discharge machine, sinking machine CNC type German (CHMER CH) as shown in Figure 1 installed at University of Technology.

Figure 1: EDM Machine.

II. Workpiece Material

Tool steel H13 was used as the workpiece in this study and that was a significant die material and the tool because of its high wear resistance, high strength, and hardness, the workpiece is square with dimension 40 × 40 mm and 4 mm as shown in Figure 2 thickness with surface roughness is (0.5µm). The chemical composition of steel H13 as shown in Table I.

Figure 2: workpiece.

TABLE I: Chemical Composition for Workpiece.

Metal	Si	C	P	Mn	Cr	S	V	Mo	Fe
Weight %	0.92	0.98	0.23	0.035	0.03	4.04	0.842	1.37	91.553

III. Tool Electrode

An electrode is copper metal of 50 mm length with a diameter of 15 (mm). Figure 3 shows the shape of the electrodes. The chemical composition of the electrode (Copper) as shown in Table II.

Figure 3: The tool (Electrode).

TABLE II: Chemical Composition of Electrode.

Metal	Mn	Cu	Fe
Weight %	0.04	99.9	0.0.06

The electrode is a move to the workpiece that is adjusted and maintained by servo motor, which maintains a uniform gap of (0.5mm). The pressure is 0.3 (Kg/cm^2) had been used during each experimental run, the dielectric fluid was kerosene.

5. (MRR) METAL REMOVAL RATE

The workpiece is separated from the EDM machine after the drilling process, dried, and cleaned up to be free, dielectric, and debris. A precision balance (Instrument) with an accuracy (0.01mg) is used in the weight method. The formula for metal removal rate (mm^3/min.) is calculated according to Equation (1) [8].

$$MRR = \frac{W_{iw} - W_{fw}}{\rho_w t} \quad (1)$$

where:
W_{fw}= workpiece final weight.
W_{iw}= workpiece initial weight.
t= duration time in (min.).
ρ_w= workpiece density.
The density of the workpiece is (8 gm/cm^3) **[9].**

6. ELECTRODE WEAR RATE (EWR)

As in the metal removal rate procedure, but the electrode was replaced by the workpiece. The formula for the electrode wear rate is calculated according to Eq. (2) [10].

$$EWR = \frac{W_{ie} - W_{fe}}{\rho_e t} \quad (2)$$

where:
W_{fe}= electrode final weight.
W_{ie}= electrode initial weight.
ρ_e= the electrode density.
The density of the electrode is (8.9 gm/cm^3) [11].

7. RESULTS

In this section, the results of the experiment would be discussed and analyzed for all input factors to find the effects of factors for the output, adding variance results analysis would be analyzed individually. When actual values and coded values of the input factors by the Taguchi method as shown in Table III and the results of experiments are for output factors metal removal rate and electrode wear rate are shown in Table IV.

TABLE III: Coded values, actual values of the input parameters

Parameters	Current(A)	Pulse on time(B)	Pulse off time (C)
Level 1	30	75	25
Level 2	42	100	50
Level 3	54	125	75

TABLE IV: Results of experimental for output factors EWR and MRR

No.	Current (Amp)	Ton (µsecond)	Toff (µsecond)	MRR (mm3/min)	EWR (mm3/min)
1	1	1	1	14.0231	0.12
2	1	2	2	15.841	0.376
3	1	3	3	16.821	1.784
4	2	1	2	16.919	0.472
5	2	2	3	18.7789	1.768
6	2	3	1	21.161	2.5328
7	3	1	3	17.668	2.0992
8	3	2	1	34.1943	3.3496
9	3	3	2	35.014	5.6

I. Analysis of Material Removal Rate

Figures 4 and 5 detect the relation between input factors and mean of metal removal rate. Table V represents the rank of the input factors when the larger is the relative significance and considered better on metal removal rate. It can be seen that Time on is 125 µsec, the current is 54A, and Time off is 50 µsec. The metal removal rate will be (35.014 mm3/min). The increase in current leads to an increase in energy. The small value of Time on is leading to less for vaporization while increasing Time on leads to be expanded in the plasma, which causes less density of energy for the workpiece that was insufficient to vaporize and melting the metal of workpiece. A high value of Time off is lead to influence cooling workpiece and electrode produced by the fluid of dielectric decreases of the metal removal rate. It observed the currents are the most influential for metal removal rate with 58.74%, then Time off had less influence on the metal removal rate with 10.59%.

