MULTI-RESPONSE ANALYSIS OF ELECTRO-CHEMICAL MACHINING PROCESS USING PRINCIPAL COMPONENT ANALYSIS

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Abstract

Electrochemical machining is one the best alternative for producing complex shapes in advanced materials used in aircraft and aerospace industries. The process is influenced by different parameters including tool and work-material. In the present investigation the electrochemical machining has been carried out taking mild steel as work material and copper as tool material. The optimization of the process parameters has been carried out to satisfy the multi-objective response criteria such as overcut and circularity error using Principal Component Analysis.

1 Introduction

Electro-chemical machining process is an advanced machining process used for industrial application. ECM is a process based on the controlled anodic dissolution process of the work-piece as anode, with the tool as cathode in an electrolytic solution. Its industrial application have been extended to electro-chemical drilling, grinding, deburring and polishing. Fortrana MG[1] has discussed the different aspects of ECM proces. It involves a number of process parameters. A number of investigators have carried out research to study the different aspects to optimize the process. Corbett *et al*.[2] and Tenigyohi[3] observes that electro-chemical machining (ECM) has seen a resurgence of industrial interest in the last decade due to its various advantages, such as no tool wear, stress free and smooth surfaces of machined product and ability to machine complex shapes in electrically conductive materials, regardless of their physical and chemical properties. Muttamora et al.[4] presented relationship between ECM parameter, goove depth and groove ratio using Taguchi Method. Sen and Shan[5] has reported that electro-chemical machining process provide a viable alternative for drilling macro and micro-holes with exceptionally smooth surface and reasonably acceptable taper in numerous application particularly aerospace, electronics, computer and micro-mechanics industries. Advanced hole-drilling process like jet electrochemical drilling have found acceptance in producing a large number of quality holes in difficult-to-machine materials.

In the present investigation, experimental investigation of electrochemical machining process has been carried out in order to optimize the multi-response criteria using principal component analysis. The mild-steel is taken as work material with copper as tool-material. The tool is made of a copper rod of length 55mm with a through hole of 4mm diameter made at the centre. The work has been carried out using electrochemical machining from METATECH-industry, Pune. The experiments have been conducted as per L_9 orthogonal array. The voltage, feed and concentration are taken as the process parameters. The optimization of the process parameters has been carried out for minimizing the over cut effect and circularity error using principal component analysis.

2 Experimentaion

The experimental set up in which ECM operation has been carried out, is shown in Fig.1. The voltage, feed and concentration are taken as the process parameters. The process parameters are varied at three levels. The voltage is varied from 8 volt to 12 volt. The feed rate is varied from 0.1mm/min to 0.5mm/min and the concentration of electrolyte are varied from 10gm/lit to 14gm/lit. The circularity error and overcut effect are measured in scanning electron microscope. Principal component analysis has been carried out for multi-response analysis. The optimum process parameters have been determined for minimizing the circularity error and overcut effect. The tool and work-piece are taken as copper and mild steel. The circularity error and overcut are measured for different combinations of process parameters as given in Table1. The overcut is the maximum difference between the size of tool and machined work-piece, The work-piece after machining is shown in Fig.2

Fig: 1 Experimental Setup

Fig: 2 Finished Work peice

Table 1 Process parameter and response criteia

Sr No.	Voltage(V)	Feed F(mm/min)	Concentration gm/lit	Circularity error mm	overcut mm
1	8	0.1	10	0.352	1.1900
2	8	0.3	12	0.179	1.0925
3	8	0.5	14	0.056	1.2390
4	10	0.1	12	0.181	0.8805
5	10	0.3	14	0.104	0.9105
6	10	0.5	10	0.073	1.1775
7	12	0.1	14	0.081	1.2315
8	12	0.3	10	0.090	1.2415
9	12	0.5	12	0.191	1.2400

3 Results and discussion

The normalization of experimental data has been carried out as shown in Table2. The normalized data are generated by dividing the responses by the maximum value. The maximum value of output parameter is converted to 1. All other values lie within 1.

Table 2 Normalization of experimental data

Sr No.	Voltage(V)	Feed F(mm/min)	Concentration	Normalised Circularity error	Normalised overcut error
1	8	0.1	10	0.0000	0.14266
2	8	0.3	12	0.58446	0.412740
3	8	0.5	14	1.0000	0.00693
4	10	0.1	12	0.57770	1.0000
5	10	0.3	14	0.83784	0.9169
6	10	0.5	10	0.94257	0.17729
7	12	0.1	14	0.91554	0.02770
8	12	0.3	10	0.88514	0.00000
9	12	0.5	12	0.54392	0.00416

Grey co-efficient and overall grey grade are determined as shown in Table3. PC referes to Principal component. Eigen values, accountability proportion(AP) and cumulative accountability proportion(CAP) computed for two major quality indicators are given in Table4. The calculation of composite principal component (Over all quality index) and corresponding S/N (signal to noise)ratios are given in Table5. The main effect plot of overcut is given in Fig.3. The main effect plot for circularity error is given in Fig.4. The response for overall Grey relational grade is in Table 6. S/N ratio plot for overall grey relational grade is Fig.6

