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Analysis and Optimization in Electrochemical Machining by using AISI D2 Tool Steel

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***Abstract* - Electrochemical machining (ECM) is the one of the best methods for machining of AISI D2 tool steel, because it's hard and difficulty-to-cut for any conventional machining process. ECM has generally used in automotive, textile, die making industries medical and electronic equipment etc. During the process of machining Material Removal Rate (MRR) consider as higher the better-quality characteristics and with aim to maximize it, since it is one of the factors to be determined in the process decisions. Whereas surface roughness has been considering as the lower the better-quality characteristics with the aim to minimize it.**

Keywords: Design of Experiment, Electrochemical machining (ECM), Surface Roughness, Taguchi Design, Material removal rate.

I. INTRODUCTION

Now a days many manufacturing company poverties to select the good quality and better productivity of work and Electro Chemical Machine (ECM) is one of the best non-traditional manufacturing processes to produced good quality of work with higher material removal rate compare to other non-traditional machining process [1-3]. During process of machining the tool is set to be negative terminal (Cathode), and workpiece set as the anode by process of electrochemical reaction with the help of electrolyte (such as NaCl) material is remove form the workpiece [4]. In this process can be machine any type complex shapes and hard and brittle material that are electrically conductive. Tiwari et al. [5] has been applied a mathematical model of material removal rate and surface finish as output by using regression equation of EN-19 tool steel material and analyzed variance of the responses through this equation.

The electrochemical machining is also used for Machining deep holes, micro-grooves, and micro-channels on the nonconductive materials [6]. Parametric optimization has been analyzed by various researches in electrochemical machining [7-10].

According to the previous research work they find that difficulty face during machining of conventional machining, for avoiding this problem using non-conventional machining process like Electro Chemical machining process for machining of hard and brittle material. The aim to the present work to machining of AISI D2 tool steel on electro chemical machining process. Machining variable was plan 3 factors with the three different range using L9 orthogonal array. Taguchi design of experiment techniques is used to find the optimum setting machining variable on the responses of Material removal rate (MRR) and surface roughness (SR).

II. EXPERIMENTATION

Exponential plan according to the three-machining variable such as voltage (V), Feed rate (F) and conductivity (C) with three different level with the help of Taguchi design. Nine experiments to be conducted based on L9 OA design by using Minitab software. Machining Control Parameters and their different levels are indicated in Table1.

TABLE 1
Design of Experiment: Machining Control Variable

Machining Variable	unit	Level 1	Level 2	Level 3
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

III. RESULTS AND DISCUSSIONS

The present work is to find the optimal setting machining variable on the responses of MRR and SR. In this analysis decided which factor is most significant affect on the responses. The machining control factors like discharge voltage, feed rate and concentration with nine different setting finding the respective value of material removal rate and surface roughness. In this analysis using Copper tool with AISI D2 tool steel workpiece with help of Taguchi design, and response are depicted in Table 2.

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TABLE 2
L_9 (OA) Collected experimental data

Run no.	Voltage (V)	Tool Feed rate (mm/min)	Concentration (g/l)	MRR (mm^3/min)	Surface roughness (μm)
1	5	0.2	20	2.513	6.46
2	5	0.4	30	5.942	6.73
3	5	0.6	40	9.396	3.79
4	8	0.2	40	4.202	4.79
5	8	0.4	20	7.292	8.59
6	8	0.6	30	10.149	4.59
7	11	0.2	30	5.526	2.86
8	11	0.4	40	10.045	7.39
9	11	0.6	20	12.149	5.46

a) Analysis of Material removal rate on machining of ECM

Analysis of Material removal rate on machining of Electro chemical machining control variable feed rate is most significant effect on it. According to the main effect plot of MRR (Fig. 1) voltage is directly proportional to material removal rate because voltage is increasing the energy of material removal rate is also increase so more material eroded form work zone with chemical reaction. The MRR is also increases with increasing of feed rate after that is also shown in surface plot in Fig. 2. But Concentration of electrolyte is not significant effect on material removal rate of machining of ECM.

