THE IMPLEMENTATION OF TAGUCHI APPROACH ON ECM PROCESS PARAMETERS FOR MILD STEEL AND ALUMINUM

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ABSTRACT

In this paper, the cutting of Mild Steel and Aluminum using electrochemical machining (ECM) with a electrode by using Taguchi approach has been reported. The Taguchi orthogonal array design is used to formulate the experimental layout, to analyze the effect of each parameter on the machining characteristics, and to predict the optimal choice for each ECM parameter such voltage, tool feed and current. It is found that these parameters have a significant influence on machining characteristic such as metal removal rate (MRR) and surface roughness (SR). The analysis of the Taguchi method show that, in general the current significantly affects the SR and voltage affects the MRR. Verification of taguchi approach is done by confirmation test.

Keywords: *ECM, Taguchi method, Aluminum, Mild steel, metal removal rate, Surface roughness, ANOVA.*

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1. INTRODUCTION:

Electrochemical machining (**ECM**) is a method of removing metal by an electrochemical process. It is normally used for mass production and is used for working extremely hard materials or materials that are difficult to machine using conventional methods.[1] Its use is limited to electrically conductive materials. ECM can cut small or odd-shaped angles, intricate contours or cavities in hard and exotic metals, such as titanium aluminates, Inconel, Wispily, and high nickel, cobalt, and . ECM is often characterized as "reverse electroplating," in that it removes material instead of adding it. Through an electrolytic material removal process having a negatively charged electrode (cathode), a conductive fluid (electrolyte), and a conductive work piece (anode); however, in ECM there is no tool wear. The ECM cutting tool is guided along the desired path close to the work but without touching the piece. High metal removal rates are possible with ECM, with no thermal or mechanical stresses being transferred to the part, and mirror surface finishes can be achieved.

In the ECM process, a cathode (tool) is advanced into an anode (work piece). The pressurized electrolyte is injected at a set temperature to the area being cut. The feed rate is the same as the rate of "liquefaction" of the material. The gap between the tool and the work piece varies within 80-800 micrometers (.003 in. and .030 in.) As electrons cross the gap, material from the work piece is dissolved, as the tool forms the desired shape in the work piece. The electrolytic fluid carries away the metal hydroxide formed in the process.

The Implementation of Taguchi Method on ECM Process of Mild Steel and Aluminum study of these parameters has been performed by many researchers; most of the studies do not much consider both engineering philosophy (DOE) and mathematical formulation (ANOVA) particularly in machining very hard materials such as Aluminum and mild steel. Therefore, the Taguchi method, which is a powerful tool for parametric design of performance characteristics, is used to determine the optimal machining parameters for maximum material removal rate and minimum surface roughness in the ECM operations. The experimental details when using the Taguchi method are described.

2. EXPERIMENTAL PROCESS

Aluminum and mild steel alloy was the target material used in this investigation. *Table 1* shows the material related properties. Experiments were performed using a Electrical Chemical Machine. *Figure 1* show schematically the experimental set-up. A tool with a diameter of 9 mm was used as an electrode to erode a work piece of Aluminum and mild steel.

