Experimental Investigation of Machining Parameter in Electrochemical Machining

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Abstract: Electrochemical machining (ECM) has inaugurated itself as one of the major other possible way to conventional methods for machining hard materials and complicated outlines not having the residual stresses and tool wear. Electrochemical machining has vast application in automotive, Aircrafts, petroleum, aerospace, textile, medical and electronic industries. Studies on Material removal rate (MRR) are of extremely important in ECM, since it is one of the factors to be determined in the process decisions. So the aim of present work is to investigate the metal removal rate, overcut and surface roughness of mild steel of diameter 50 mm as work piece by using copper electrode and brine solution as electrolyte by using Taguchi L_9 orthogonal array approach. Then optimized the best setting of process variables for higher MRR, lower surface roughness and overcut. Three parameters were chosen as process variables are: voltage, tool Feed rate and Electrolyte concentration.

***Key Words:** Electrochemical machining (ECM), Surface Roughness, Taguchi Design, Material removal rate, overcut.*

1. INTRODUCTION

ECM is one of the well established non-traditional manufacturing processes nowadays. ECM is opposite of electrochemical or galvanic coating or deposition process. Thus ECM can be thought of a controlled anodic dissolution at atomic level of the work piece that is electrically conductive by a shaped tool due to flow of high current at relatively low potential difference through an electrolyte which is quite often water based neutral salt solution. It is a good and effective method in machining of complex shapes. ECM is the controlled removal of metal by anodic dissolution in an electrolytic cell in which the work piece is the anode and the tool is cathode. Electrochemical machining is developed on the principle of Faradays law. The metal is removed by the controlled anodic dissolution of the anode according to the well-known Faradays law of electrolysis. Since this machining method is achieved by electrochemical reaction, hard and difficult-to-cut materials can be machined. Various variants of ECM like: electrochemical sinking, ECM with numerically controlled tool-electrode movement, electrochemical deburring and electrochemical polishing are used in industrial practice. Aim of the present work is to find the responses, their interaction with input variables, and to find combination of input variables to find optimum value of the response variables using cylindrical electrode on mild steel as work piece in brine solution using Taguchi L_9 OA approach. The input variables selected are voltage; tool feed rate and electrolyte concentration. To find optimum value of factors for higher the better (MRR) small the better (surface roughness and overcut).Taguchi designs provide a powerful and efficient method for designing products that operate consistently and optimally over a variety of conditions. Taguchi proposed several approaches to experimental designs that are sometimes called "Taguchi Methods." These methods utilize two, three, four, five, and mixed-level fractional factorial designs. Taguchi refers to experimental design as "off-line quality control" because it is a method of ensuring good performance in the design stage of products or processes. In the experiment using three factors and three levels setup the total number of experiments to be conducted is 9. In this study, an L_9OA based on Taguchi design are used machining parameters like voltage (V), Feed rate (F) and conductivity (C) were varied to conduct 9 different experiments and the measurements weights of the work piece were taken for calculation of MRR. Minitab software was used to analysis the findings.

Table. 1

Machining parameter and their levels

Parameters	symbols	unit	Level 1	Level 2	Level3
voltage	V	V	5	8	11
Tool feed rate	F	mm/min	0.2	0.4	0.6
concentration	C	g/l	20	30	40

Table. 2

Observation table

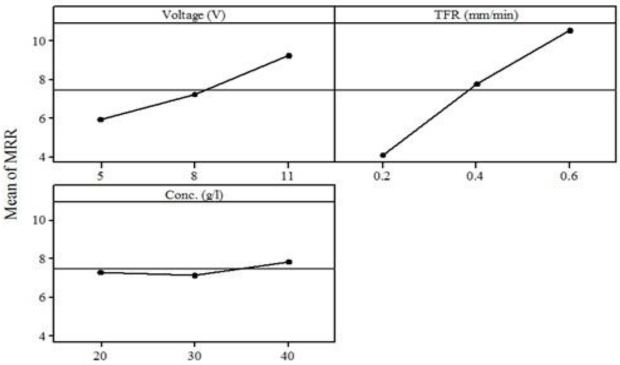
Run	Voltage (v)	TFR (mm/min)	Conc. (g/l)	MRR (mm^3/min)	Avg. surface roughness (μm)	Overcut (mm)
1	5	0.2	20	2.513	6.46	0.29
2	5	0.4	30	5.942	6.73	0.38
3	5	0.6	40	9.396	3.79	0.43
4	8	0.2	40	4.202	4.79	0.40
5	8	0.4	20	7.292	8.59	0.41
6	8	0.6	30	10.149	4.59	0.49
7	11	0.2	30	5.526	2.86	0.40
8	11	0.4	40	10.045	7.39	0.49
9	11	0.6	20	12.149	5.46	0.55

2. RESULTS AND DISCUSSION

In This chapter are related about influences of MRR, SR, and OC and finding the result which factors discharge voltage, feed rate and concentration of Cu tool, is most with mild steel workpiece important with help of orthogonal array based on Taguchi design.

