Optimization of Surface Roughness For Al-alloy in Electro-chemical Machining (ECM) Using Taguchi Method

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ABSTRACT

Electro-chemical Machining is significant process to remove metal with using anodic dissolution. Electro-chemical machining use to removed metal workpiece from (7025) aluminum alloy using Potassium chloride (KCl) solution .The tool used was made from copper. In this present the optimize processes input parameter use are (current, gap and electrolyte concentration) and surface roughness (Ra) as output. The experiments on electro-chemical machining with use current (30, 50, 70)A, gap (1.00, 1.25, 1.50) mm and electrolyte concentration (100, 200, 300) (g/L). The method (ANOVA) was used to limited the large influence factors affected on surface roughness and found the current was the large influence factors with (72.17%) . The results of the optimization of comparison of experimental and prediction conditions current at level-1(30 A), gap at level-1 (1.00mm) and electrolyte concentration at level-1(100(g/L)) shown the average experiments and prediction surface roughness (1.352 μm) and (1.399 μm) respectively..

Keywords: Electro-chemical machining, surface roughness, optimization, taguchi, ANOVA.

امثلية الخشونة السطحيةلسبيكة الالمنيوم في التشغيل الكهروكيمياوي باستخدام طريقة تاكوشي

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الخلاصة

التشغيل الكهروكيمياوي هي طريقة مؤثرة لإزالة المعادن باستخدام محلول انحلال . في هذا البحث التشغيل الكهروكيمياوي يستعمل لإزالة معدن المشغولة المكون من سبائك الألومنيوم (7025) باستخدام محلول من ملح (كلوريد البوتاسيوم) و الأداة المستخدمة مصنوعه من النحاس. تم في هذه العملية تحديدالمتغيرات المدخلة باستعمال التيار، الفجوة وتركيز المحلول. وباستخدام أسلوب تاكوشي لتصميم وتحليل التجارب للحصول على الأمثل.وتكون خشونة السطح كمخرج لسبكة الألومنيوم نوع (7024). التجارب اجريت التشغيل الكهروكيمياوي باستعمال قيم تيار (30، 50، 70)امبير وهناك فجوة (1.00، 1.25، 1.50) ملم وتركيز المحلول (100، 200، 300) (غرام / لتر). تم استخدام أسلوب (أنوفا) لتحديد اي

العوامل يكون كبير التأثير على خشونة السطح . وجد أن التيار كان من اكبر العوامل تأثيرا بنسبة (72.17٪). نتائج الاستغلال الأمثل والمقارنة بين مستويات الظروف التجريبية باستعمال التيار المستوى الاول (30)امبير، الفجوة في المستوى الاول (1.00) ملم وتركيز المحلول في المستوى الاول (100)(غرام/لتر) أظهر متوسط التجارب والتنبؤ للخشونة السطح هي (1.352)مايكرون و (1.399) مايكرون على التوالي.
الكلمات الرئيسية : التشغيل الكهروكيمياوي،الخشونة السطحية ،الامثلية ،تاكوشي،انوفا.

1. INTRODUCTION

Electro-chemical machining (ECM) is a non-conventional process that depends on the removal of workpiece atoms by electro-chemical dissolution process, **Al-Hofy, 2005.**The removal process of use anodic dissolution, where anode is workpiece and tool is cathode. To dissolve metal from the work piece, electrolyte is push on the gap between metal and electrode, while the current is passed on the cell ,**Hiba, 2011,** focused on the effect of the change in current , gap on surface roughness of . The results obtained show that, increasing of the gap size between the tool and the workpiece from (1mm) to (3mm) leads to increase of (46%) in the surface roughness of the workpiece, increasing of the current density from (2.4485 Amp/cm^2) to (3.6728 Amp/cm^2) leads the to decrease in surface roughness of the workpiece by approximately (31%). Used the Statistical Package for the Social Sciences (SPSS) software to prediction the results. **Babar, et al, 2013,** discuss the effect and condition optimization of ECM process used titanium based alloy. The condition of process that use are applied voltage, electrolyte concentration sodium chloride (NaCl) and feed ,which optimization according to material removal rate (MRR) as output. Analysis of variation contribution to performance characteristics. The results shown that the large influnance condition is voltage and then the electrolyte concentration and feed. The raise material removal rate (MRR) lead to raise in electrolyte concentration and voltage. The optimum values of process parameters are (electrolyte concentration (15 wt%), applied voltage (20 V)), tool feed rate (0.32mm/min).