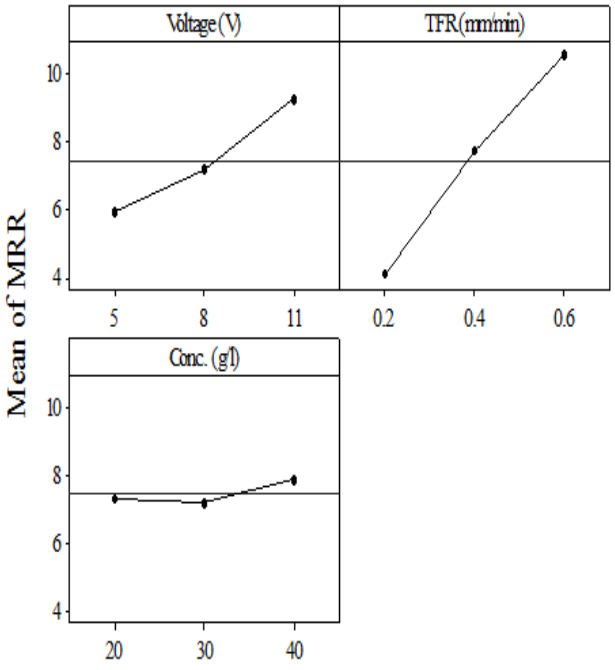
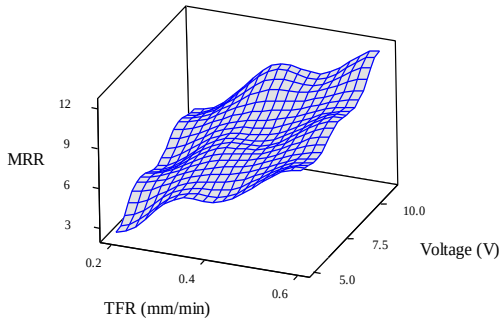


Figure 1: Main effect plots for MRR

(a)



(b)

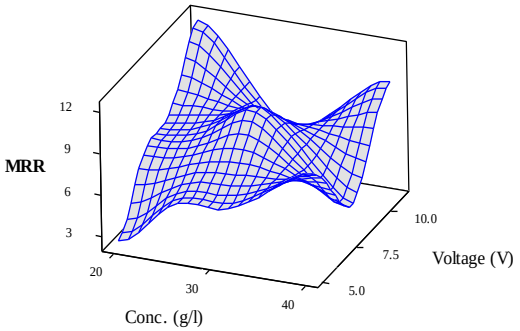


Figure 2: Surface plot for MRR (a) MRR Vrs Voltage and TFR (b) MRR Vrs Voltage and Conc.

In ANOVA (Table 3) is clarity define the control factor "feed rate" is most significant factor that contribution is 78.52 % on MRR calculation. Also specifies concentration of electrolyte is not affect when process of metal removal of AISI D2 tool steel. Voltage is also significant factor for contribution of calculation of MRR is 2044 %. According to ANOVA intention of MRR the amount of variation of our result is 99.9 % (R-squar) value.

TABLE 3
ANOVA for MRR

Source	DF	Seq SS	Adj MS	F	P	%Con.
Voltage (V)	2	16.5229	8.2615	353.49	0.003	20.44
TFR (mm/min)	2	63.4521	31.726	1357.4	0.001	78.52
Conc. (g/l)	2	0.7857	0.3928	16.81	0.056	0.972
Residual Error	2	0.0467	0.0234			
Total	8	80.8074				
% Con. = % Contribution, S = 0.1529 R-Sq = 99.9% R-Sq(adj) = 99.8%						

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b) Analysis of surface roughness on machining of ECM

According to the main effect and surface plot of surface roughness (Fig 3 and 4) in the machining of ECM. The selected control variable has given the significant effect on finding of surface roughness on machine surface. With the range of 5V to 8V surface roughness value is increases slightly with increase in voltage. But in the range of after 8V roughness value is decreases. When the value of feed rate is increasing the roughness, value is also increase up to optimum level after that they are decreasing.