3. INFLUENCE ON MRR

During the process of electrochemical machining, the influence of various machining parameter like voltage, feed rate and concentration has significant effect on MRR, as shown in main effect plot and surface plots for MRR in Fig. The MRR is slightly increases at the range of 0.2 feed rate after that the electrode feed rate have enormous effect on MRR and it increases with increase in feed rate. This result was expected because the material removal rate increases with feed rate because the machining time decreases. MRR also increases with increase in voltage however; the effect is less than the feed rate on MRR. But MRR decreases with larger diameter of electrode.



Main effect plots for MRR

Graph. 1

3. INFLUENCE OF SURFACE ROUGHNESS

The analysis of variances for the factors is shown in Table which is clearly indicates that the concentration is not important for influencing MRR and V and F are the most influencing factors for MRR and other factors are not significant .The delta values are Voltage, Feed rate, Concentration are 3.290, 6.484, 0.675respectively, depicted in Table. The case of MRR, it is “Larger is better”, so from this table it is clearly definite that feed rate is the most important factor then V and concentration of solution.

Table. 3

Analysis of Variance for MRR

Source	DF	Seq SS	Adj MS	F	P
Voltage (V)	2	16.5229	8.2615	353.49	0.003
TFR (mm/min)	2	63.4521	31.7260	1357.47	0.001
Conc. (g/l)	2	0.7857	0.3928	16.81	0.056
Residual Error	2	0.0467	0.0234		
Total	8	80.8074			
S = 0.1529 R-Sq = 99.9% R-Sq(adj) = 99.8%					

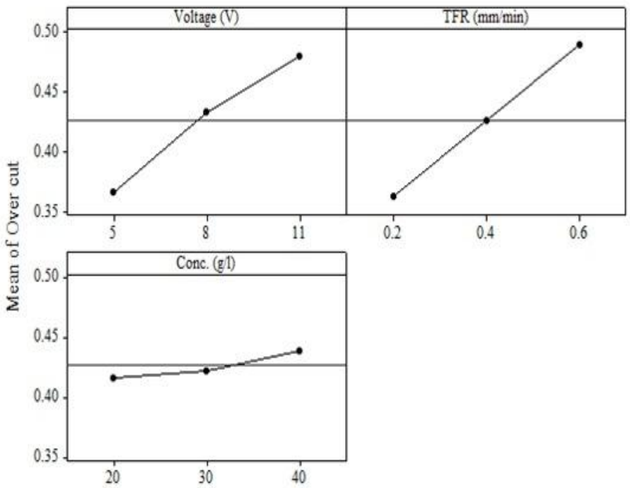
Table. 4

Response Table for Means for MRR

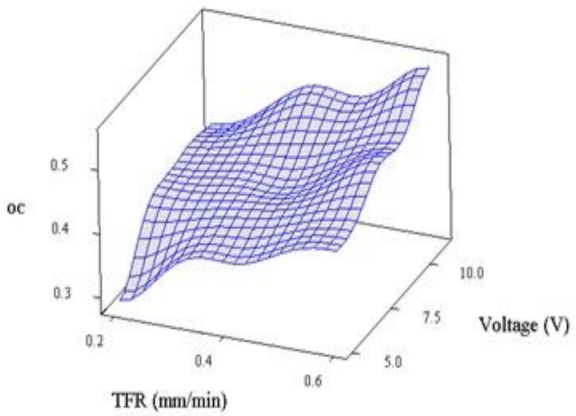
Level	Voltage (V)	Feed rate (mm/min)	Conc. (g/l)
1	5.950	4.080	7.318
2	7.214	7.760	7.206
3	9.240	10.565	7.881
Delta	3.290	6.484	0.675
Rank	2	1	3

4.INFLUENCE ON OVERCUT

The influence of various machining parameters on overcut is shown in Fig.5 with surface plots. The feed rate has enormous effect on width over cut and it increases with increase in feed rate. Overcut-diameter also increases with increase in voltage. The below figure shows if voltage is increases the overcut-diameter is also increases. Trends are shown by the plot of main effects (means) on overcut. The analysis of variances for the factors is shown in Table which is clearly indicates that the concentration is not important for influencing MRR and V and F are the most influencing factors for OC and other factors are not significant .The delta values are Voltage, Feed rate, Concentration are 0.1133, 0.1267, 0.0233respectively, depicted in Table. The case of OC, it is " loweris better", so from this table it is clearly definite that feed rate is the most important factor then V and concentration of solution.

