Experimental Investigations of Hole - EDM to optimize Electrode Wear through Full Factorial of Design of Experiment

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ABSTRACT:

Electrical discharge machining (EDM) is a process where the material removal of the workpiece is achieved through high frequency sparks between the tool (electrode) and the workpiece immersed into the dielectric solution. It is commonly used to produce moulds and dies, to drill small, burr free holes and to make prototypes for the aerospace and electronics markets. In this work, micro-holeswere fabricated on copper alloys by using EDM. The output responses investigated was electrode wear weight (EWW). Full factorial of Design of Experiment (DOE) module in Minitab was used as a principal methodology to examine the effects of current and machining time over output responses. Experimental results indicate that the EWW was mainly affected by current, and can be reduced by increasing the current parameter. Minimum EWW (0.12gm) obtained at 10A.

Keywords: micro-EDM, Design of Experiments, Full Factorial Design

دراسة تجريبية لإنتاج الثقوب بالتشغيل بالتفريغ الكهربائي للحصول على امثل قيمة لبلى الألكترود من خلال استخدام طريقة تصميم التجربة كامل التحليل

الخلاصة:

يعد التشغيل بالتفريغ الكهربائي من العلميات التي يتم فيها ازالة المعدن من المشغولة من خلال حصول شرارت عالية التردد بين الأداة (الألكترود) والمشغولة المغمورة في محلول. تستخدم هذه العمليات عادة لإنتاج القوالب والثقوب الصغيرة الخالية من الحافات الخشنة وعمل النماذج المستخدمة في الصناعات الفضائية والإلكترونية. في هذا العمل، تم تصنيع ثقوب مايكروية في سبائك النحاس باستخدام التفريغ الكهربائي. تم دراسة وزن البلى في الألكترود كمؤثر فاعل. تم استخدام نموذج تصميم التجربة كامل التحليل في برنامج (Minitab) كطريقة عمل رئيسية لدراسة تأثير التيار وزمن التشغيل على البلى في الألكترود. اظهرت النتائج العملية إن البلى في الألكترود يتأثر بشكل أساسي بالتيار ، ويمكن تقليل تأثيره بزيادة عامل التيار. تم الحصول على اقل بلى الألكترود (0.12gm) عند قيمة تيار 10 أمبير.

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INTRODUCTION

EDM is one of the most extensively used non-conventional material removal processes. Its unique feature of using thermal energy to machine electrically conductive parts regardless of hardness has been its distinctive advantage in the manufacture of mould, die, automotive, aerospace and surgical components. In addition, EDM does not make direct contact between the electrode and the workpiece eliminating mechanical stresses, chatter and vibration problems during machining [1].

EDM is the machining process of controlled erosion of electrically conductive materials by the rapid and repetitive spark discharge between the workpiece (anode) and the tool (cathode) separated by flooded dielectric fluid through the small gap (about 0.02 to 0.5) mm, and known as spark-gap [2].

Electrical discharge machining is a process that removes metal with good dimensional control from any soft or hard metal. It cannot be used for machining glass, ceramics or other non-conducting materials[3].

The basic principle in EDM is the conversion of electrical energy into thermal energy through a series of discrete electrical discharges occurring between the electrode and workpiece immersed in the dielectric fluid. The insulating effect of the dielectric is important in avoiding electrolysis of the electrodes during the EDM process [4,5].

The objective of this work was parameters optimized by statistical design of experiments for micro-holes machined by using EDM. The experiment material was copper alloy with height 10 mm, and 10 mm thickness. The experiments were designed by 3^k full factorial experimental design at 3 level and 2 factors and 9 experiments. The two factors were current and machining time.

Experimental procedures:

1. Cutting by using electrode with diameter 0.2 mm.
2. Workpiece made of copper alloy.
3. Cutting with dielectric fluid, water tab.
4. Workpiece with height 10 mm and thickness 10 mm to produce through holes of diameters 400, 300, 210, 200, 120, 100, 85, 75 and 70µm.
5. A response of this experiment was different electrode wear weight.
6. Not consider other factors such as temperatures, gap distance, and dielectric flow rate.

