Investigation and Prediction of MRR in ECM Process Using Taguchi Method

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ABSTRACT:-

This paper studies prediction the values of material removal rate (MRR) of A7025 Al-Alloy in Electro-chemical operations. It is operation which the material removal rate is machined with elevation spark in the midst workpiece and electrode sunken through dielectric solution. Through theory of Taguchi found that the accuracy of the measured and prediction values that have been is 93% for the MRR. The effect of different Electro-chemical machining (ECM) factors are (current, Gap and Electrolyte concentration) to predict the (material removal rate). Note that connected pole that was used is copper. By use analysis of variance method (ANOVA) found that large parameter influence on MRR is current 75% and Gap 15%. The least influential factor in material removal rate is Electrolyte concentration with 0.2%.

Keywords: Electro-chemical machining; Material removal rate; Taguchi.

1. Introduction and Review:

Electro-chemical machining (ECM) is a non-conventional machining method belonging to electro-chemical category. Electro-chemical Machining is a old machining .Uses non-traditional energy sources like mechanical, light, sound, electrical, chemical, ions and electrons. With the growth of technological and industrial, development of difficult to machine materials and more harder [1]. The problems of higher demand, size and high complexity in shape for product accuracy and surface roughness can solve through non-traditional ways. Thus ECM can be attention of as a proscribed anodic dissolution at atomic level the material of workpiece that is electrically conductive by a formed tool owing to flow high of current at relatively low potential difference during an electrolyte which is rather often water based neutral salt solution. ECM is the controlled removal of material by anodic disbanding in an electrolytic cell in which the tool is cathode and the work machined is the anode. The electrolyte is push through the gap between the workpiece and the tool, while direct current is voted for through the cell, to dissolve material from the workpiece [2].

[3] Showed the feasibility of fast tooling for electro-chemical machining (ECM). An experimental was pulse ECM system was constructed, and physical experiments were conducted. Results indicate that electrode voltage and gap size have the largest influence on surface roughness and material removal rate. The volume of material removed was approximately 8% lower than that obtained with solid copper electrodes under identical operating conditions. The surface roughness was approximately 19% higher than those obtained with solid copper electrodes under identical conditions.

[4] Focused on the influences of electrolyte concentration, voltage, tool feed rate, electrolyte flow rate and on the material removal rate (MRR), and surface finish (Ra) to complete the effective utilization of electrochemical machine of LM25 Al/10%SiC composites produced throughout stir casting. The electrolyte used for experiment was fresh NaCl solution. The best machining parametric arrangement, i.e., electrolyte attention, 12.53 (g/l), applied voltage, 13.5 (V), electrolyte flow rate, 7.51 l (min), tool feed rate, 1 (mm/min) be found out to achieve the maximum material removal rate as 0.8773 (g/min) and minimum surface finish as 6.5667 (μm).

[5] Focused on the influences of the change in size of gap, current density, and tool roughness on material removal rate and Surface Roughness of the workpiece. The results gave that, increasing in size of gap between the tool and the workpiece from 1(mm) to 3 (mm) leads to increase off (46%) in the surface finish of the workpiece, while MRR and dissolution rate decrease to (16%) at a current density of (2.856 Amp/cm^2). Increasing the density of current from (2.4485-3.6728) (Amp/cm^2) leads to decrease in surface finish of the workpiece by approximately (31%), while material removal rate and dissolution rate increase efficiency of the process by (93.9%) at a gap size of (1mm).

[6] This paper was focused on enhance of material removal rate and surface roughness in electrochemical machining during the materials of workpiece are two aluminum alloy aluminum 1100 and (AL Zn Mg Cu

1.5-DIN 1725-1), also NaCl solution as electrolyte was used with using tools are brass and steel ck35. Experiments show that increasing flow rate of electrolyte from 6-14 l (min at electrolyte concentration 200 (g/l) give increase material removal rate reach to (63.07%) and enhancement of surface roughness by reducing roughness from (6.63 to 1.2) (μm) maximum and from (5.07-3.25) (μm) minimum using material from aluminum alloys to perform that.

2. Theory of Taguchi Method:

In this method, the (mean) refers to the output characteristic, (signal) to the desirable value and the term (noise) is the typical deviation. 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), in addition to (signal to noise ratio) [7].

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

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

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

Where, yi 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

3. Experimental Work:

ECM machine is available in University of technology. With workpiece A7025 Al-Alloy dimension (20 x 20)mm and width (20)mm . This operation needs some accessories and experimental setup to made hole with diameter (10mm) and machining time constant (5 min).

