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"AN INVESTIGATION ON PROCESS PARAMETER OPTIMIZATION FOR SURFACE ROUGHNESS AND OVERCUT USING ELECTROCHEMICAL MACHINING"

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ABSTRACT

The machining of complex shaped designs was difficult earlier, but with the advent of the new machining processes incorporating in it chemical, electrical & mechanical processes, manufacturing has redefined itself. Electrochemical Machining is a non-traditional machining process which is used to machine difficult-to-machine materials such as super alloys, Ti-alloys, stainless steel etc. The basic working principle is based on Faraday law of electrolysis due to which the material removal takes place atom by atom by the process of electrolysis. This experiment highlights features of the development of a comprehensive mathematical model for correlating the interactive and higher order influences of various machining parameters on the dominant machining criteria i.e. surface roughness (SR) and overcut (OC) phenomenon through Response Surface Method (RSM) method using the pertinent experimental data as obtained by experiment. The present work has been undertaken to find the material removal rate, surface roughness and overcut by electrochemical dissolution of an anodically polarized work piece (AISI304 stainless steel) with a copper electrode of hexagonal cross section. Experiments were conducted to analyse the influence of machining parameters such as feed rate, voltage and electrolyte concentration. Analysis of variance (ANOVA) is employed to indicate the level of significance of machining parameters. It is observed that voltage is the most significant factor for surface roughness and for response of overcut, voltage is most significant factor.

***Keyword**:* Electrochemical Machining (ECM), Material removal rate, Voltage, ANOVA

I. INTRODUCTION

In ECM work piece is dipped in a working fluid also called the electrolyte and electrolyte continuously flows through the inter electrode gap between the anode and the cathode. When power supply is switched on, removal of material takes place from work and ions are washed away by flowing electrolyte solution. Metal hydroxide ions are formed by the ions which by centrifugal separation are removed from the conductive electrolyte solution. ECM process is found advantageous particularly for high strength super alloys. ECM is an important process for semiconductor devices and thin metallic films because a basic requirement of semiconductor industry is the machining of components of critical shape and high strength alloys. This process is also used for shaping and finishing operation in aerospace and electronic industries for different parts of the opening. ECM is a non-traditional machining process which is used to machine difficult to machine materials such as alloy steel, Ti alloys, super alloys and stainless steel etc. ECM is characterised as reversed electroplating process. In the year 1983, Faraday established the laws of electrolysis (electroplating). This is the basis for this process which is very very popular not only in the industries, but outside these industries also for some other purposes like for electroplating of different materials. ECM is a controlled anodic dissolution process in which a very high current is passed between the tool which is cathode and work piece which is made anode, through a conductive fluid which is also called electrolyte. It is a non contact process in which the cavity obtained is the replica of

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the tool shape.

II. LITERATURE REVIEW

Mukherjee et.al talks about role of NaCl in process of carrying current in electrochemical machining of iron work piece. Over-voltage-computed regarding equilibrium gap and penetration rate, demonstrates that only a small range of penetration rate and equilibrium gap are allowable. K. P. Rajurkar et.al examined the important advantages of the ECM procedure, for example, high MRR, damage-free and smooth machined surface, are regularly counterbalanced by the poor control of dimension. This paper based on the fundamental ECM dynamics presents a model of controlling ECM that accounts for the dynamic nature of the ECM process. The approach of state space is used to change it into the control model appropriate to a ECM control system based on a digital computer. The simulations were made for checking of model and controller configuration. Bhattacharyya et.al has reported that the electrochemical micro machining as it offers numerous advantages, seems to be promising as a future micro-machining method. A suitable micro tool vibration framework is created, which comprises of micro tool vibrating unit, micro tool vibrating unit, etc. The framework developed was utilized effectively to control MRR and accuracy of machining to meet small scale machining prerequisites. Micro-holes were created on thin copper work piece by EMM using micro tool of stainless-steel. Trials have been completed out to estimate the process parameters for example electrolyte concentration, amplitude and micro-tool vibration frequency for creating micro-hole with high exactness and calculable measure of MRR. Joao Cirilo da Silva Neto et.al demonstrates an investigation of of the intervening parameters in ECM. The parameters studied in this papaer are material removal rate (MRR), over-cut and hardness. Four parameters were changed amid the experiments: flow rate of electrolyte, feed rate, voltage and electrolyte. Two solutions of electrolyte were used: sodium nitrate ($NaNO_3$) and sodium chloride (NaCl).

