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OPTIMIZATION OF ELECTRO CHEMICAL MACHINING PROCESS PARAMETER BY USING FUZZY LOGIC

Sumit Pamnani, Sunil Swami Dubey, Sharda Pratap Shrivas

Mechanical engineering Department
Chouksey Engineering College, Bilaspur

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Email: info@jusres.com

ABSTRACT

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. 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.

KEYWORDS: Electrochemical machining (ECM); Surface Roughness; Taguchi Design; Material removal rate

1. Background of ECM

Electrochemical Machining (ECM) is a non-conventional machining process going to electrochemical category. 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 designed tool due to flow of high current at comparatively low potential difference through an electrolyte which is quite often water based NaCl solution.

The new idea of manufacturing uses non-conventional drive sources like sound, light, mechanical, chemical, electrical, electrons and ions. With the industrial and technological growth, development of harder and difficult to machine materials, which find wide application in aeronautics, nuclear engineering and other diligences owing to their high strength to weight ratio, hardness and heat resistance qualities has been witnessed. New expansions in the field of material science have led to new engineering metallic materials, composite materials and high tech ceramics having better mechanical properties and thermal conductivities as well as sufficient electrical conductivity so that they can readily be machined by spark erosion. Non-conventional machining has grown out of the need to machine these exotic materials. The machining processes are Non-conventional in the sense that they do not employ traditional tools for metal removal and instead they directly use other forms of energy. The problems of high difficulty in shape, size and higher demand for product accuracy and surface finish can be solved through Non-conventional methods. Currently, Non-conventional processes virtually unlimited capabilities except for volumetric material removal rates, for which great advances have been made in the past few years to increase the material removal rates. As removal rate increases, the cost efficiency of operations also increase, stimulating ever greater uses of non-conventional processes.

STAGES BY WHICH ECM PRECEDES:

Through ECM, there will be reactions happening at the electrodes i.e. at the anode or work piece and at the cathode or the tool along with within the electrolyte. Let us take an example of ECM machining of low carbon steel which is mainly a ferrous alloy mainly containing iron. For of steel, usually a NaCl solution is taken as the electrolyte. The electrolyte and water undergoes ionic dissociation as shown below as potential difference is used.

$$NaCl \leftrightarrow Na^{+} + Cl^{-}$$

$$H_2O \leftrightarrow H^{+} + (OH)^{-}$$

When the potential difference is applied between the work piece (anode) and the tool (cathode), the positive ions move towards the tool and negative ions move towards the work piece. Thus the hydrogen ions will take away electrons from the cathode (tool) and from hydrogen gas as:

$$2H^{+} + 2e^{-} = H_2\uparrow \text{ at cathode}$$

Similarly, the iron atoms will come out of the anode (work piece) as:

$$Fe = Fe^{++} + 2e^{-}$$

Within the electrolyte iron ions would combine with chloride ions to form iron chloride and similarly sodium ions would combine with hydroxyl ions to form sodium hydroxide.

$$Na^{+} + OH^{-} = NaOH$$

In practice $FeCl_2$ and Fe $(OH)_2$ would form and get hastened in the form of sludge. In this manner it can be noted that the work piece gets gradually machined and gets precipitated as the sludge.

2. OBJECTIVE OF PRESENT WORK

Aim of the existing 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 a material for work piece and 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). After that the calculation of all responses (MRR, SR and Overcut) these responses are converted into single objective that is multi performances characteristics index (MPCI). This calculated MPCI values with the help of Taguchi quality loss function. They give the low value of SR and OC and high value of MRR.

3. EXPERIMENTAL SET-UP

For this experiment the whole work has been approved out by Electrochemical Machining set up from ManTech-Industry, Pune which is having contribution Supply of - 415 v +/- 10%, 3 phase AC, 50 HZ. Production supply is 0-300A DC at any voltage from 0-25V and competence is better than 80% at partial and full load disorder. The lining resistance is not less than 10 Mega ohm with 500V DC. And contain of three major sub schemes which are being debated in this section. The set up consists of three major sub systems.

a. Machining Cell

b. Control Panel

c. Electrolyte Circulation

Mechanical Data

- Tool part - 30 mm^2.
- Cross head stroke - 150 mm.
- Job container - 100 mm initial X 50 mm depth X 100 mm width.

- Tool feed motor - DC Servo type.

Fig. 1 ECM Set Up

4. SECTION OF WORKPIECE AND TOOL

In this experiment mild steel was used as a workpiece material which is shown in Fig.2 with copper electrode (tool). This tool steel has increasing range of applications like plastic molds, frames for plastic weight dies, hydro founding tools.

