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INVESTIGATION OF ECM PARAMETERS ON THE MRR IN MACHINING OF AISI 304 STEEL

Vivek Kumar*
*Department of Mechanical Engineering, Sant Longowal Institute of Engineering and Technology, Sangrur, India

ABSTRACT

The present paper deals with the investigation of effect of electrolyte concentration and voltage on MRR in ECM of AISI 304 stainless steel. The relation among material removal rate and ECM process parameters has been developed first by using face centered CCD design of RSM. The MRRmodel so developed is improved by applying Box Cox power transformation. The result showed that both the choosen parameters namelyelectrolyte concentrationand voltage affect MRR significantly.

Keywords: *Material removal rate, ECM, Transformation.*

I. INTRODUCTION

Electro chemical method of machining is used to machine difficult-to-machine materials like super alloys,very hard materials, stainless steel etc. and complex contours and shapes [1].These hard and difficult-to-machine materials gives better finish when machined through ECM, and it makes ECM, most common process to be used in automotive, aircraft industries to shape turbine blades [2-4].This method of machining is just the reverse of electrolysis.ECM is defined as controlled anodic dissolution of the workpiece by passing aheavy current between the electrodes, in presence of a conductive fluid called electrolyte. The process is non-contact type and thus there is no tool wear. The cavity obtained in the process exactly replicates the tool shape. Aminor gap of the order of 0.1 to 1 mm is kept between electrodesgenerating a high current density resulting in high rate of material removal from the workpiece.

In the last few decades, number ofresearches have been done with a view to generate the mathematical relations for predicting the surface roughness and MRR etc. An experimental study is being conducted by Neto et al. to examine the influence of the intervening variables on MRR with dissimilarelectrolytes [5].Kasdekar et. al. [6] have used full factorial design to determine the main factors influencing the MRR in machining AA6061. The experimental data is beinganalyzed with ANOVA and ANN model is also being proposed for predicting MRR.The ANN model was found to be more effective in predicting MRR. Burger et al. [7] have studied the influence of ECM input parameters on output response in machining of Ni-base alloy through ECM. Kozak et al. discussed a method of computer aided engineering to find the optimum machining parameters [8].Goswami et. al. [9] uses Taguchi method for optimization of MRR and surface roughness in ECM of Al and mild steel(MS).

In this paper an attempt has been made to examine the effect of process parameters on MRR in machining of AISI-304 through ECM. The face centered central composite design of RSM has been used tomodelthe mathematical relation for prediction of material removal rate. The Box-Cox power transformation is also being applied to increase the accuracy and correctness of the model.

II. EXPERIMENTATION

To develop the predictive MRR model electro chemical machining of AISI304 has been performed by using cylindrical electrode. Copper is chosen as electrode material. The parametersconsideredin the analysisarevoltage and electrolyte concentration.The design layoutobtained through face centered central composite design of RSM is used to investigate the influence of input parameters on material removal rate. The levels of these factors are given in

Table 1.The design matrix along with MRR is shown in Table 2.The data set as per the design matrix based on central composite face centered cubic design is ginen in Table 2.

Table 1:Factors along with levels as per face centered central composite design

Process Parameters	Type	Levels		
Voltage(V)	Numeric	10	14	18
Electrolyte Concentration(gm/lit)	Numeric	100	125	150

III. ANALYSIS OF VARIANCE

Based on design layout presented in Table 2, experimentation is done to obtain the material removal rate. ANOVA has been applied to experimental output to test the significance and lack of fit of the developed model.The normal probability plot is obtained through Design Expert software and the same is shown in Figure 1 to test the trueness of ANNOVA assumptions. The normal probability is used to testnormality of the data.Figure 1indicates the normal distribution of residual except few points, placed far from straight line. As few points are away from the line, the residuals don'tfollow the normal behavior completely.Table 3presents the ANOVA table for quadratic model for material removal rateusingforward elimination to removetrivialtermsfrom model. The analysis is done for CI 95%. From table one can observe that the p-value for the model is less than 0.05 and thus the model is significant.