3.1 ECM Machine:

The machine used is performed on 2-axis, as shown in **Fig. 1.**

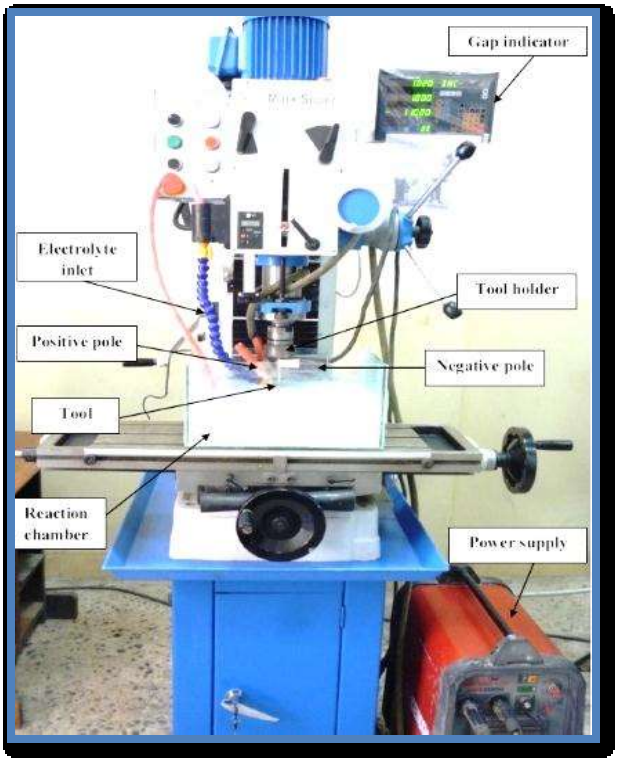

Fig. 1. ECM Machine being used in experimental work.

3.2 Workpiece:

A7024 Al alloy was select to be machine. The chemical work of art shown in **Table 1.** which was check in the Central Organization for Standardization and Quality Control

Table 1. Chemical work of art for 7024 Al alloy.

Fe%	Mn %	Si %	Cu%	Cr%	Mg%	Ni%
0.422	0.216	0.163	2.14	0.090	1.55	0.012
Ti%	**V%**	**Zn %**	**Ga%**	**Other%**	**Pb%**	**AL %**
0.038	0.007	4.93	0.010	0.132	0.07	90.21

3.3 Cutting Tool:

One type of electrode was used copper rod with 10 mm diameter **Fig. 2** Shows this rod.

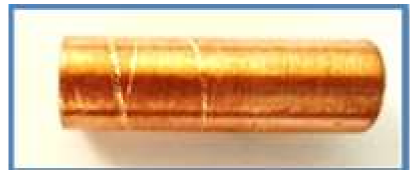

Fig. 2. Copper rod with 10 mm diameter.

3.4 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(MRR). The cutting parameters used (current, gap and electrolyte construct). The parameters were Current unit (Amper), Gap unit (mm) and Electrolyte concentration unit (g/L). The levels of cutting parameters are listed in **Table 2.**

Table 2. Cutting conditions.

No	Parameter	Level 1	Level 2	Level 3	Units
1	Current	30	50	70	Amp
2	Gap	1.00	1.25	1.50	mm
3	Electrolyte constriction	100	200	300	(g/L)

The final parameter distribution of the experiment are listed in **Table 3:**

Table 3. Experimental design for the work.

No.	Current (A)	Gap (mm)	Electrolyte constriction (g/L)	Measured of MRR (g/min)	Predicted of MRR (g/min)
1	30	1.00	100	0.25	0.307
2	30	1.25	200	0.13	0.121
3	30	1.50	300	0.22	0.171
4	50	1.00	200	0.53	0.481
5	50	1.25	300	0.27	0.327
6	50	1.50	100	0.34	0.331
7	70	1.00	300	0.77	0.761
8	70	1.25	100	0.61	0.561
9	70	1.50	200	0.52	0.577

In **Fig. 3** the nine specimens are displayed use ECM process depending on linear interpolation.

Fig. 3. The nine specimens.

3.5 Metal Removal Rate (MRR):

The material removed(mrrr) by a single discharge . The spark is reflect as a uniform rise temperature source on the electrode surface .The (mrr) of the process will be measure by dividing the weight of workpiece before and after cutting against the machining time that was achieved [8].

$$MRR=\frac{WPVB-WPWA}{MT} \quad .... (3)$$

Where:
MRR= Material removal rate (g/min)
WPVB= Weight before machining (g).
WPWA= Weight after machining (g).
MT = time of machining (5 min).