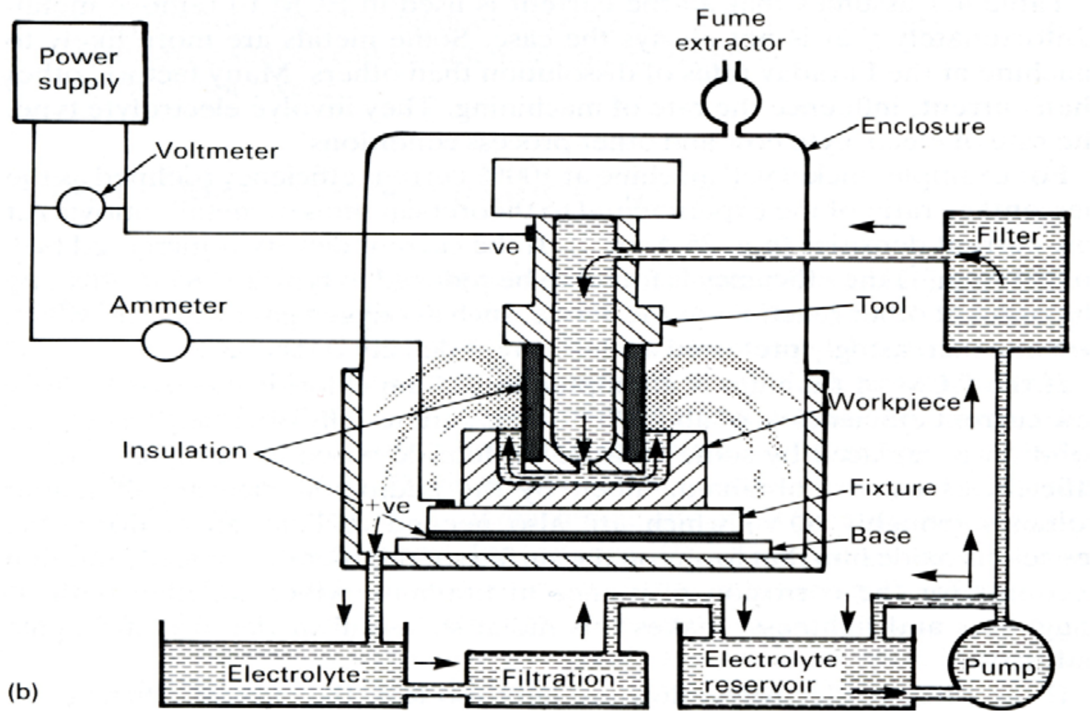


Figure 1: schematically the experimental set-up ECM

Table1 : Properties of Mild Steel

Property	Value
Young's modulus	210,000M
Density	7.85gm/cm^3
Carbon with rage	0.16%to 0.19%

Table2: Properties of Aluminum

Property	Value
Modulus of Elasticity (GPa)	68.3
Poissons Ratio	0.34
Thermal Conductivity (0-100°C) (cal/cms. °C)	0.57
Co-Efficient of Linear Expansion (0-100°C) (x10-6/°C)	23.5
Electrical Resistivity at 20°C (Ω.cm)	2.69
Density (g/cm^3)	2.6898
Melting Point (°C)	660.2
Boiling Point (°C)	2480

3. DESIGN OF EXPERIMENTS AND DATA ANALYSIS

3.1. Design of Experiments

The experimental plan for the machining parameters using the L9 orthogonal array was used in this study. This array consists of three control parameters and three levels, as shown in table 3. In the Taguchi method, most all of the observed values are calculated based on 'the higher the better' and 'the smaller the better'. Thus in this paper, the observed values of MRR and SR were set to maximum and minimum respectively. Each experimental trial was performed with three simple replications at each set value. Next, the optimization of the observed values was determined by comparing the standard analysis and analysis of variance (ANOVA) which was based on the Taguchi method.

3.2. Selection of the machining parameters and their levels

The experimental plan has three variables, namely, tool feed, current and applied voltage. On the basis of preliminary experiments conducted by using one variable at a time approach, the feasible range for the machining parameters was defined by varying the voltage (05-15 V) , tool rate (0.10 – 0.30 mm/min) and current (0 – 100 A). In the machining parameter design, three levels of the cutting parameters

Table 3: Design scheme of experiment of Parameters and levels

	Process parameter	Level 1	Level 2	Level 3
A	Voltage(V)	05	10	15
B	Tool feed (mm/min)	0.10	0.20	0.30
C	Current(A)	20	60	100

Table 4: Experimental layout using L9 orthogonal array

Experiment No.	A Voltage(V)	B Tool feed (mm/min)	C Current(A)
1	1	1	1
2	1	2	2
3	1	3	3
4	2	2	3
5	2	3	1
6	2	1	2
7	3	3	2
8	3	1	3
9	3	2	1

3.3. Analysis of Variance (ANOVA)

Analysis of variance (ANOVA) and the F test (standard analysis) are used to analyze the experimental data as follows [2, 3, 4]:

$CF = T^2/n$ (1)

$S_T = \sum_{i=1\ to\ 27} Y_i^2 - CF$ (2)

$Sz = (Y_{z1}{}^2/N_{z1} + Y_{z2}{}^2/N_{z2} + Y_{z3}{}^2/N_{z3}) - CF$ (3)

f_z = (number of levels of parameter z) – 1 (4)

f_T = (total number of results) – 1 (5)

$f_e = f_T - \Sigma f_z$ (6)

$V_z = S_z/f_z$ (7)

$S_e = S_T - \Sigma S_z$ (8)

$V_e = S_e/f_e$ (9)

$F_z = V_z/V_e$ (10)

$S_z' = S_z - (V_e * f_z)$ (11)

$P_z = S_z'/ S_T * 100\%$ (12)

$P_e = (1 - \Sigma P_z) * 100\%$ (13)

Where;

CF	correction factor
T	total of all results
n	total number of experiments
S_T	total sum of squares to total variation
Y_i	value of results of each experiment (i= 1 to 27)
S_z	sum of squares due to parameter z(z= A, B and C)
N_{z1}, N_z , N_{z3}	repeating number of each level(1, 2, 3) of parameter z
Y_{z1}, Y_z , Y_{z3}	value of results of each level(1, 2, 3) of parameter z
f_z	degree of freedom(DOF) of parameter z
f_T	total degree of freedom
f_e	degree of freedom(DOF) of error term
V_z	variance of parameter z
S_e	sum of squares of error term
V_e	variance of error term
$F_{z,}$ F	ratios of parameter z
$S_{z'}$	pure sum of square
P_z	percentage contribution of parameter z
P_e	percentage contribution of error term

3.4. Data Analysis

In this paper, all the analysis based on the Taguchi method is done by Taguchi to determine the main effects of the process parameters, to perform the analysis of variance (ANOVA) and to establish the optimum parameter conditions. The main effects analysis is used to study the trend of the effects of each of the factors, as shown in figures 2. The machining performance (ANOVA-significant factor) for each experiment of the L9 can be calculated by taking the observed values of the as an example from table 5 and 8.

Table 5 : Result /observed value for Aluminum

Result /observed value for Aluminum						
No. of Trial	**MRR (g/min)**			**SR (Ra)**		
	1	2	3	1	2	3
1	1.12	1.11	1.41	2.14	2.18	2.17
2	0.99	0.97	1.2	3.12	3.16	2.16
3	0.98	0.97	0.96	2.15	2.19	2.18
4	0.91	0.89	0.91	3.18	3.16	3.19
5	0.95	0.96	0.97	2.15	2.2	2.22
6	0.91	0.89	0.88	2.56	2.5	2.2
7	0.85	0.89	0.84	3.19	3.21	3.19
8	0.9	0.89	0.88	2.16	2.21	2.25
9	0.94	0.93	0.93	2.18	2.19	2.2

Table 6: Analysis of variance (ANOVA) and F-test for MRR

Factor	DF	SS	Varience	F-ratio	s'z	%
A	2	0.181	0.090	12.857	0.177	46.286
B	2	0.005	0.003	0.428	0.001	0.262
C	2	0.070	0.035	5.000	0.066	17.272
e	18	0.126	0.007		0.121	31.675

Table 7: Analysis of variance (ANOVA) and F-test for SR

Factor	DF	SS	Varience	F-ratio	s'z	%
A	2	0.213	0.107	1.138	0.129	2.407
B	2	1.672	0.836	8.893	1.588	29.613
C	2	1.783	0.892	9.489	1.699	31.682
e	18	1.695	0.094		1.611	30.039