The quadratic model for material removal rate is given by Eq. 1
$MRR = 107.21-14.268\,A-6.790B-33.773A^2-13.817B^2$ (1)

The output of the above equation can be improved by using Box Cox transformation. It provides a group of transformations to increase the normality by finding an exponent λ. Figure 2 shows the Box Cox plot for above model. The blue line in figure 2 shows the existing lemda (λ) value whereas green one indicates the recommended lemda (λ) value as -0.37.

Table 2:Design layoutand measurement

Standard Order	Run Order	Independent Process Parameters		MRR (gm/min)
		A: Electrolyte Concentration (gram/lit)	B:Voltage (V)	
12	1	14	125	95.1234
6	2	14	150	52.1696
2	3	10	150	56.1021
4	4	18	150	41.623
11	5	14	125	111.133
7	6	10	125	92.802
9	7	14	125	120.977
13	8	14	125	107.137
5	9	14	100	82.568
3	10	18	100	68.812
8	11	18	125	81.848
1	12	10	100	84.1213
10	13	14	125	113.866

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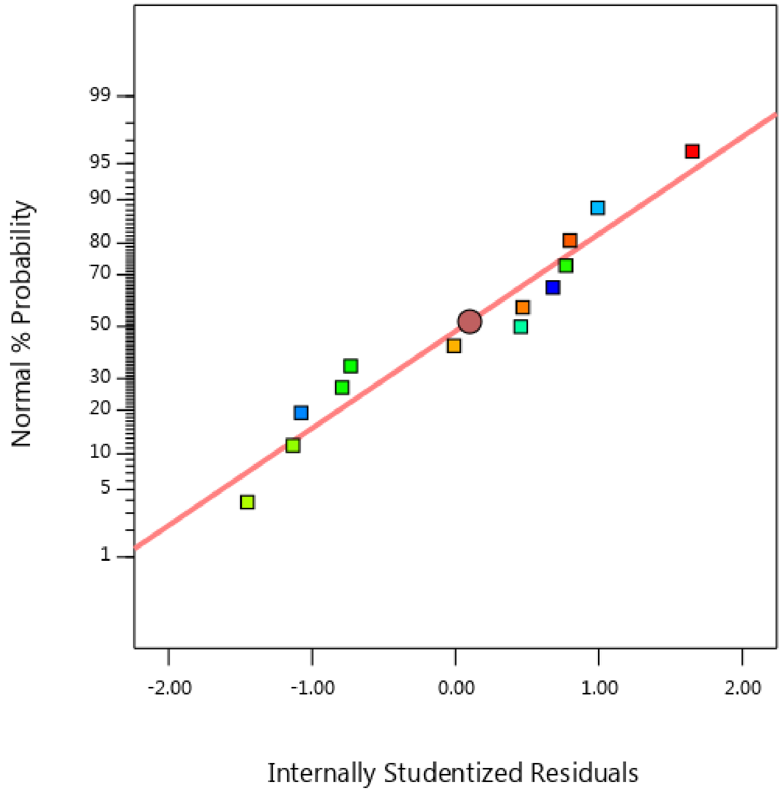

Figure 1: Normal probability plot

Table 3: ANOVA for reduced quadraticMRR model

Source	**Sum of Squares**	**df**	**Mean Square**	**F-value**	**p-value**	
Model	0.0073	4	0.0018	53.90	< 0.0001	significant
A-Electrolyte Concentration (gm/lit)	0.0020	1	0.0020	60.06	< 0.0001	
B-Voltage(V)	0.0004	1	0.0004	12.44	0.0078	
A^2	0.0030	1	0.0030	89.28	< 0.0001	
B^2	0.0003	1	0.0003	10.13	0.0129	
Residual	0.0003	8	0.0000			
Lack of Fit	0.0001	4	0.0000	0.9524	0.5183	not significant
Pure Error	0.0001	4	0.0000			
Cor Total	0.0075	12				

Table 4 Shows the ANNOVA for MRR model after application of power transformation. The p-value for the model is still below 0.0001 showing that the model is still significant. The lack of fit is also insignificant. The p-value for

main effect of electrolyte concentration, voltage and 2-order effect of concentration and voltageare also below 0.05 and thus these terms are significant and plays an important role in pridiction of MRR.