TABLE V: Analysis of Variance (ANOVA)

Variance Source	D.O.F	Squares Sum	Variance	F ratio	P (%)
Current (Amp)	2	291.1	145.55	7.51	58.72
Pulse on time(µsec)	2	113.37	56.69	2.93	22.87
Pulse off time(µsec)	2	52.51	26.25	1.35	10.59
Error, (e)	2	38.75	19.38		7.81
Total	8	495.73			100

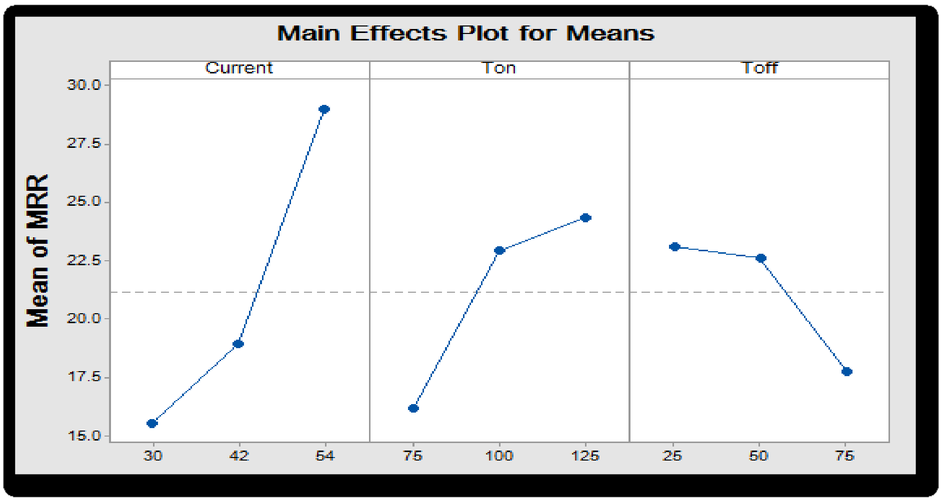

Figure 4: Mean of MRR

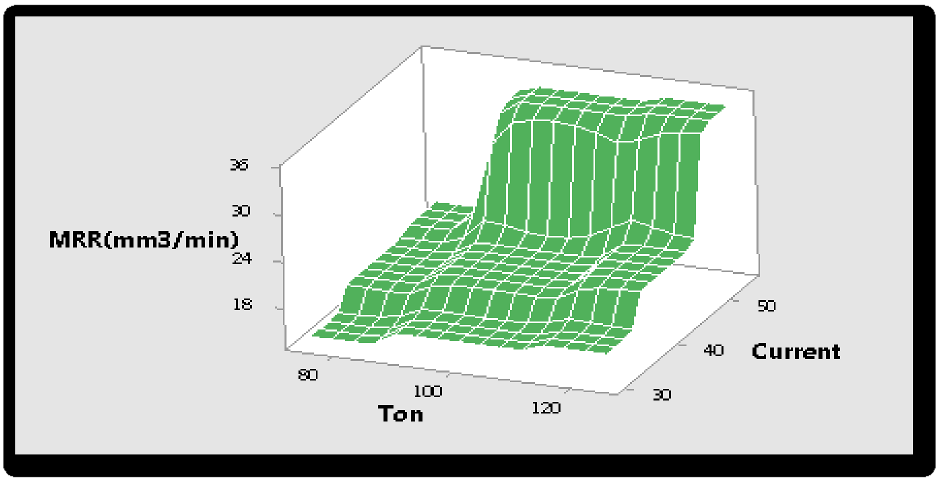

Figure 5: Plot of Surface for MRR (mm3/min) vs Current; Time on

II. Analysis of Electrode Wear Ratio

Figure 6 detects the comparison between factors results of the main effect of input factors for electrode wear rate analysis. The most effective factor is current then Time on, Time off that gave the least influential of all, according to the analysis of variance results as shown in Table VII. The lower value of the electrode wear rate can be obtained the value of the electrode wear rate will be 0.12 mm3/min. Figure 7 explains increasing current leads to increase EWR, which is an increase of current lead in generating high density of current in the gap of the workspace that leads to a high amount of heat that works. It was observed that the current is the more influential on electrode wear rate with 57.42%, then Time off has less influence on electrode wear rate with 7.81%.

