Experimental Study of Effect of Parameters on Material Removal Rate for Electrochemical Machining of Aluminium Matrix Composite

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Abstract— **The electrochemical machining (ECM) is to bring highly alloyed materials to the required design configurations. The present work investigates the influence of some predominant electrolytic cavity sinking process parameters such as applied voltage, current, electrolyte concentration, pulse on time, pulse off time and duty cycle on the material removal rate (MRR) to fulfill the effective utilization of ECM of Al 6082, SiC and boron glass powder composites cast by stir casting process. This aluminium matrix composite (AMCs) can be used for making trusses, frames and containers which are used to store chemicals, milk and other corrosive liquids, it can replace stainless steel which is used in the salty environment to avoid corrosion. In this study, the influence on the removal of material, caused by ECM is analyzed.**

Keywords— **Aluminium matrix composite, Electrochemical machining, Material removal rate.**

I. INTRODUCTION

Conventionally is very difficult to machine AMCs. ECM technique is an alternative method to machine AMCs in these metals can be machined without contact, independent of material hardness and thermal or mechanical impact [1]. ECM removes material by anodic dissolution it does not produce any stress (residual). As dissolution of the workpiece material occurs the tool electrode is moved at a controlled rate, to remove material is required. It's carried out by passing an electric current through an electrolyte in the gap of tool and workpiece. However, there are many parameters which influence the MRR, those parameters represents the machining phenomenon between the tool and work piece [2]. The relationships between the applied voltage and the parameters (% of gap) with two different electrolytes, $NaNO_3$ solution and NaCl solution were determined [3]. The influence parameters such as applied voltage, current, electrolytic concentration, pulse on time, pulse off time, duty cycle and machining time on the material removal rate were discussed in [4].

After, AMCs were fabricated by six different compositions of weight percentage shown in the table I using stir casting technique, the objective is focused on the MRR calculations through non-linear regression analysis (NRA) using Minitab software.

TABLE I

WEIGHT PERCENTAGE OF AMCs

Composition No	**SiC** (% of weight)	**Boron Glass Powder** (% of weight)	**A 6082 alloy** (% of weight)
1	1	1	98
2	1	3	96
3	3	3	94
4	3	5	92
5	5	5	90
6	5	7	88

II. EXPERIMENTAL WORK

In this study, experiments were planned on the basis of proposed by Box and Hunter [5]. The experimental parameters and their levels shows in the table II. Consider six parameters Voltage A (9-17 volts), Current B (0.6-1 amps), Electrolyte concentration E (0.23-0.50 mole/lit), Pulse ON time D (10-17.5 ms), Pulse OFF time F (2.5-10 ms) and Machining time C, in which machining time is an output parameter this value is measured during the machining a hole. The electrolyte used in this experiment was NaCl.

TABLE II

EXPERIMENTAL PARAMETERS AND THEIR LEVELS

<table>
<tr><th>Set No</th><th>Holes No</th><th>Constant parameters</th><th colspan="2">Variable parameters</th></tr>
<tr><td rowspan="5">SET-I</td><td></td><td rowspan="5">Voltage-15 (volts)
Current-1 (amps)
Electrolyte concentration-0.23 (mole/lit)</td><td>Pulse on time (ms)</td><td>Pulse off time (ms)</td></tr>
<tr><td>1</td><td>10</td><td>10</td></tr>
<tr><td>2</td><td>12.5</td><td>7.5</td></tr>
<tr><td>3</td><td>15</td><td>5</td></tr>
<tr><td>4</td><td>17.5</td><td>2.5</td></tr>
<tr><td rowspan="5">SET-II</td><td></td><td rowspan="5">Voltage-15 (volts)
Pulse ON & OFF time-17.5 & 2.5 (ms)
Electrolyte concentration-0.23 (mole/lit)</td><td colspan="2">Current (amps)</td></tr>
<tr><td>5</td><td colspan="2">0.6</td></tr>
<tr><td>6</td><td colspan="2">0.7</td></tr>
<tr><td>7</td><td colspan="2">0.8</td></tr>
<tr><td>8</td><td colspan="2">0.9</td></tr>
<tr><td rowspan="5">SET-III</td><td></td><td rowspan="5">Voltage-15 (volts)
Current-1(amps)
Pulse ON & OFF time-17.5 & 2.5 (ms)</td><td colspan="2">Electrolyte Concentration (mole/lit)</td></tr>
<tr><td>9</td><td colspan="2">0.23</td></tr>
<tr><td>10</td><td colspan="2">0.32</td></tr>
<tr><td>11</td><td colspan="2">0.41</td></tr>
<tr><td>12</td><td colspan="2">0.50</td></tr>
<tr><td rowspan="5">SET-IV</td><td></td><td rowspan="5">Current-1(amps)
Electrolyte concentration-0.23 mole/lit
Pulse ON & OFF time-17.5 & 2.5 ms</td><td colspan="2">Voltage (volts)</td></tr>
<tr><td>13</td><td colspan="2">9</td></tr>
<tr><td>14</td><td colspan="2">11</td></tr>
<tr><td>15</td><td colspan="2">13</td></tr>
<tr><td>16</td><td colspan="2">15</td></tr>
</table>

III. Mathematical Model

To maximization of MRR the mathematical model were developed by NRA for MRR with their indices. The parameters concerned for this model were A, B, C, D, E and F [6].

$$MRR = Constant \times A^a \times B^b \times C^c \times D^d \times E^e \times F^f$$

Where a, b, c, d, e and f are the indices of Voltage, Current**,** Machining time, Pulse on time, Electrolyte concentration and Pulse off time. The formulated models for MRR using Minitab are shown in a following Table III.