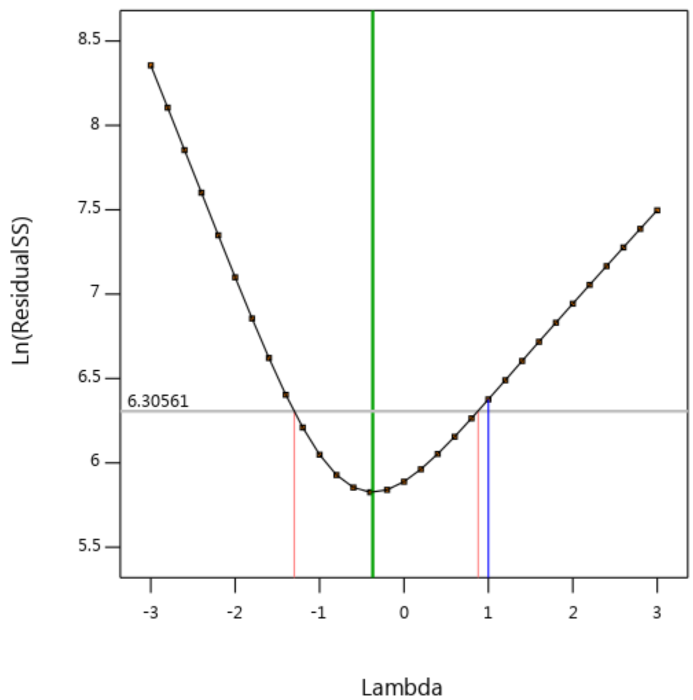

Figure 2: Box Cox plot

Table 4: ANOVA table for MRR model with transformation

Source	**Sum of Squares**	**df**	**Mean Square**	**F-value**	**p-value**	
Model	6948.58	4	1737.15	23.65	0.0002	significant
A-Electrolyte Concentration (gm/lit)	1221.41	1	1221.41	16.63	0.0035	
B-Voltage(V)	276.66	1	276.66	3.77	0.0882	
A^2	3150.29	1	3150.29	42.89	0.0002	
B^2	527.27	1	527.27	7.18	0.0280	
Residual	587.62	8	73.45			
Lack of Fit	222.01	4	55.50	0.6072	0.6796	not significant
Pure Error	365.60	4	91.40			
Cor Total	7536.20	12				

The final MRR model after transformation is given by Eq. 2.

$MRR^{-0.37}$= 0.177367 + 0.0183757A + 0.00836424B + 0.0330222 A^2 + 0.0111229 B^2(2)

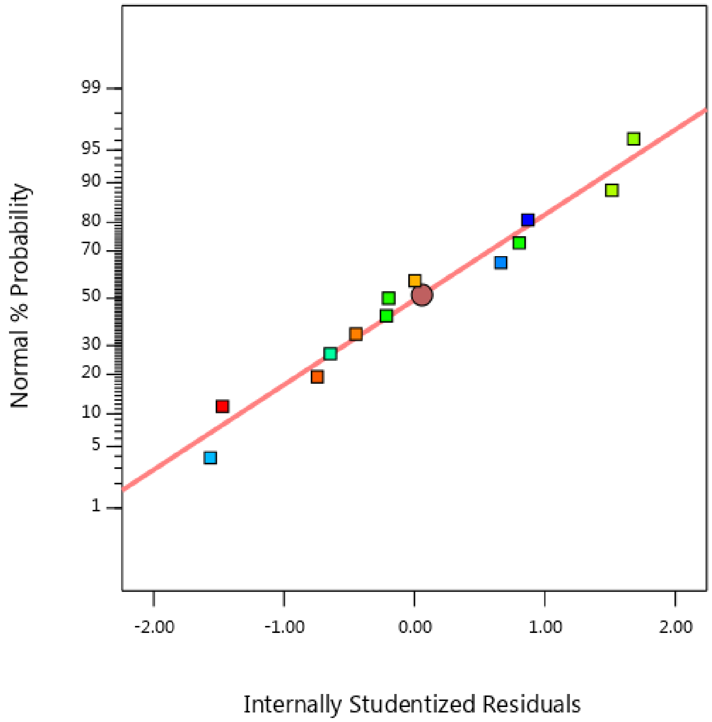

Figure 3: Normal probability plot with transformation

Figure 3 presents the normal probability plot for MRR with the Box Cox transformation. It can easily be observed that most of the points are now close to straight line signifying normal distribution of the residuals.