4. Results and Discussion:

The compression for data MRR predicted and MRR measured as shown in **Fig. 4**, it is indicate there is an agreement in more values for two charts, this shows the effected Taguchi method to predict the variables. The output values (MRR) able to predict the use R^2 pieces are 93.9% for mean material removal rate. The mean of S/N ratio and these Characteristics shown. To study the effect of parameter which use in cutting on output MRR using analysis of variance (ANOVAThe "P%" values in **Table 4.** current is the large effect parameter for maximum MRR, and the Gap is the next significant factor for maximum metal removal rate. **Figs. 5 and 6** shows the

The Variance	DOF	SS between	V	F	P(%)
Current (A)	2	0.284	0.142	15.77	78.88
Gap, mm	2	0.057	0.0285	3.16	15.83
Electrolyte concentration	2	0.001	0.0005	0.05	0.27
Error ,e	2	0.018	0.009		5
Total	8	0.360			100

plot of the means of mrr and the means of S/N ratio. In the Figures it is concluded that the optimum parameter combination for maximum material removal rate is level (3) level (1) level (3), i.e., at 70 (A) current, 1.00 mm Gap and 300 (g/L) Electrolyte concentration.

A **Fig. 7** shows the effect of current and Gap on MRR. From this figure, it can be seen, that the increase in current leads to increase MRR, but the increase in Gap leads to decrease MRR. This is due to low rates of melting at high values of Gap while Electrolyte concentration has a little effect on MRR. Also, from this figure, shown that high rates of MRR when low levels of Gap.

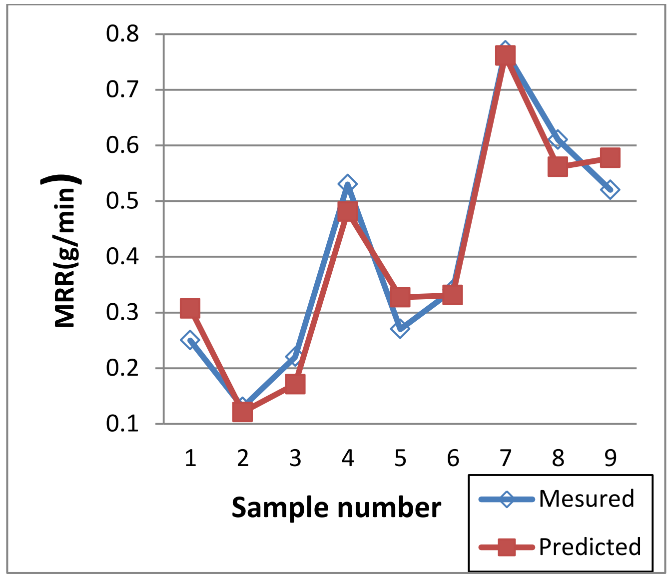

Fig. 4. Measure & predict MRR for the experimental.

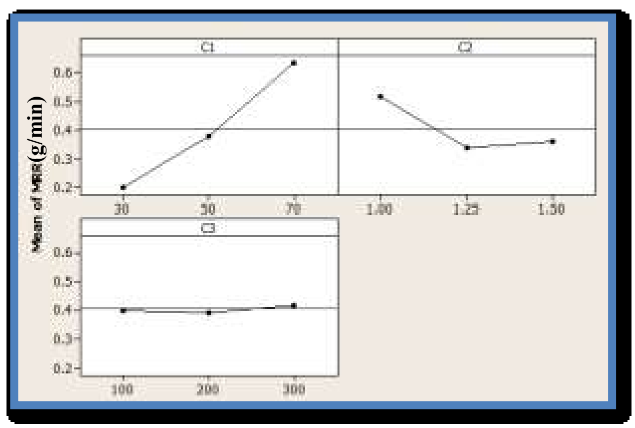

Fig. 5. Effects diagram for means (MRR).

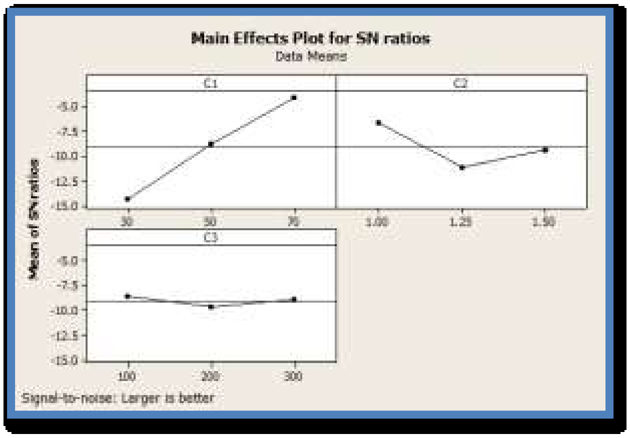

Fig. 6. The mean S/N ratio plot for (MRR).