III. METHODOLOGY

3.1 Experimental set up

The experiments the have been carried out on ECM set up supplied by Metatech-Industry, Pune which is having Supply of - 415 v +/- 10%, 3 phase AC, 50 Hz. And consist of three major sub systems which are being discussed in this chapter.

Tool area = 259.8 mm^2, Cross head stroke = 150 mm.

3.2 Specifications of work piece materials

Work piece material: AISI 304 Stainless Steel

For this experimental investigation we have chosen AISI 304 Stainless steel as work piece. Work piece is having dimension of 100 X 60 mm and 5 mm in thickness. I have taken 2 pieces of AISI 304 material and carried out the experiment .In one work piece 15 cavities are done while in second work piece 5 experiments were done. And the corresponding material removal rate is evaluated by measuring initial and final weight of work piece before and after the experiment.

Table 1 Structure varieties for AISI 304 mark stainless steel

Grade		**C**	**Si**	**P**	**S**	**Mn**	**Cr**	**Ni**	**N**
304	**Minimum**	-	-	-	-	-	18.0	8.0	-
	Maximum	0.07	0.74	0.044	0.03	2.0	20.0	10.4	0.1

Table 2 Mechanical properties of AISI 304 grade stainless steel

Grade	**Tensile strength (MPa) (Minimum)**	**Yield strength (MPa) (Minimum)**	**Elongation%**	**Hardness**	
				Rockwell	**Brinell**
304	516	206	40	91	202

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Copper is used as tool material because they are easily machined, they are conductive materials, and they will not corrode. It is made up of copper rod of length 40 mm with hexagonal cross section at one end having length of each side equal to 10 mm, a through gap is made at the middle by a 3 mm boring tool made up of fast steel.

3.3 Preparation of Brine Solution/Electrolyte

In Electrochemical Machining Process the making of brine solution plays an essential role in material removal rate. Electrolyte is prepared by addition of common salt with water while maintaining the conductivity of water. So we have to take salt solution. In order to maintain the material removal rate correctly we have to maintain the conductivity through out the end of the experiment. For this experiment we have taken 100 gm of salt,125 gm of salt and 150 gm of salt sample in 1000 mL of water in room temperature.

3.4 Procedure of the experiment

Before starting the experiment measure the initial weight of the work piece using a precision electronic balance (least count 0.001 g) to calculate the MRR. After setting all the parameters in the control panel (like feed rate, voltage, current and time) and setting the work piece in the chamber, machining was started by using a copper electrode. The time of machining of the work piece at certain feed rate and voltage is being noted down. The values of surface roughness are measured by means of an portable type profilometer, Talysurf (Model: Surtronic 3+, Taylor Hobson). After measurement it is calculated by arithmetic mean of two data as the absolute value. Overcut is calculated after observation of machined surface under Tool makers microscope.

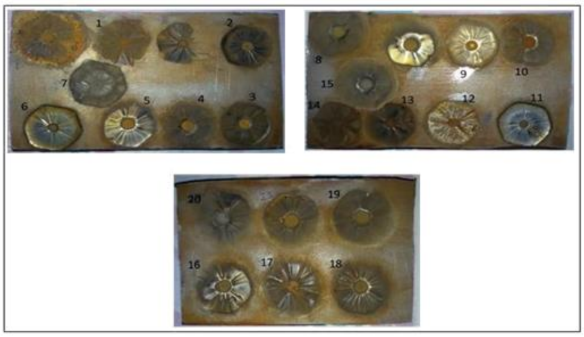

Figure 3 Work piece after machining

3.5 Observation table

Table 4.4 Experimental Layout (RSM Design Stainless steel AISI 304)

Std Order	Concentration (in gm/litre)	Voltage (volts)	Feed (mm/min)	Ra (µm)	Overcut (µm)
1	100	10	0.4	2.22	0.9685
2	150	10	0.4	2.20	0.4755
3	100	17	0.4	2.52	0.0795
4	150	17	0.4	2.72	0.0894
5	100	10	0.8	2.18	0.0099

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6	150	10	0.8	1.34	0.0298
7	100	17	0.8	3.64	0.3865
8	150	17	0.8	3.22	0.5886
9	100	13.5	0.6	1.70	0.5396
10	150	13.5	0.6	0.94	0.5311
11	125	10	0.6	1.42	0.5796
12	125	17	0.6	2.46	0.5058
13	125	13.5	0.4	2.64	0.2369
14	125	13.5	0.8	3.24	0.2486
15	125	13.5	0.6	2.44	0.4890
16	125	13.5	0.6	2.24	0.4953
17	125	13.5	0.6	2.18	0.5206
18	125	13.5	0.6	2.86	0.4965
19	125	13.5	0.6	2.32	0.5205
20	125	13.5	0.6	2.84	0.5249