Table 3 Principal component analysis for L9 OA experimental observations

Sr. No.	Grey coefficient 1	Grey coefficient 2	overall grey grade	PC1 (Ψ_1)	PC2 (Ψ_2)	PC1square (Ψ_1^2)	PC2 square (Ψ_2^2)
1.	0.33333	0.36837	0.350850	-0.140312	-0.025771	0.019688	0.000664
2.	0.54613	0.45987	0.502999	-0.300373	-0.649404	0.090224	0.421725
3.	1.00000	0.33488	0.667440	0.173834	-0.984799	0.030218	0.969830
4.	0.54212	1.00000	0.771062	-0.879189	-0.748843	0.772974	0.560766
5.	0.75510	0.85748	0.806292	-0.750462	-0.989687	0.563193	0.979480
6.	0.89697	0.37801	0.637490	-0.004099	-0.959086	0.000017	0.919847
7.	0.85549	0.33960	0.597548	0.138143	-0.905482	0.019083	0.819898
8.	0.81319	0.33333	0.573260	0.159895	-0.870573	0.025566	0.757898
9.	0.52297	0.33426	0.428614	0.094169	-0.535721	0.008868	0.286997

Table 4 (Analysis of covariance matrix) eigenvalues, accountability proportion (AP) and cumulative accountability proportion (CAP) computed for the two major quality indicators, Eigen analysis of the Covariance Matrix

Eigenvalue	0.15963	0.09685
Proportion	0.622	0.378
Cumulative	0.622	1.000

Variable	PC1(Ψ_1)	PC2(Ψ_2)
normalisation 1	0.181	-0.984
normalisation 2	-0.984	-0.181

Table 5 Calculation of composite principal component (overall quality index) and corresponding S/N ratios

Sr.No.	Eigen vector	composite principal component	S/N Ratio composite
1.	0.44400	0.14266	16.9140
2.	1.15922	0.71551	2.9077
3.	1.78122	1.00002	-0.0002
4.	1.66330	1.15488	-1.2507
5.	0.81139	1.24204	-1.8827
6.	0.92994	0.95910	0.3628
7.	0.91931	0.91596	0.7625
8.	0.92980	0.88514	1.0598
9.	0.44400	0.54393	5.2891

Table 6 Response table (mean) for overall Grey relational grade

Factors	Grey relational grade				
	Level 1	Level 2	Level 3	Delta	Rank
feed	0.5732	0.6275	0.5778	0.0544	3
Voltage	0.5071	0.7383	0.5331	0.2312	1
concentration	0.5205	0.5676	0.6904	0.1699	2

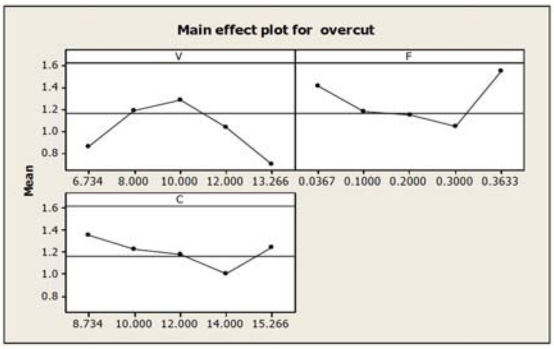


Fig: 3 Main Effect Plot of over cut verses voltage, feed and concentration respectively.

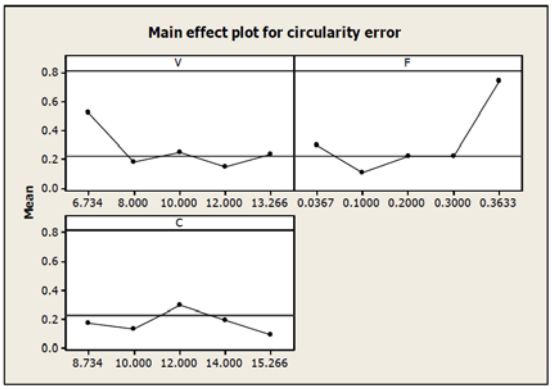
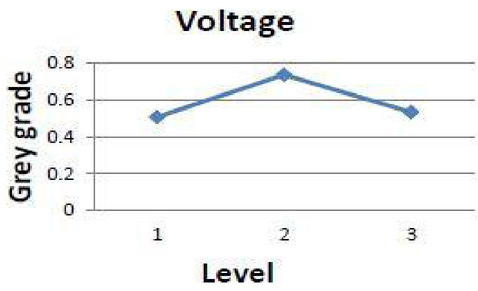
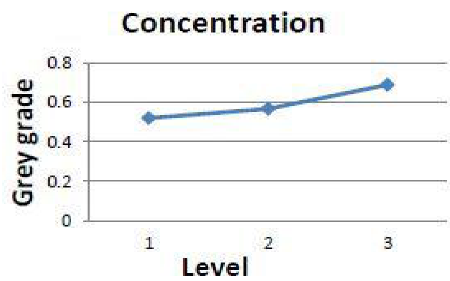


Fig: 4 Main Effect Plot of circularity error verses voltage, feed and concentration respectively.



(a)

(b)



(c)

Fig: 5 (a), (b), (c) S/N ratio plot For Overall Grey Relational Grade

Conclusion

For grey relation grade, voltage is the most influencing factor than concentration and feed rate.

References:

1. M. G. Fortana, Corrosion Engineering, McGraw Hill, New York ,1986.
2. J. Corbett, P. A. Mckeown, G. N. Peggs, R. Whatmore, Nanotechnology:international development and emerging products
3. N. Tenigyohi, Current status in and future trends of ultraprecision machining and ultrafine materials processing, Ann. CIRP 2(2)(1983)573-582.

4. M. Sen, H. S. Shan, A review of electrochemical macro- to micro-hole drilling process, International Journal of Machine Tools & Manufacture 45(2005)137-15
5. A. Muttamora and S. Perktong “Improving the quality of groove in Electro Chemical machining(ECM) processed by taguchi method, Int. Conf in Mechanical Engg,20-22, Oct, Ubon Ratchathai, 2010