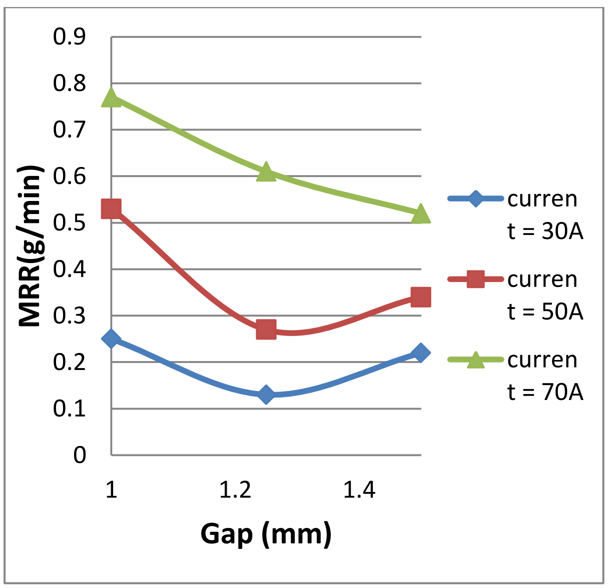

Fig. 7. Effect of current and Gap on the MRR.

5. Conclusions:

The conclusions of this paper can be summarized as: At current supplied (50A) get more accurate machining and MRR using copper electrode and workpiece with thickness (20 mm), this process gives best surface roughness. The accuracy between the predicted and experimental values at the optimum combination of variables characteristics for MRR, within 93%. Obviously, this confirms excellent reproducibility of the experimental conclusions.

References

[1]A. Mallick, **"Estimation of MRR by using U-shape Electrode in Electro-chemical Machining",** M.Sc thesis, National Institute Technology, India, 2009.

[2]C. Hee Jo, B. Hyun Kim, H. Shik Shin, D. Kwan Chung, M. Ho Kwon,C. Nam Chu" **Micro Electrochemical Machining for Complex Internal Micro Features"** International Conference on Smart Manufacturing Application, vol.143 pp. 247–250,2008.

[3] E. Srisawad **"An Investigation Of Rapid Tooling For Electrochemical Machining Of TI-6AL-4V Alloy"** M.Sc thesis, North Carolina State University , 2006.

[4] G. Senthilkumar, Ganesan, R. Karthikeyan, **"Study Of Electro Chemical Machining Characteristics Of Al/Sic$_p$ Composites"**, Journal of Advanced Manufacturing Technology, vol.43, pp.256 – 263, London, 2009.

[5] H. H.Alwan" **Study of some Electrochemical Machining Characteristics of Steel Ck 35"**, M.Sc thesis University of Technology, Iraq, 2011.

[6] karim, S. et al **, "Enhancement Of Metal Removal Rate (MRR) and Surface Finish In Electrochemical Machining "**, Eng. & Tech. Journal, University of Technology, Vol. 13, Part (A), No. 1, 2013.

[7] Mohammed , Atheer R, Abdullah , Mostafa A, Abdulwahhab,Ahmed B,**"Effect of Cutting Parameter on Material Removal Rate and Surface Roughness in Deep Drilling Process"**, Arab Journal of Science and Research, Vol.2- Issue (5), PP.274-285,2016.

[8] Maan A. Tawfiq, Shukry H. Aghdeab and Ahmed B. Abdulwahhab, **" Studying the Effect of Current on (MRR) and (EW) in Electrical Discharge Machining (EDM)** ", Eng. & Tech. Journal, University of Technology, Vol. 31, Part (A), No. 17, 2013.

بحث وتنبوأ بمعدل المادة المزالة في عملية التشغيل الكهروكيميائي باستخدام طريقة تاكوشي

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ا.م.د. شكري حميد غضيب

م.م. مصطفى عادل عبد الله

الخلاصة

الغرض من البحث الحالي هو التنبؤا بمعدل ازالة المادة باستخدام نظرية تاكوشي لعملية التشغيل الكهروكيميائي هي العملية التي يزال منها المعدن من المشغولة من خلال قوة التفاعلات الكهربائية بين كل من القطب والمشغولة والذي يكون كل منهما مغمور في سائل. من خلال تقنية تاكوشي وجد ان الدقة بتنبؤا معدل ازالة المادة هي(93٪) .

في البحث الحالي تم اخذ متغيرات القطع التالية (التيار, الفجوة, المحلول) للتنبؤا بقيم معدل ازالة المعدن. علما ان القطب الموصل الذي تم استخدامه هو نحاس. من خلال تحليل التباين وجد ان اكثر عامل مؤثر على معدل ازالة المعدن هو التيار بنسبة 75٪ والعامل الذي يليه هو الفجوة بنسبة(15٪) والعامل الاقل تأثرا لمعدل ازالة المعدن هو المحلول المستخدم (0.2٪).

الكلمات الرئيسيه: التشغيل الكهرو كيمياوي, معدل ازاله المعدن ,تاكوشي.