IV. RESULT & DISCUSSION

4.1 Effect on surface roughness

The Estimated Regression Coefficients for SR is R^2 = 84.27% indicates that the model is able to predict the response with good accuracy. Adjusted R^2 is a modified R^2 that has been adjusted for the number of terms in the model and its value is R^2 (adj) = 70.12%. The standard deviation of errors in the modelling, S = 0.363136, parameter voltage (P=0.001) is significant while concentration (P=0.140) and feed (P=0.277) is insignificant. Squares F*F, C*C and interactions V*F are significant while square V*V and interactions C*V, C*F are insignificant. Normal probability plot shows that the data are not normally distributed and the variables are influencing the response. A standardized residue ranges from -2 and 2. Residuals versus fitted values indicate the variance is constant and a nonlinear relationship exists as well as no outliers exist in the data. Histogram proves the data are almost normally distributed it may be due to the fact that the number of points are very less. Residuals versus order of the data indicate that there are nearly systematic effects in the data.

From RSM, empirical relationship between response and factors in coded forms are given as, SR = -7.10806 - 0.0593878 ×Voltage - 0.00112000×(Concetration)^2 + 23.0000×(Feed)^2 + 0.450000×Voltage×Feed

4.2 Effect on Overcut (OC)

The influence of various machining parameters on overcut (means) are shown in figure 5.5. The overcut increases with increase in electrolyte concentration in the range 100 to 125 and then decreases. Overcut increases with increase in

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voltage in the range of 10 to 13.5 and then decreases. Overcut increases with increase in feed rate in the range 0.4 to 0.6 and then decreases.

4.3 Determination of optimum solution

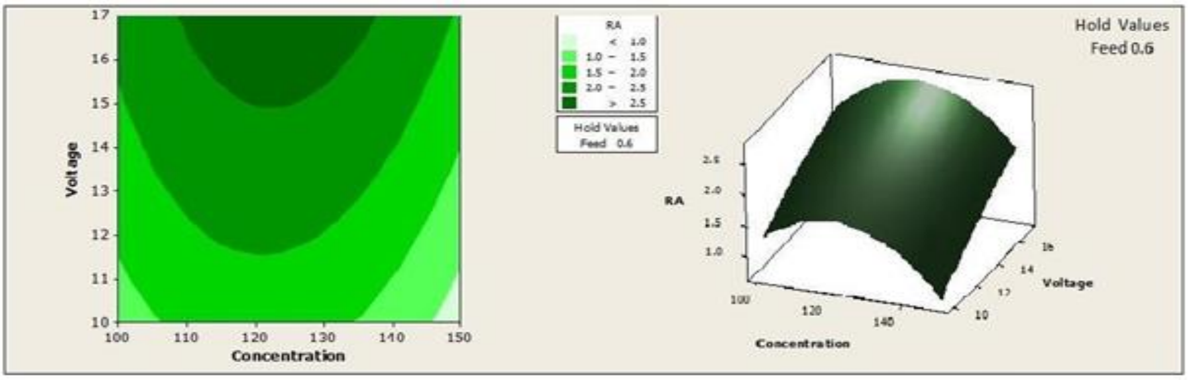
The optimum condition for maximum MRR is electrolyte concentration 100gm/lit, voltage 17 volts and feed 0.6 mm/min.

4.4 Contour and Surface Plot

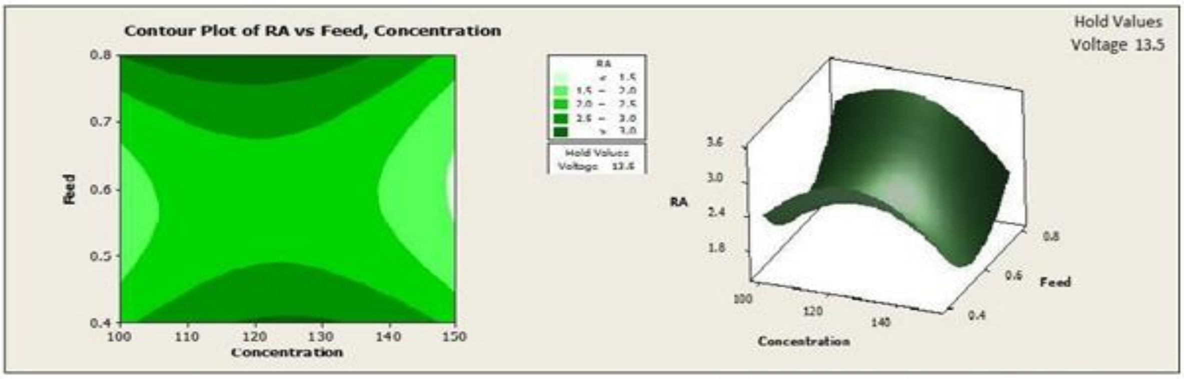
4.4.1 Surface Roughness

SR decreases with decrease in voltage. SR initially increases and then decreases when concentration increases. SR initially decreases and then increases when feed increases.