TABLE VII: Analysis of Variance (ANOVA)

variance source	DOF	Squares Sum	Variance	F ratio	P (%)
Current (Amp)	2	13.61	6.8	9.16	57.47
Pulse on time (μsecond)	2	8.48	4.24	5.95	37.36
Pulse off time (μsecond)	2	0.106	0.053	0.06	0.45
Error	2	1.484	0.742		6.2
Total	8	23.68			100

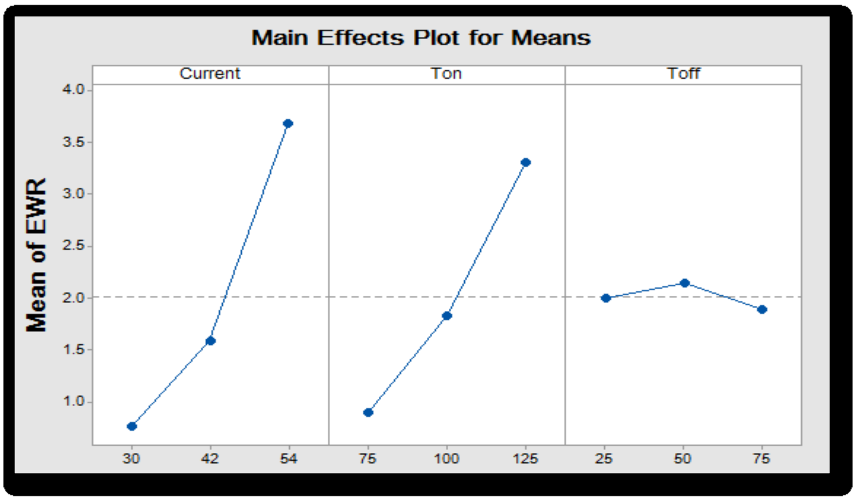

Figure 6: Mean of MRR

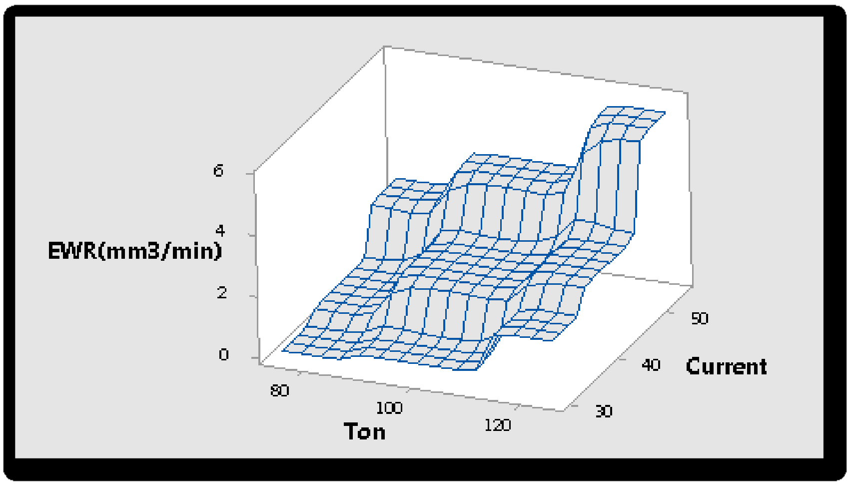

Figure 7: Plot of Surface of Electrode Wear Rate (mm3/min) vs Current; Ton

8. CONCLUSION

A confirmation test was conducted to validate the output result. The important conclusion drawn from the present work are summarized in this; All the main effects of input factors, i.e., I, time on, and time off are found to be highly affecting the electrode wear and metal removal. As regards the main effects analysis, all the outputs behave in the same way. Rising either current or time on results is given the high value of response electrode wear and metal removal whereas an increasing time off causes the reverse effect. The experimental tests show that non-conducting materials can be machined successfully by using EDM.

9. RECOMMENDATIONS

Results analysis of the present work advocates quite a few possible extensions of the research. Like: few works had state to research the influences of non-electrical factors like workpiece rotation and electrode rotation, the influence of electrical discharge machining drilling factors on the crack density of surface should be investigated and modeling of optimization should be based upon the requirement of the industry.

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