Design of Experiments:

Full factorial design statistical method helps to improve the operation through considering the important of operation factors and to ascertain the relative importance of each of these factors on response parameter. This method also helps to try various combinations of factors settings to establish the best way to run the operation.

Using full model means running the full complement of all factor combinations to estimate all the main and interaction effects [6].

Using Minitab's general full factorial design program, the full factorial 3^k design at 3 level 2 factors, 9 experiments was designed for this experiment as shown in Table 2.

The Experiment:

Electrode wear is weight difference of the electrode before and after machining. Electrode wear depends on a number of factors associated with the EDM like voltage, current, electrode material and polarity [7,8].

The melting point is the most important factor in determining the tool wear. Electrode wear ratios are expressed as end wear, side wear, corner wear, and volume wear.
Erosion in the electrode material is calculated by weighing the electrode before and after the machining process determining the difference in weight which is multiplied by 100 as mentioned in equation (1) [9] .

$$EW(gm) = (W_1 - W_2)\ b \qquad \ldots(1)$$

Where:
W_1 = weight of electrode before machining, gm.
W_2 = weight of electrode after machining, gm.

Electrode wear have been determined using the method of calculation of weight of electrode before machining (W1) and subtract from the weight of electrode after machining (W2).

To determine the electrode wear we used a sensitive balance (Mettler Toledo AB204-S/FACT Analytical Balance) with details listed in Table 1 and Fig. 1.

Results and Discussion:

The first experiment results are shown in Table 3.
The general full factorial design with confidential interval 95% analyzes the experiment results by Minitab software with General Linear Model. The residual plots for Electrode Wear Weight (EWW) show in Fig. 2, that show the residual plots with normal distribution, mean of error equals zero, constant variance and errors are independent.
From the analysis in Fig. 3, considering the confidential interval of 95% (α =0.05) are the main factors affecting significantly the Current (which is determined by the P-value less than 0.05 (P-value = 0.007)) and with no interaction effect significantly. This is determined by the P-value greater than 0.05 and graphs with no potential impact on the Fig. 4.
From main effect plot in Fig. 5, the smallest Electrode Wear with current equal to 10A.
This is leads to the conclusion that, the electrode wear will be improved (i.e. reducing electrode wear ratio) by increasing the current factor.

Conclusion:

The experiment results from Fig. 3, the P-value of current factor was less than 0.05 so that current factor was the main factor affecting significantly at confidential interval of 95% (α=0.05) and Fig. 4 the EDM set up. The electrode wear was improved as increasing the current from Fig. 5, the results shows that the smallest Electrode Wear Weight (EWW) with current equal to 10 A will had EWW equal to 0.12gm.

Table (1): Mettler Toledo AB204-S/FACT Analytical Balance data.

Technical data	AB204-S/FACT
Readability	0.1 mg
Max. capacity	220 g
Repeatability (sd)	0.1 mg
Linearity	0.2 mg
Sensitivity temperature drift (10 °C … 30 °C)	2.5 ppm/ °C
Settling time, typical	4 s
Adjustment weight	built-in
Backlight	yes
External dimensions of balance (W/D/H)	245x321x344 mm
External dimensions of packaging (W/D/H)	419x494x521 mm
Weighing pan	ø 80 mm
Usable height of draft shield	237 mm
Net weight (with packaging)	6.4 kg (9.1 kg)