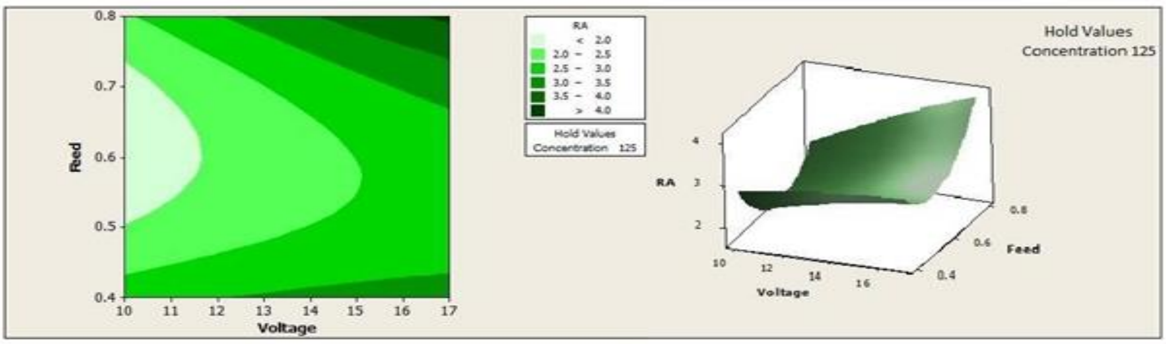
(a). Concentration v/s Voltage



(b). Concentration v/s feed



(c). Voltage v/s feed



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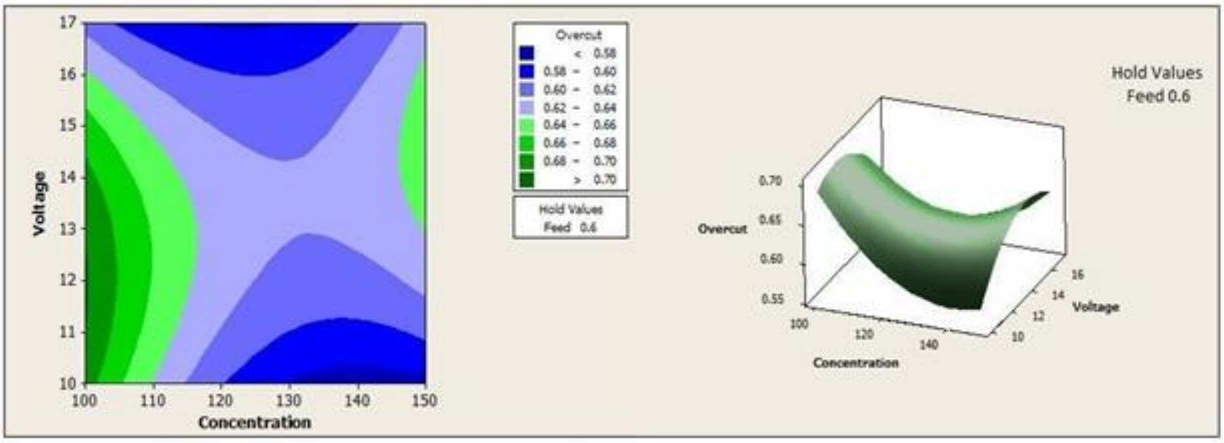
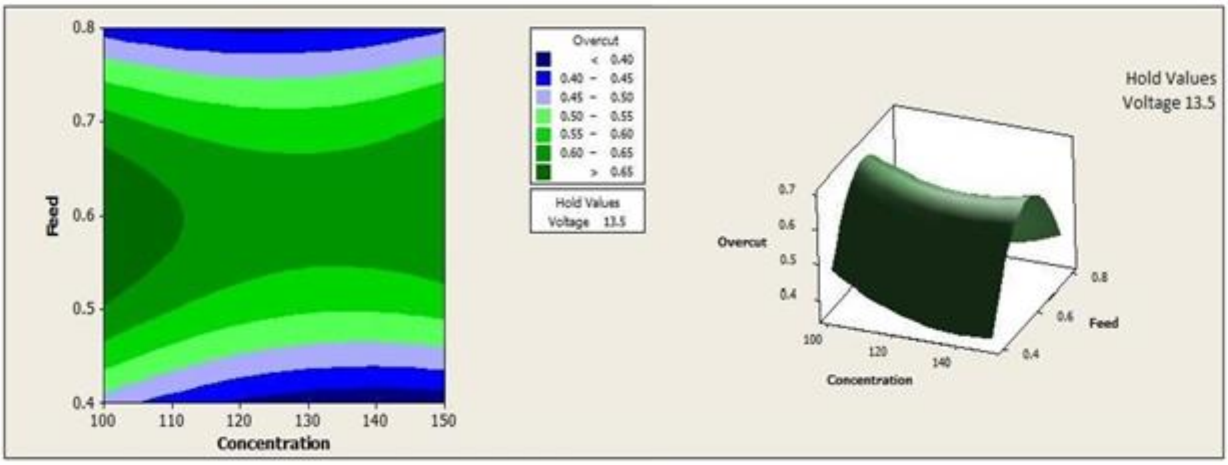
4.4.2 Overcut