Mohanty, et al., 2014, studied the effect of process parameter (voltage, electrolytic concentration and feed rate) on performance characteristics such as roughness average (Ra) affecting the surface roughness. The surface roughness initially increases with concentration, but it decreases at maximum concentration. The optimal condition for SR was found to be at (30 g/l) concentration of when electro-chemical machining used a tool of copper in an aqueous sodium chloride (NaCl). ANOVA were used to study the effect of parameters on cutting machining. It was observed that an increase in voltage where is roughness average (Ra) decreased. Voltage was found to be significantly electrolyte, (15V) voltage and (0.2 mm/min) feed rate. **Habib, 2014,** studied the effect of (ECM) cutting condition (voltage, electrode feed, and current) on the surface roughness. Taguchi method and analysis of variance (ANOVA) are used to optimization the electro-chemical machining process. The results show that maximum factor effect on surface roughness are current with (53%)then feed with (21%), voltage (11.5%). The optimum parameter(30V) voltage, (1 mm/min) feed rate used to get better roughness average (Ra=3.218 μm).

2. THEORY OF TAGUCHI

Taguchi discovers a novel conception for the quality control method named as (Taguchi parameter design). The method stated that the quality of manufactured part must be computed by the deviation amount from the required value. He takes into consideration not only the operation mean, but also the variation magnitude or (noise) created with manipulating the inputs parameters or operation variables. The technique is focus on two major groups; a unique matrix type called orthogonal array (OA), all the columns include number of experiment depending on the level number for the control factor, in addition to (signal to noise ratio) S/N **Abbas,2009 .**

$$S/N = -10\log\left[\frac{1}{n}\sum_{i=1}^{n}(y_i^{\,2})\right] \quad ; \qquad i=1, 2,\ldots\ldots \qquad \ldots\ldots(1)$$

The formula is utilized to calculating signal to noise ratio are given Eq(2):

$$S/N = -10\log\left[\frac{1}{n}\sum_{i=1}^{n}(1/y_i^{\,2})\right] \quad ; \qquad i=1,2,\ldots\ldots \qquad \ldots\ldots(2)$$

Where, y_i the measurements of output , and n is the measurements of input.

The final design of input parameter for work done according to MINITAB16 software as follow:

STAT → DOE → Taguchi → Create Taguchi Design

3. ANALYSIS OF VARIANCE

The results using (ANOVA) to explain the effect of machining condition on the roughness average (Ra) depend on machining condition current, gap and electrolyte construct while others are independent variables., F- ratio refer to mean square error and (%) percent is refer to influence rate of operation variables to (Ra), **Mohammed,2016.**

4. EXPERIMENTAL WORK

In electro-chemical machining design using drilling machine and other parts accessories with workpiece (7024)Aluminum alloy .The percentages of chemical composition is given in **Table 1.** with anode workpiece dimension (40x 30) mm and thickness (20) mm as shown in **Fig 1**,with using nine simple with change in machining parameter and constant machining time(5)min and different depth of hole.

4.1 The ECM machine

The ECM cell used in these experiments is shown in **Fig 2**. It consists of :
The drilling machine, workpiece fixture, electrolyte pump and power supply.

The drilling machine Provides a rigid base and good control of the tool feeding with manual controlling to maintain the gap size between tool and workpiece. workpiece fixture is made from cast iron. Pumps the electrolyte in the reaction chamber to gap between tool and workpiece. The used power supply in the experiment is a (D.C) welding machine with current (5 A/10 V-400 A/36V) type CEBORA .

4.2 Cathode Tool

In this paper, copper tool used with purity is (99.9%). The reason for using copper metals is because they are (easy to machine, have high electric conductivity and high corrosion resistance). with diameter (10 mm) , length (5 cm) and roughness average (Ra) (0.475 μm) as shown in **Fig 3.**

4.3 Electrolyte

The electrolyte use to creates appropriate conditions for anodic dissolution (workpiece), conducts the current and removes the waste from the gap. In this work as KCl as electrolyte with compost, listed in **Table 2.**

4.4 Design of Experiments

The total of experiments machining is (nine experiments) with (3) levels (3) parameters as (3^3). A partial factorial design was done use (9)to study the effect of parameter on surface roughness (Ra). The cutting parameters used (current, gap and electrolyte construct). The levels of cutting parameters are listed in **Table 3.**

4.5 Surface Roughness measurements

The Pocket Surf gauge is portable surface measurements use ,with selectable traverse length (1, 3 or 5)mm as shown in **Fig 4 .**