IV. RESULT AND DISCUSSION

Table 5 presents the comparison of MRR model with and without transformation. One can clearly notice that after application of Box-Cox transformation "R-square value" and "predicted R-square value"have been increased significantly. It clearly indicates more accurate prediction ability of MRR model with transformation.

Table5: Comparison of MRR Models

Model	R-Squared value	Adj R-Squared value	Pred R-Squared
Model-without-transformation	0.9220	0.8830	0.8193
Model with Box-Cox-transformation	0.9642	0.9463	0.9012

To study the effect of electrolyte concentration and voltage on material removing capability of the process, plot between MRR and these variables have been made and are presented in figures 4-6

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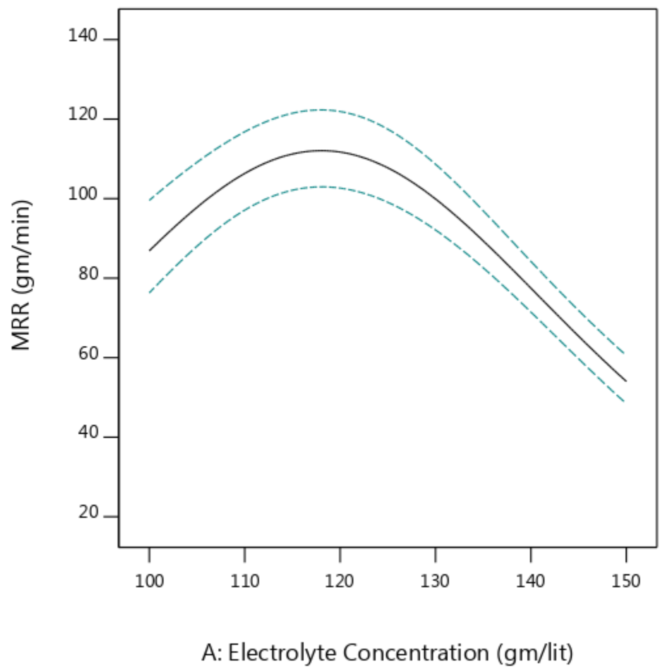

Figure 4: Variation of MRR with electrolyte concentration

To examine the influence of input parameters like voltage, flow rate and type of electrolyte on MRR, the plots between these parameters and MRR have been createdthrough developed quadratic model. Influence of electrolyte concentration on the MRR atconstant voltage of 14 V is shown in Fig. 4. From the plotit is clear that MRR increases by increasing concentration up to certain extent and then starts decreasing. Figure 5 shows the plot between MRR and voltage and it is clearly noticed from the plot that MRR reduces with rise in voltage.

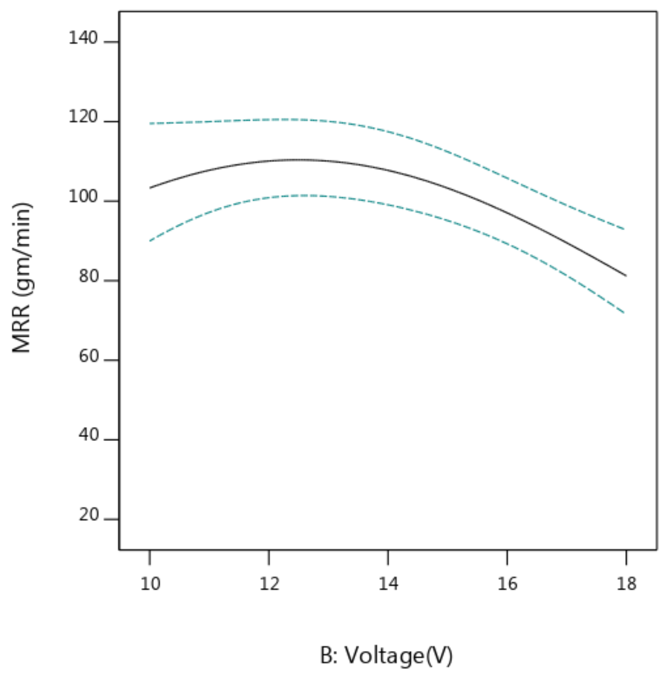

Figure 5: Variation of MRR with voltage

Figure 6 shows the 3D surface graph for MRR. From the plot it can easily be noticed that MRR decreases with rise in voltage and MRR increases with concentration up to peak value and there after it decreases.