Table 8: Result observed valau for Mild steel

Result /observed value for Mild steel						
No. of Trial	**MRR (g/min.)**			**SR (Ra)**		
	1	**2**	**3**	**1**	**2**	**3**
1	0.73	0.76	0.77	3.14	3.12	3.16
2	0.67	0.66	0.65	3.28	3.3	3.32
3	0.76	0.73	0.73	3.69	3.7	3.71
4	0.97	0.88	0.89	3.63	2.99	2.36
5	0.89	0.91	0.9	2.64	2.66	2.68
6	1.02	1.09	1.11	3.69	3.71	3.73
7	0.9	0.9	0.91	3.5	3.51	3.53
8	1.03	1.04	1.02	3.69	3.7	3.72
9	0.88	0.89	0.87	2.69	2.72	2.7

Table 9: Analysis of variance (ANOVA) and F-test for MRR

Factor	DF	SS	Varience	F-ratio	s'z	%
A	2	0.326	0.163	32.600	0.322	71.912
B	2	0.010	0.005	1.000	0.006	1.339
C	2	0.012	0.006	1.200	0.008	1.737
e	18	0.100	0.005		0.096	21.428

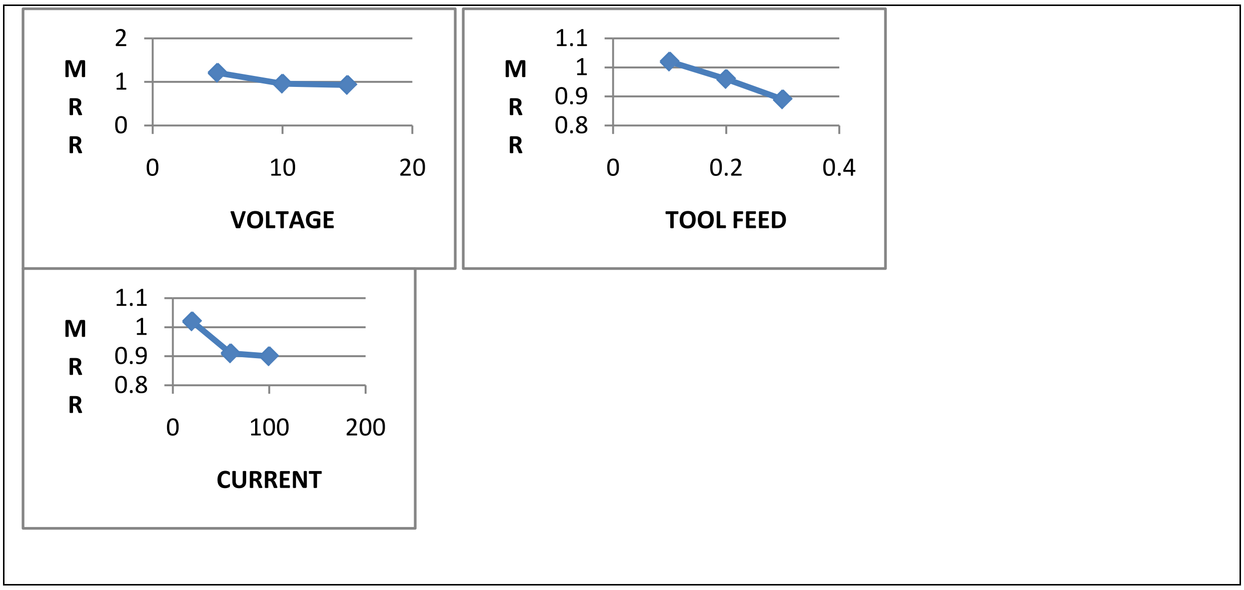
Table 10: Analysis of variance (ANOVA) F-test for SR

Factor	DF	SS	Varience	F-ratio	s'z	%
A	2	0.320	0.160	1.428	0.236	4.683
B	2	0.140	0.070	.625	0.056	1.112
C	2	2.560	1.280	11.428	2.476	49.034
e	18	2.03	0.112		1.946	38.534