TABLE III

MRR MATHEMATICAL MODEL FOR SIX DIFFERENT COMPOSITION

Composition No	MRR Mathematical model
1	$MRR = 121.5104 \times A^{1.40} \times B^{-0.52} \times C^{-0.17} \times D^{0.39} \times E^{0.122} \times F^{-1.44}$
2	$MRR = 24.04675 \times A^{1.07} \times B^{-0.741} \times C^{-1.34} \times D^{1.64} \times E^{-1.14} \times F^{-0.5}$
3	$MRR = 242801.6 \times A^{1.24} \times B^{-1.68} \times C^{-1.39} \times D^{0.09} \times E^{-0.354} \times F^{-1.08}$
4	$MRR = 6.6859 \times A^{1.26} \times B^{-0.42} \times C^{-0.242} \times D^{0.80} \times E^{0.297} \times F^{-1.37}$
5	$MRR = 24.5323 \times A^{1.27} \times B^{-0.619} \times C^{-0.219} \times D^{0.89} \times E^{0.196} \times F^{-1.03}$
6	$MRR = 239.8467 \times A^{0.627} \times B^{-1.59} \times C^{-0.611} \times D^{0.83} \times E^{-0.681} \times F^{-0.715}$

From the mathematical model, the MRR was negatively influenced by Current**,** Machining time, Electrolyte concentration and Pulse OFF time whereas positively influenced by Voltage and Pulse ON time.

IV. Results and Discussion

MRR values for six different composition was calculated from NRA mathematical model is shown in table IV.

TABLE IV

MRR VALUES FOR SIX DIFFERENT COMPOSITION

Holes No	MRR (mg/min) values for different Composition No						Average
	1	2	3	4	5	6	
1	1.083	1.033	1.602	1.024	0.992	1.014	1.125
2	1.779	1.893	2.533	1.687	1.720	1.898	1.918
3	3.488	3.206	4.460	3.294	3.142	3.113	3.451
4	10.536	7.269	11.511	9.794	8.780	5.917	8.968
5	4.965	5.840	5.867	4.896	4.409	5.166	5.191
6	6.206	5.189	6.423	5.800	5.957	6.285	5.977
7	7.510	6.391	9.001	6.771	7.475	7.377	7.421
8	8.890	8.670	9.064	7.799	8.196	4.999	7.936
9	10.385	**13.741**	12.319	9.150	10.284	11.593	11.245
10	10.496	7.510	9.502	**12.048**	11.448	10.794	10.300
11	11.335	12.239	13.437	10.176	9.261	11.199	11.275
12	12.277	12.753	**14.605**	11.070	**11.779**	11.368	12.309
13	**12.692**	12.429	14.188	11.499	11.309	12.003	12.353
14	11.319	12.486	13.517	11.389	11.614	**14.631**	**12.493**
15	10.574	11.978	11.904	10.973	9.752	12.044	11.204
16	9.892	10.934	12.367	9.072	8.571	13.766	10.767

It was experimental that MRR was significantly affected by voltage and electrolyte concentration. MRR increased by increasing current, pulse on time and pule off time because speed of chemical reaction and mobility of ions was more from the AMC to the solution.

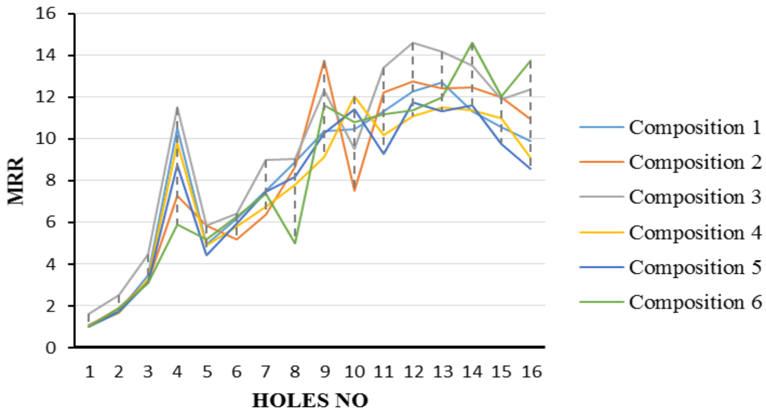

Fig. 1 Shows the MRR values with respective hole no for six different compositions

V. CONCLUSIONS

In the present work, mathematical models were developed and maximum MRR 14.631 mg/min was found on hole no 14 (11 volts, 1 amps, 17.5 ms [on time], 0.23 mole/lit and 2.5 ms [off time]) in sixth composition. In ECM the MRR significantly influenced by the various predominant parameters considered in the present study. Achieved the combination of parameter for maximum MRR to effective utilization of ECM for Al 6082, SiC and boron glass powder composites.

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