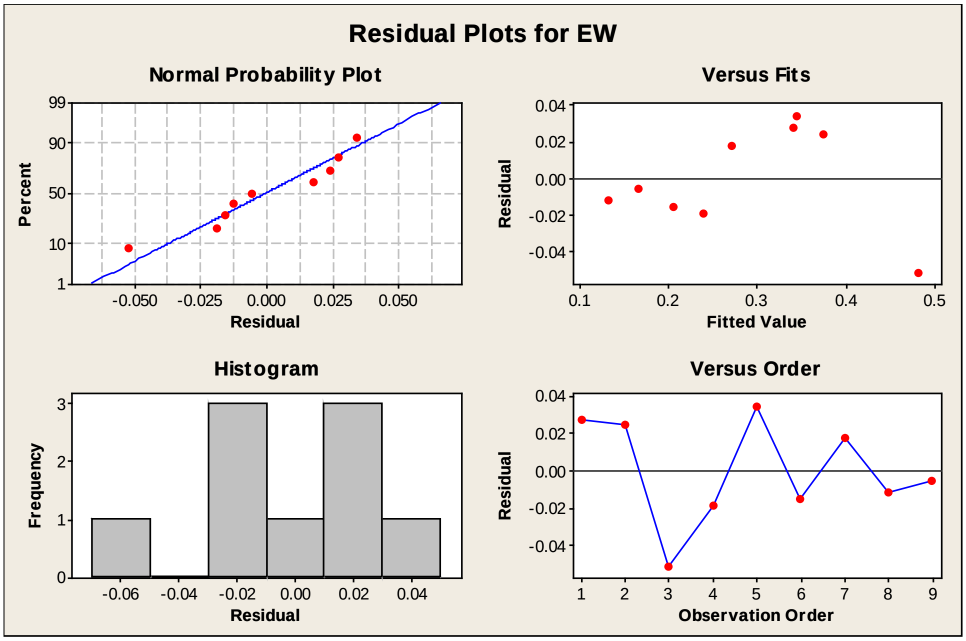
Table (2): Factors and levels for the experiment.

Factors	Level		
	1	2	3
Current (A)	4	6	10
Machining Time (min)	5	7	10

Table (3): Experiment results.

Experiment No.	Factor		Electrode Wear (gm) , EWW
	Current (A)	Machining Time (min)	
1	4	5	0.37
2	4	7	0.40
3	4	10	0.43
4	6	7	0.22
5	6	10	0.38
6	6	5	0.19
7	10	10	0.29
8	10	5	0.12
9	10	7	0.16

Figure(1): Mettler Toledo Analytical Balance.



Figure(2): Residual Plots for Electrode Wear (EW).

General Linear Model: EW versus Current, Machining Time

Factor	Type	Levels	Values
Current	fixed	3	4, 6, 10
Machining Time	fixed	3	5, 7, 10

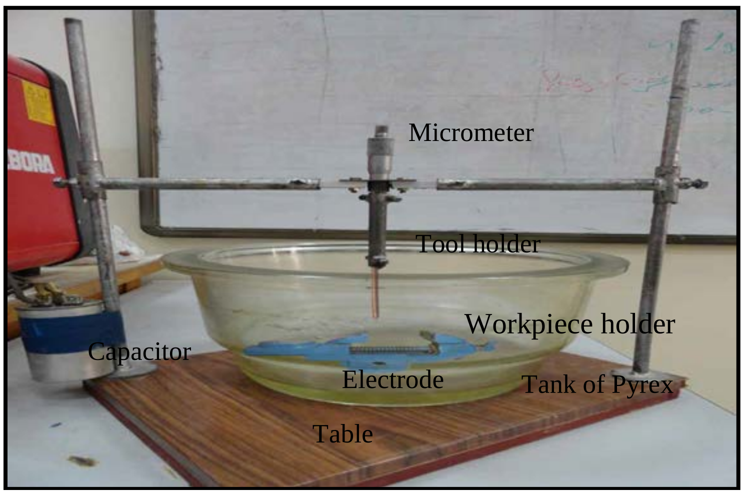
Analysis of Variance for EW, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Current	**2**	**0.068156**	**0.068156**	**0.034078**	**21.37**	**0.007**

Machining Time   2 0.032089 0.032089 0.016044 10.06 0.027
Error   4 0.006378 0.006378 0.001594
Total   8 0.106622

S = 0.0399305   R-Sq = 94.02%   R-Sq(adj) = 88.04%
Least Squares Means for EW
Current   Mean SE Mean
 4   0.4000 0.02305
 6   0.2633 0.02305
10   0.1900 0.02305

Machining Ti
 5   0.2267 0.02305
 7   0.2600 0.02305
10   0.3667 0.02305
Fig. 3 Analysis data by using Minitab software.