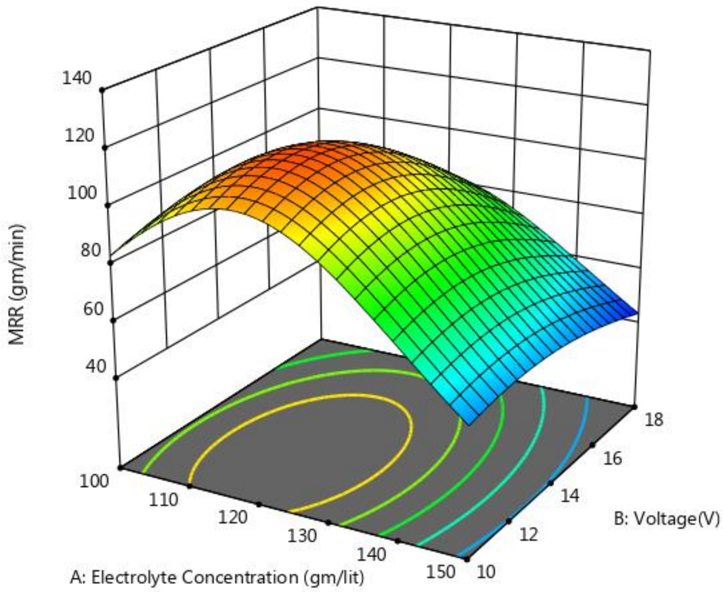

Figure 6: 3D surface graph for MRR

V. CONCLUSION

In this paper, Box-Cox method of power transformation has been usedto generate more preciseMRR model in electro chemical machining of AISI-304 steel.The face centered central composite design of RSM has been used to model the mathematical relation for prediction of material removal rate.It has been found that the using Box Cox transformation the prediction ability of the model was greatly improved due to improvement in linearity and normality of data. The effect of electrolyte concentration and voltage on MRR has also been studied using the prediction model.The results showed that the MRR decreases with increase in voltage and MRR rises with concentration up to peak value and there after it decreases

REFERENCES

1. *Kozak, J., &Zybura-Skrabalak, M. (2016). Some problems of surface roughness in electrochemical machining (ECM). Procedia CIRP, 42, 101-106.*
2. *Jain, V. K., &Rajurkar, K. P. (1991). An integrated approach for tool design in ECM. Precision engineering, 13(2), 111-124.*
3. *Hewidy, M. S., Rajurkar, K. P., Royo, G. F., &Fattouh, M. (1989). Theoretical and experimental investigation of electrochemical ballizing. International journal of production research, 27(8), 1335-1347.*
4. *Tiwari, A., Mandal, A., & Kumar, K. (2015). Multi-objective optimization of electro-chemical machining by non-dominated sorting genetic algorithm. Materials Today: Proceedings, 2(4-5), 2569-2575.*
5. *da Silva Neto, J. C., Da Silva, E. M., & Da Silva, M. B. (2006). Intervening variables in electrochemical machining. Journal of Materials Processing Technology, 179(1-3), 92-96.*
6. *Kasdekar, D. K., Parashar, V., & Arya, C. (2018). Artificial neural network models for the prediction of MRR in Electro-chemical machining. Materials Today: Proceedings, 5(1), 772-779.*
7. *Burger, M., Koll, L., Werner, E. A., & Platz, A. (2012). Electrochemical machining characteristics and resulting surface quality of the nickel-base single-crystalline material LEK94. Journal of Manufacturing Processes, 14(1), 62-70.*

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DOI- 10.5281/zenodo.1245869 Impact Factor- 5.070
8. *Kozak, J., Dabrowski, L., Lubkowski, K., Rozenek, M., &Sławiński, R. (2000). CAE-ECM system for electrochemical technology of parts and tools. Journal of Materials Processing Technology, 107(1-3), 293-299.*
9. *Goswami, R., Chaturvedi, V., Chouhan, R. (2013). Optimization of Electrochemical Machining Process Parameters Using Taguchi Approach. International Journal of Engineering Science and Technology 5, 999-1006.*