5. RESULTS AND DISCUSSION

The experiments work using the design parameter array **Table 4**. as shown in **Fig 5.** The complete response data to get minimize surface roughness. The Signal-to-Noise ratio (S/N) should be as small as possible, because the quality characteristic "smaller is better" was used. S/N values were calculated from Eq.(1), and the results have been arranged in the last column of array in **Table 4.** The results were analyzed by using main effects for both surface roughness values and signal-to-noise ratio, and ANOVA analyses. Then the estimate results which obtained checked experimentally to insure the estimate value. In terms of the average effects, the average value of surface roughness for each parameter (A, B and C) listed in **Table 4.**

5.1 Analysis of Variance

The results are analyzed by using (ANOVA) method to find the effect of machining condition on the surface roughness, surface roughness as the output, current, gap and electrolyte concentration as input. Therefore, the most influential parameter is the current (72.17%), gap (17.81%) and minimize effect electrolyte concentration (5.63%) as shown in **Table 5.**

5.2 Optimal Design Conditions For Surface Roughness

The main effects figure used to find the better design parameter to get the better surface roughness and to select the better machining parameters using **Fig 6.** which shows the main effect figure conditions for minimum surface roughness were: current at level-1 (30 A), gap at level-1 (1.00 mm and electrolyte concentration at level-1(100(g/L)).

The **Fig 6**.and **Fig 7.** depending on data in **Table 4.** Because of using "smaller is better" quality characteristic in this study, The difference (max-min) parameter of three levels for each parameter indicates that the current has the highest effect on the surface roughness followed by a gap and electrolyte concentration.

6. CONCLUSION

This research used Taguchi's design (minimum number of experiments can use this method)for get optimum parameter with lowest surface roughness,.

- The Maximum surface roughness when current (70 A) , gap (1.50 mm) and electrolyte concentration (300(g/L)).
- Through ANOVA method , found current is very important factor influnes (72.17%) on surface roughness.
- The compare of experimental and prediction conditions levels (A1B1C1) (current at level-1(30 A), gap at level-1 (1.00 mm) and electrolyte concentration at level-1(100(g/L)). shown the average experiments measure and prediction surface roughness from Taguchi (1.352 μm) and (1.399 μm) respectively .

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Table 1. Chemical composition of Aluminum (7024).

Element	Cu%	Mg%	Si%	Fe%	Mn%	Cr%	Ni%
Percentage(%)	2.14	1.55	0.163	0.422	0.216	0.090	0.012
Element	Ga%	Pb%	Zn%	Ti%	V%	Other%	AL%
Percentage(%)	0.010	0.071	4.93	0.038	0.007	0.132	90.219

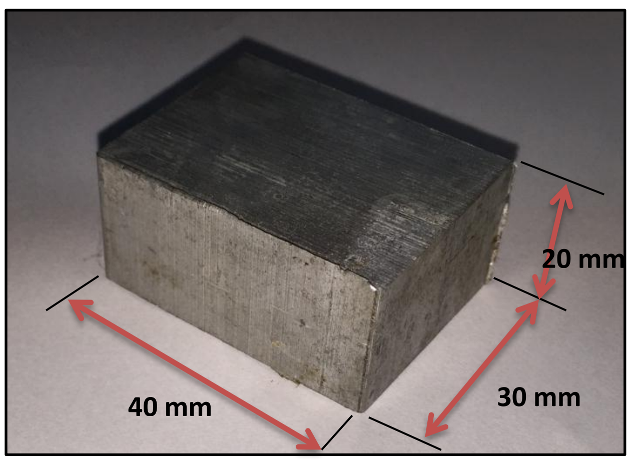


Figure 1. Workpiece dimension.