Fig. 2 Mild steel workpiece and tool

The calculation of Surface Roughness (SR) (Ra value) was made with portable style type profilometer, Talysurf (Model: Taylor Hobson, Surtronic 3+) , with parameters cut-off length, Ln = 4 mm, sample length, Lc = 0.8mm and filter = 2CR ISO. Overcut (OC) is stated as half the difference of diameter of the hole produced to the tool diameter that is shown in these equations.

$$OC = (Djt-Dt)/2 \quad \text{……………………..(1)}$$

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_9 OA based on Taguchi design are used machining parameters like voltage (V), Feed rate (F) and conductivity (C) were varied to conduct 9 altered experiments and the measurements weights of the work piece were taken for calculation of MRR. Minitab software was used to analysis the findings.

5. RESULT

Throughout the process of electrochemical machining, the effect 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 3 to 5

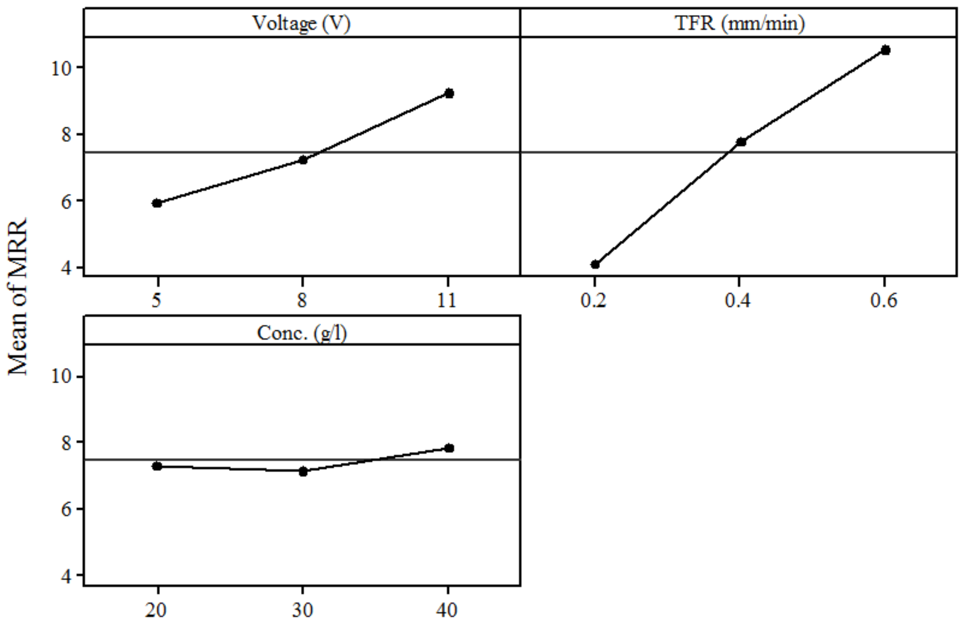

Fig 3 Main effect plots for MRR

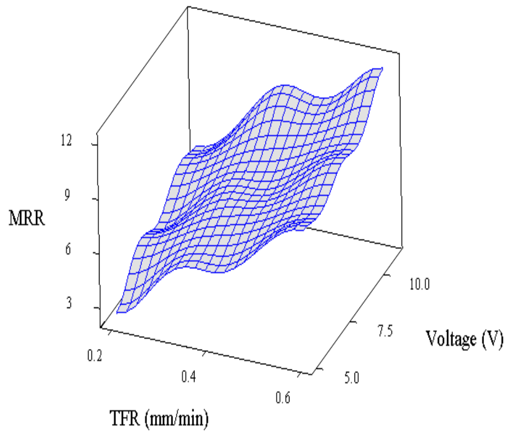	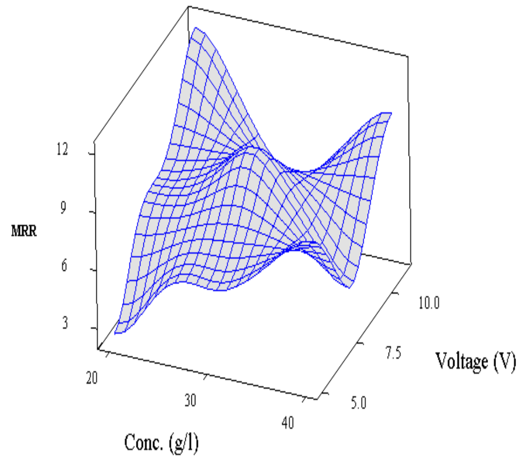
Fig 4 Surface plot for MRR Vs feed rate and voltage	Fig 5 Surface plot for MRR voltage and concentration.