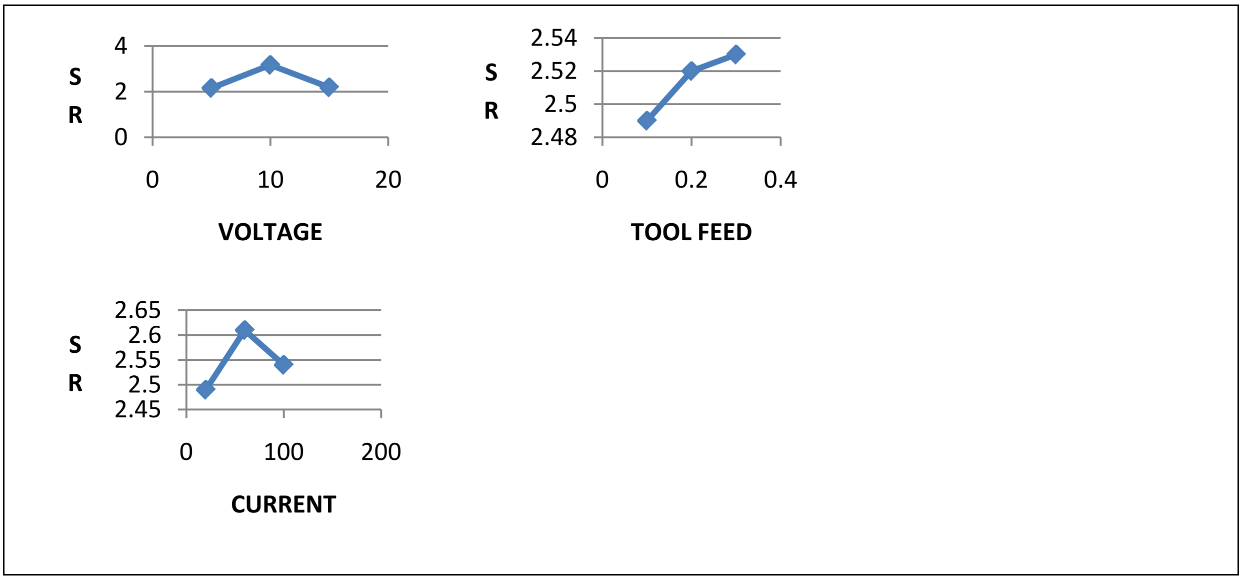
Figure 2: Influence of process parameters performances for Aluminum and Mild Steel