In the analysis of surface roughness electrolyte concentration is also play an important role when the percentage of concentration is increasing the surface roughness value is also increasing but for machining of after 30 g/l (electrolyte concentration) machine surface roughness value is increasing.

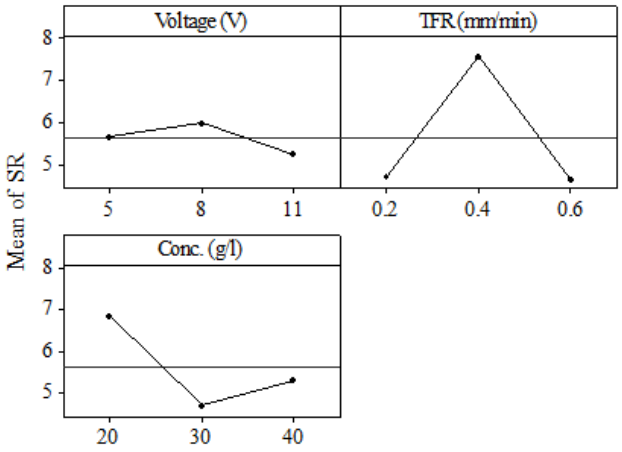
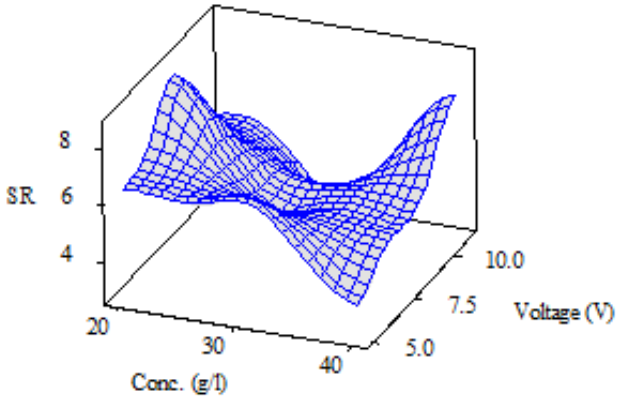


Figure 3: Main effect plots for SR

(a)



(b)

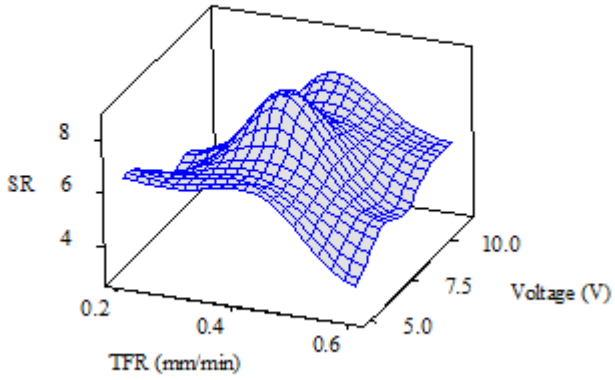


Figure 4: Surface plot for SR (a) SR Vrs Voltage and Conc. (b) SR Vrs Voltage and TFR

ANOVA measurement of surface roughness is presented in Table 4 which is specifies that the measurement of surface roughness the contribution of Voltage, tool feed rate and concentration is 03.21, 63.71 and 26.65 % respectively.

TABLE 4
ANOVA of Surface roughness

Source	DF	Seq SS	Adj MS	F	P	%Con.
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				
% Con. = % Contribution, S = 0.9249 R-Sq = 93.6% R-Sq(adj) = 74.3%						

IV. CONCLUSION

The analysis of electro chemical machining of AISI D2 tool steel. Experimental design was plane for selected control parameters voltage, tool feed rate and concentration have given the significant effect on the analysis and optimization of Material removal rate and surface roughness measurement. Following conclusion are listed below:

- Analysis of material removal rate the feed rate is most significant factor followed by voltage and electrolyte concentration. Optimum setting of MRR is finding that 11 V, 0.6 mm/min and 40 g/l.
- The outcome of surface roughness, feed rate effects it most then concentration and at last voltage. Optimum setting of SR is finding that 11 V, 0.6 mm/min and 30 g/l for better (low value) of surface roughens.

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