The analysis of variances for the factors gives better responses are shown in fig 6 which is visibly indicates that the concentration is not important for manipulating 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, 0.0233 respectively. The case of OC, it is " lower is better", so from this table it is evidently definite that feed rate is the greatest important factor then V and concentration of solution.

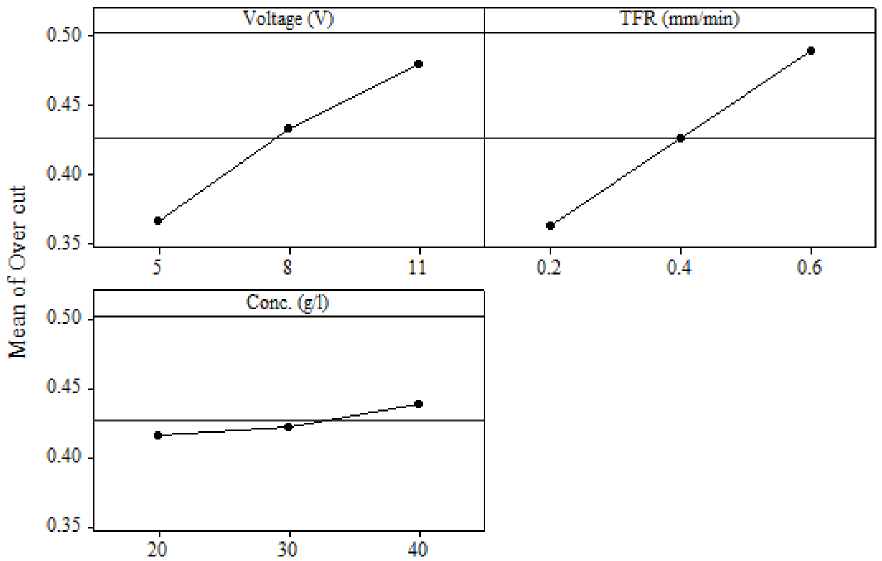

Fig. 6 Main effect plots for overcut

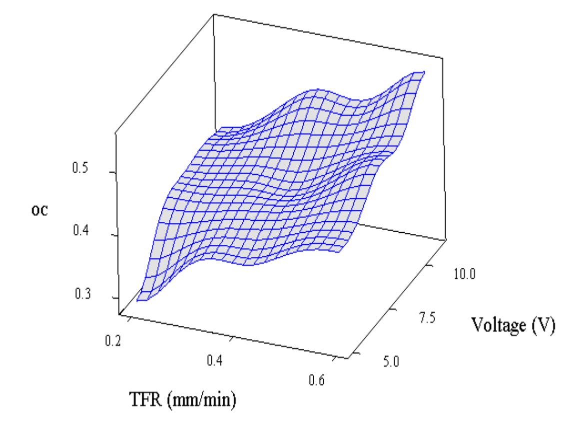

Fig 7 Surface plot for OC Vs feed rate and voltage

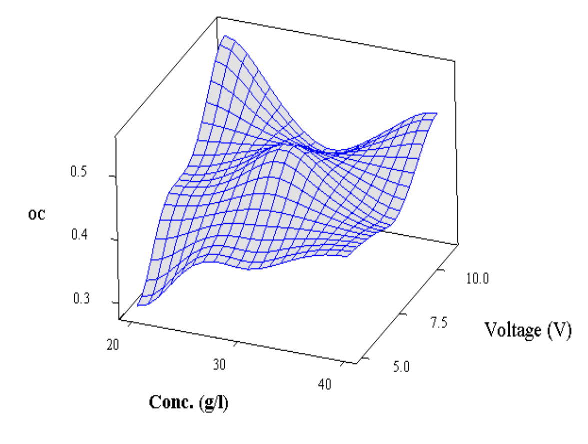

Fig 8 Surface plot for OC Vs voltage and concentration

For each rule, the three inputs are assigned in the fuzzy subsets of Small, Medium and Large and the corresponding membership functions, μ_{x1}, μ_{x2} and μ_{x3} respectively. The output is assigned to any of the five fuzzy subset membership functions $\mu_{Y.}$ The crisp value Y_0 is called as MPCI. Based on the above discussion, larger the MPCI smaller is the variance of the performance characteristics around the desired value. Table 1 shows the MPCI for each run and the rule of fuzzy logic is shown in fig. 9.