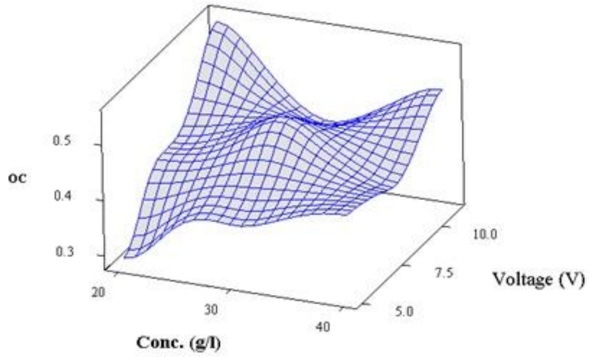


Main effect plots for overcut
Graph 2



Surface plot for OC Vs feed rate and voltage

Graph. 3



Surface plot for OC Vs voltage and concentration

Graph. 4

Table 5

Analysis of Variance for overcut

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Voltage (V)	2	0.019467	0.019467	0.009733	13.90	0.067
TFR (mm/min)	2	0.024067	0.024067	0.012033	17.19	0.055
Conc. (g/l)	2	0.000867	0.000867	0.000433	0.62	0.618
Residual Error	2	0.001400	0.001400	0.000700		
Total	8	0.045800				
S = 0.02646 R-Sq = 96.9% R-Sq(adj) = 87.8%						

Table. 6

Response Table for overcut

Level	Voltage (V)	TFR (mm/min)	Conc. (g/l)
1	0.3667	0.3633	0.4167
2	0.4333	0.4267	0.4233
3	0.4800	0.4900	0.4400
Delta	0.1133	0.1267	0.0233

5. PREDICTED THE SR USING FUZZY LOGIC

The effect of control factors voltage, tool feed rate and concentration on surface roughness are shown in Figure. And surface plots Fig. Surface roughness value increases slightly with increase in voltage value from 5V to 8V and then decreases with increase in value of voltage value from 8V to11V.Surface roughness value increases with increase in feed rate from 0.2mm/min to 0.4mm/min and then decreases with increase in value of feed rate from 0.4-0.6mm/min. In case of concentration surface roughness decreases with increase in value of concentration from 20-30 g/l and then increases with increase in concentration from 30- 40 g/l.so most effective factor looks to be tool feed rate and then concentration.

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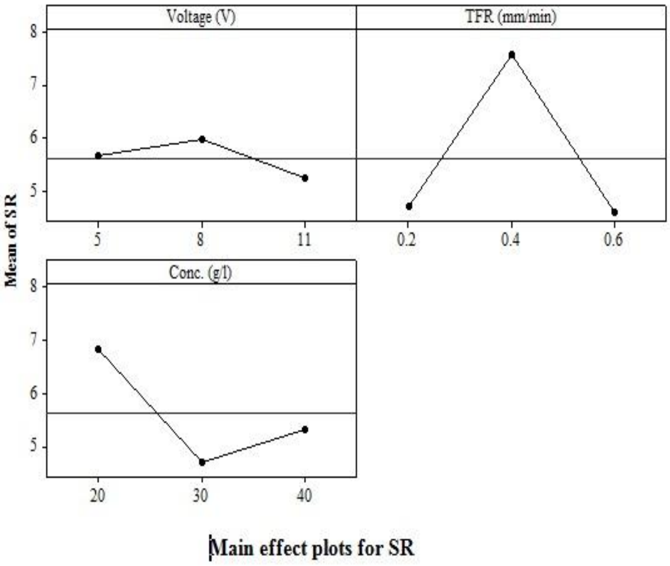

Graph. 5

The analysis of variances for the factors is shown in Table which is clearly indicates that the on one factor is not important for influencing MRR and V and F.

Table. 7

Analysis of Variance for Means

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Voltage (V)	2	0.8556	0.8556	0.4278	0.50	0.667
TFR (mm/min)	2	16.9678	16.9678	8.4839	9.92	0.092
Conc. (g/l)	2	7.0983	7.0983	3.5491	4.15	0.194
Residual Error	2	1.7110	1.7110	0.8555		
Total	8	26.6327				
S = 0.9249 R-Sq = 93.6% R-Sq(adj) = 74.3%						

Table. 8

Response Table for Means

Level	Voltage (V)	TFR (mm/min)	Conc. (g/l)
1	5.660	4.703	6.837
2	5.990	7.570	4.727
3	5.237	4.613	5.323
Delta	0.753	2.957	2.110
Rank	3	1	2

In this study of ECM process on Mild steel by round shaped diameter of 50 mm. The considered L_9OA based on Taguchi design. Three factors were considered that are voltage, tool feed rate and electrolyte concentration. These 9 experiments were conducted to obtain high MRR, low overcut and low surface roughness. The following conclusions are given below.

1. Among 3 factors feed rate is effecting MRR most then comes voltage and at last electrolyte concentration.

2. For surface roughness, feed rate effects it most then concentration and at last voltage.

3. Tool feed rate effects most to overcut at second rank is voltage and at third rank is concentration which affects most to overcut.

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