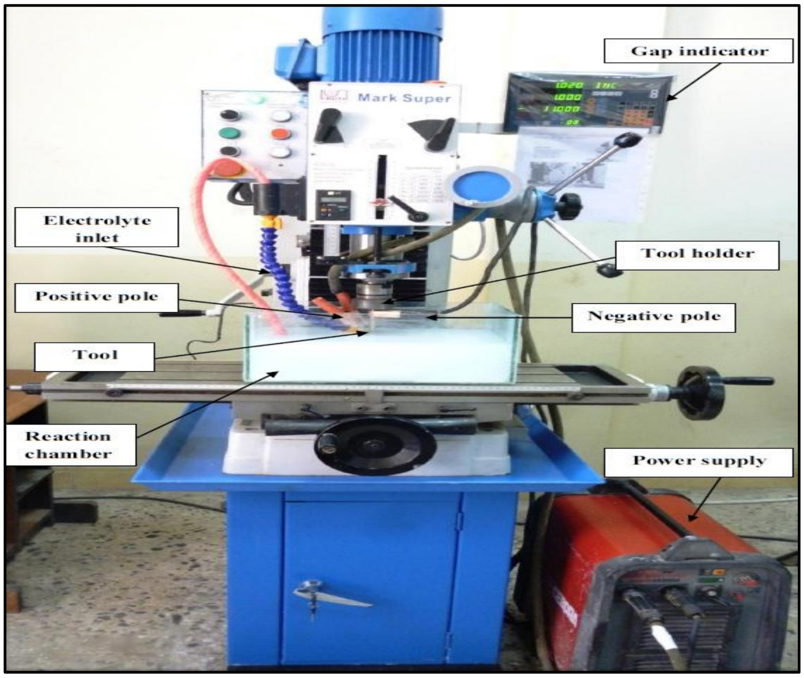


Figure 2.ECM machine model .

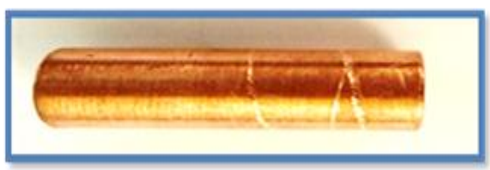


Figure 3. Cathode copper tool.

Table 2. The chemical composition (KCl).

Element	Ca%	SO_4%	Fe%	Br%	Mg%	Na%
Percentage(%)	0.001	0.003	0.0002	0.01	0.0005	0.02
Element	Gu%	Pb%	Ba%	PO_4%	N%	I%
Percentage(%)	0.0002	0.0002	0.001	0.0005	0.001	0.002

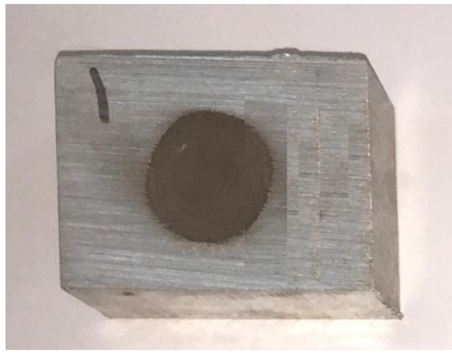
Table 3. Cutting conditions.

No	Parameter	Level 1	Level 2	Level 3	Units
1	Current	30	50	70	A
2	Gap	1.00	1.25	1.50	mm
3	Electrolyte concentration	100	200	300	g/L

Figure 4.The portable surface roughness measurements .

Table 4. The ECM conditions of experiments and S/N results.

No	Current(A)	Gap(mm)	Electrolyte concentration (g/L)	Surface roughness (Ra) (μm)			Average Ra (μm)	S/N ratio
	A	B	C	Ra $_1$	Ra $_2$	Ra $_3$		
1	30	1.00	100	1.37	1.11	1.21	1.23000	-1.83089
2	30	1.25	200	2.10	2.14	1.80	2.01333	-6.10291
3	30	1.50	300	2.56	2.32	2.34	2.40667	-7.63717
4	50	1.00	200	2.51	2.42	2.35	2.42667	-7.70336
5	50	1.25	300	2.71	2.68	2.76	2.71667	-8.68137
6	50	1.50	100	2.79	2.90	2.85	2.84667	-9.08782
7	70	1.00	300	3.08	3.00	2.88	2.98667	-9.50702
8	70	1.25	100	3.07	3.00	3.03	3.03333	-9.63879
9	70	1.50	200	3.11	3.23	3.10	3.14667	-9.95854



Current=30 ,Gap =1,00
Electrolyte =100

Figure 5.The sample of work use .

Table 5. Analyses ANOVA for surface roughness.