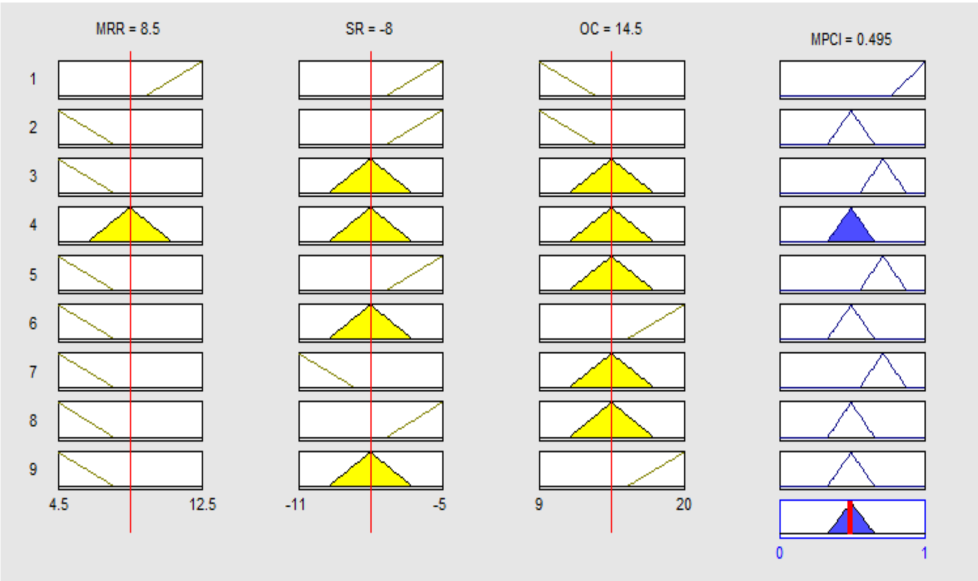

Fig 9 Rule of fuzzy logic

Table 5 MPCI Value and S/N ratio of response

S.N.	MRR	SR	OC	S/N MRR	S/N SR	S/N OC	MPCI
1	2.513	6.46	0.29	12.494	-6.171	9.301	0.914
2	5.942	6.73	0.38	6.461	-6.039	11.899	0.581
3	9.396	3.79	0.43	5.139	-8.641	13.641	0.715
4	4.202	4.79	0.4	8.020	-7.349	12.565	0.495
5	7.292	8.59	0.41	5.795	-5.353	12.913	0.605
6	10.149	4.59	0.49	4.968	-7.555	16.139	0.668
7	5.526	2.86	0.4	6.735	-10.956	12.565	0.715
8	10.045	7.39	0.49	4.990	-5.756	16.139	0.605
9	12.149	5.46	0.55	4.610	-6.782	19.258	0.495

The following factor settings have been identified as to yield the best combination of process variables: Factor: Voltage = 5V, Tool feed rate = 0.2 mm/min and Concentration is 20 g/l.

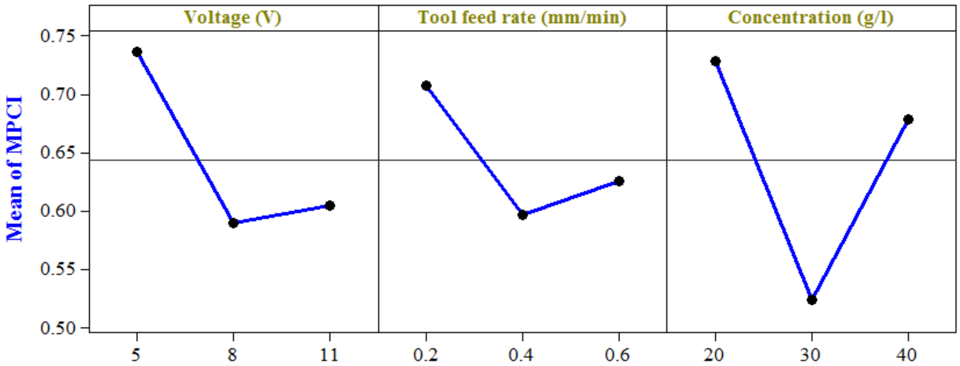

Fig. 10 Main effect Plot for MPCI

6. CONCLUSIONS

After completed the experiment all responses are converted into single response that is MPCI by using multi objective optimization techniques such as Taguchi quality loss function. And the following conclusions are given below.

- Amongst three factors feed rate is influencing MRR most then comes voltage and at last electrolyte attentiveness.
- For surface roughness, feed rate belongings it most then concentration and at latter voltage.
- Tool feed rate effects maximum to overcut at second rank is voltage and at 3rd rank is concentration which disturbs most to overcut.
- By using fuzzy logic technics are for optimal setting of Voltage = 5V, Tool feed rate = 0.2 mm/min and Concentration is 20 g/l for maximum MRR, minimum SR and OC.

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