OC increases with decrease in concentration. OC increases when voltage increases. OC initially increases and then decreases when feed increases.

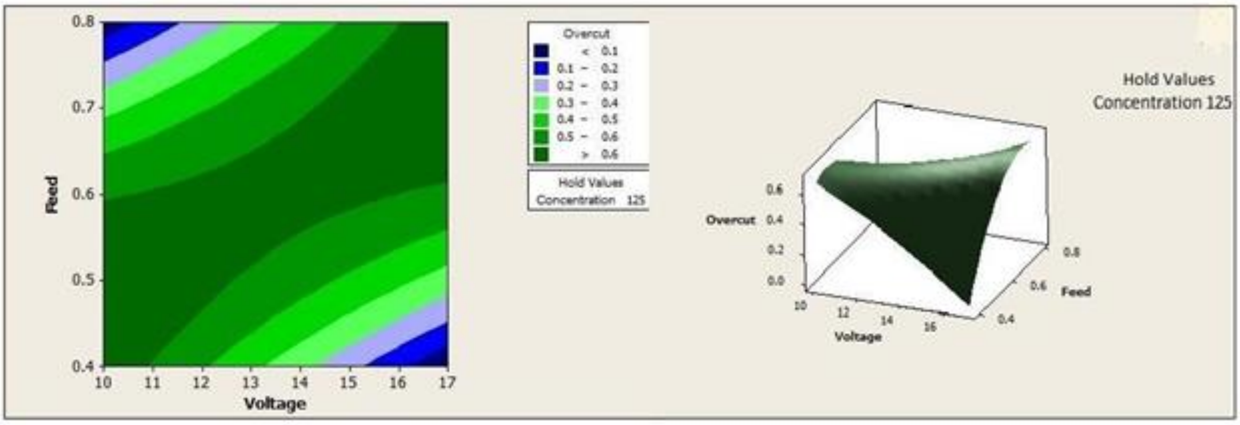
(a). Concentration v/s Voltage



(b). Concentration v/s feed



(c). Voltage v/s feed



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V. Conclusion

- Parameters affecting surface finish are voltage then interaction feed*feed and then interaction voltage*feed. SR increases with increase in voltage. The SR slightly increases with increase in concentration in the range 100 to 125 and then decreases. But SR decreases with increases in feed in the range 0.4 to 0.6 and then increases. The optimum condition for minimum surface roughness is electrolyte concentration 125 gm/lit, voltage 10 volts and feed 0.6mm/min.
- Parameters affecting overcut are interaction feed*feed and voltage*feed then voltage and then electrolyte concentration. OC increases with increase in electrolyte concentration in the range 100 to 125 and then decreases. Overcut increases with increase in voltage in the range of 10 to 13.5 and then decreases. Overcut increases with increase in feed rate in the range 0.4 to 0.6 and then decreases. The optimum condition for minimum overcut is electrolyte concentration 150 gm/lit, voltage 17volts and feed rate 0.4 mm/min.

The optimum condition for minimum SR and minimum OC is electrolyte concentration 100gm/lit, voltage 17 volts and feed 0.6 mm/min. Overall response for minimum SR and OC was most influenced by feed rate, then voltage and then electrolyte concentration.

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