Source of variance	DOF	Sum of squares	Variance, V	F ratio	P (%)
current	2	2.136	1.068	0.5	72.17%
gap	2	0.527	0.264	0.5	17.81%
electrolyte concentration	2	0.167	0.083	0.49	5.63%
Error, e	2	0.130	0.065	-	4.36%
Total	9	2.960	-	-	100

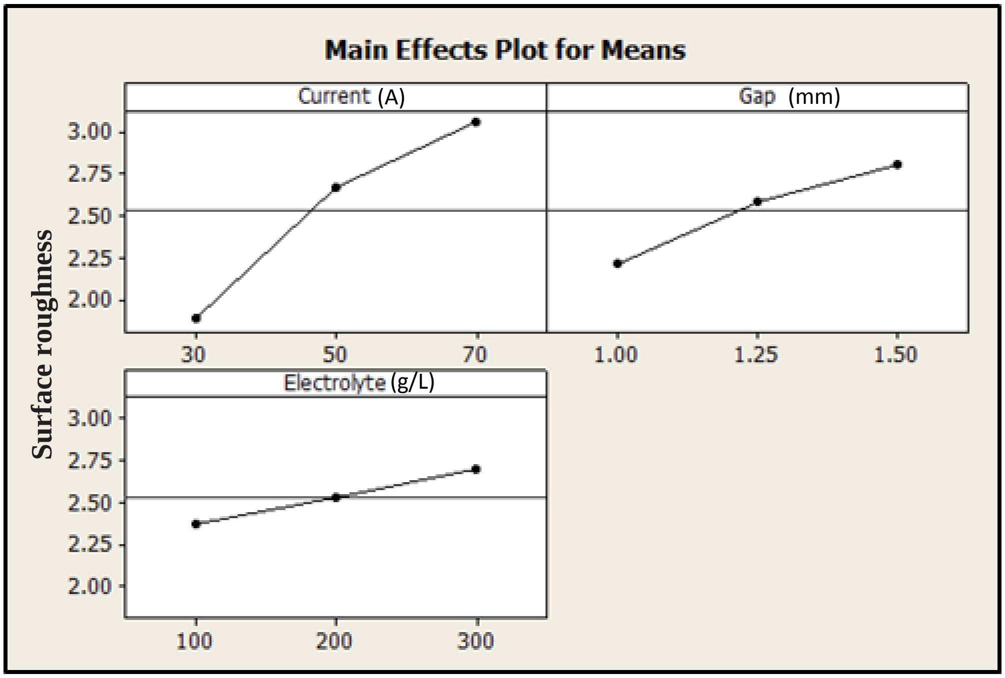


Figure 6. The main effect plot for Surface roughness.

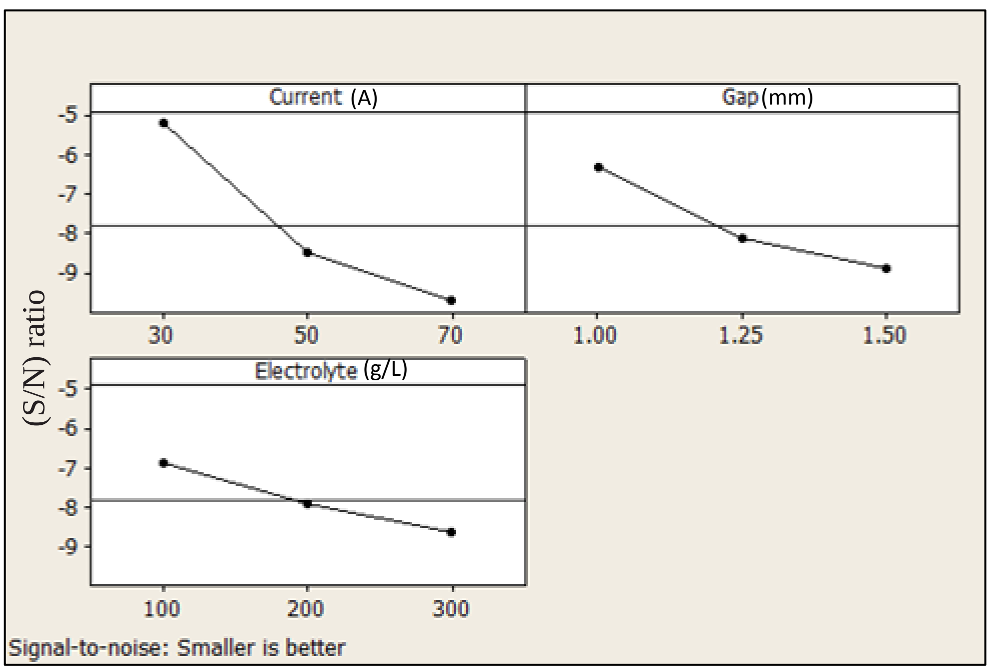


Figure 7. The main effect plot for (S/N) ratio.