Figure(3). EDM set

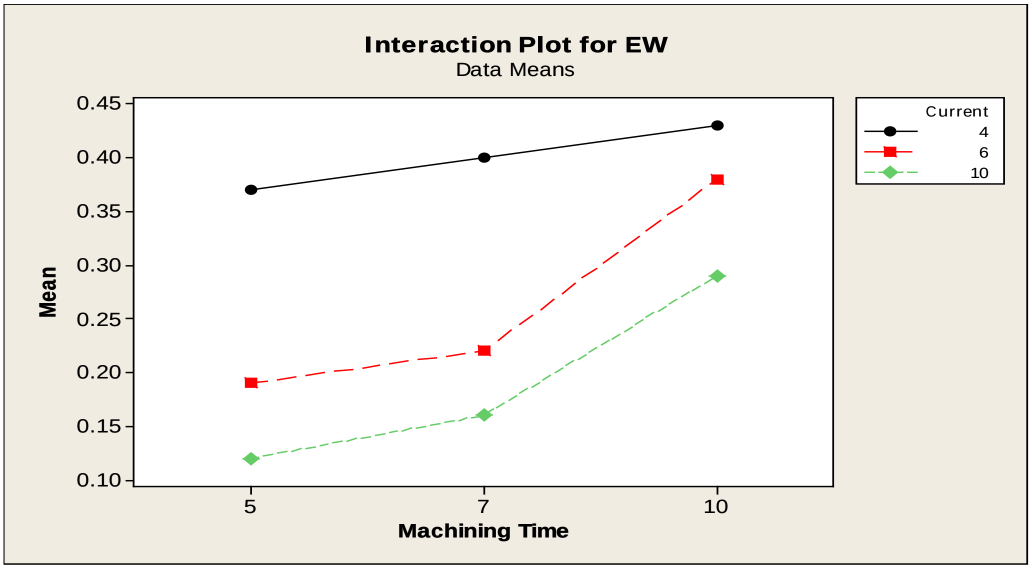
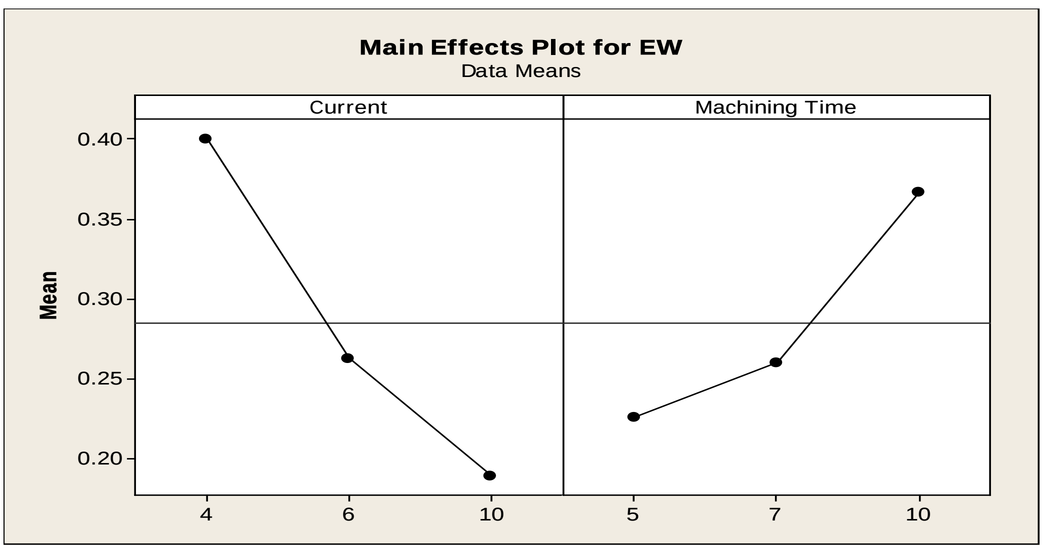


Figure.(4): Interaction plot for Electrode Wear (EW).



Figure(5): Main effect plot for Electrode Wear (EW) in the experiment.

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