For Aluminum

Main effects of each factor on MRR

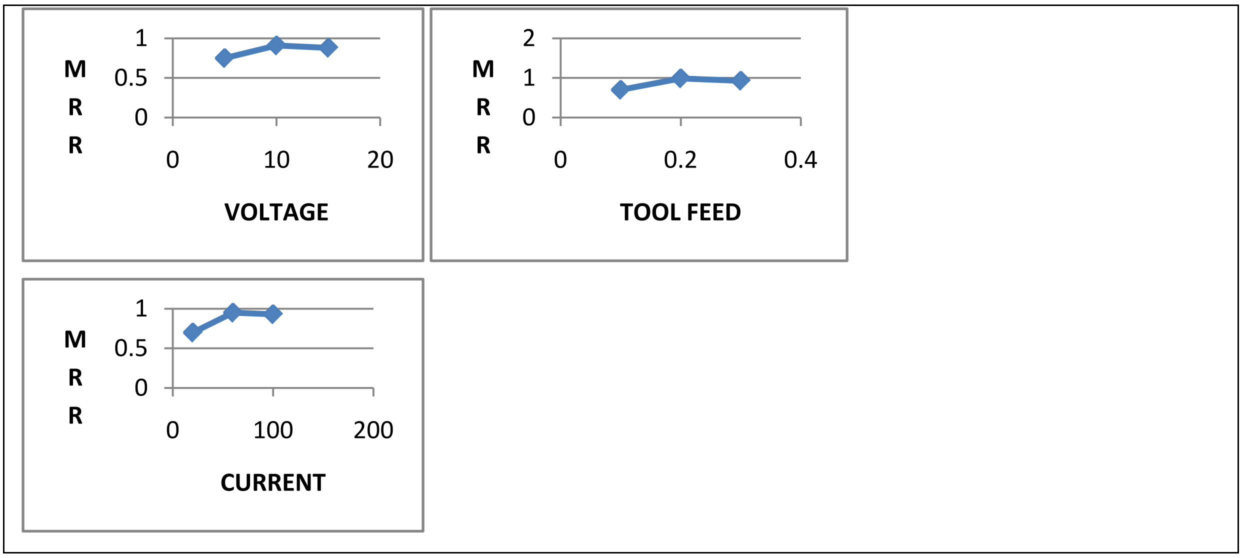


Main effects of each factor on SR

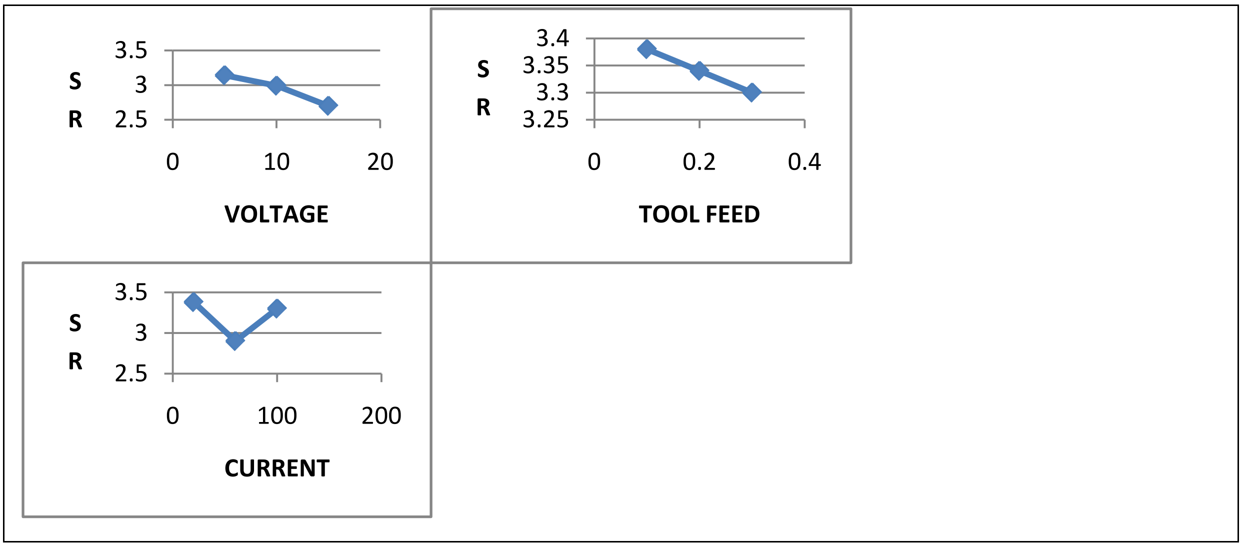


For Mild Steel

Main effects of each factor on MRR



Main effects of each factor on SR



CONCLUSION

This research paper is used to optimize the machining condition of Aluminum and Mild Steel by ECM with an electrode. Taguchi approach has been used to determine the main effects, significant factors and optimum machining condition to the performance of ECM Based on the results presented herein, we can conclude that, the voltage is the most significant parameter for MRR in both material, and the current most significant parameter for SR in both material and according to graph predicted optimal parameter setting for MRR of Aluminum is (A1,B1,C1) and SR of Aluminum is (A1,B1.C1). In case of Mild Steel predicted optimal parameter setting for MRR is (A2,B2,C2) and SR of Mild Steel is (A3,B3,C2).

CONFIRMATION TEST

According graph to predicted optimal parameter setting for MRR of Aluminum (A1,B1,C1) used have been consider the experiment found is MRR 1.08 (g/min.) and SR of Aluminum (A1,B1,C1) have been used to consider the experiment for SR and found the value 1.99(Ra).In case of parameter setting for MRR of Mild Steel (A2,B2,C2) have been consider for the experiment and found MRR is 1.02(g/min.) and SR of Mild Steel (A3,B3,C2) have been consider for the experiment for SR and found the value 2.20(Ra). These result those same implementation of Taguchi Method ECM.

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