Effect of Electrochemical Machining Process Parameters on Anisotropic Property of Metal Matrix Composites Al7075

N. Rajan¹, R. Thanigaivelan R.² and K.G. Muthurajan³ *

¹Department of Mechanical Engineering, Annapoorana Engineering College, Salem, Tamilnadu, India
²Department of Mechanical Engineering, Mahendra Engineering College (Autonomous), Namakkal, Tamilnadu, India
³Department of Mechanical Engineering, Vinayaka Missions Kirupananda Vaiyar Engineering College, Salem, Tamilnadu, India

Received: April 16, 2018, Accepted: July 17, 2018, Available online: November 28, 2018

Abstract: Electrochemical Machining has wide application in the specialized fields such as aerospace and defense industries. In this study Al7075 composite is considered as a workpiece material due its applications in die and mould making industries. The effect of heated electrolyte on machining rate was studied. The electrolytes are heated with infra-red light source. The experiments were conducted with unheated sodium nitrate (NaNO₃) and acidified sodium nitrate electrolyte. Moreover the machinability of anisotropic property of Al7075 was studied by drilling blind holes on plain top surface (i.e. X – plan) and on the side surface (i.e. Y – plan). The surface topography was analyzed using Scanning Electron Microscope and the effect of the machining parameters on the depth of the blind hole and the respective surface quality were studied. Based on the experimental results, the infra-red light heated electrolyte with addition of concentrated H₂SO₄ shows better machining rate which is nearly two times than the electrolyte at room temperature. The machining rate is better for infra-red heated electrolyte compared to the electrolyte at room temperature. Applied voltage, Duty cycle and electrolyte concentration has a significant effect on the machining rate. The heated electrolyte improves the machining rate but decrease the quality of the blind hole. The anisotropic property has the notable effect on the machining rate. The Y-direction plane shows good machinability compared to X-direction plane.

Keywords: electrochemical machining, acidified electrolyte, anisotropic, metal matrix composites, blind holes.

1. INTRODUCTION

Electrochemical machining (ECM) are gaining more industrial applications for its advantages such as no thermal affected area, no mechanical force is required, no tool wear, good surface quality and machined products with no stress. Researcher’s worldwide pursuing research in improving the output process parameters of ECM. Thanigaivelan et al. (2018) used heated electrolyte to improve the machining rate. Wang et al. (2017) used the mixed electrolyte composed of NaCl and NaNO₃ to enhance the surface quality of the work piece.

Zhu et al. (2017) improved the machining rate by increasing the radius of the tool resulting in uniform distribution of flow field in the machining gap. Anasane and Bhattacharyya (2017) have analyzed the effect of the electrolyte namely ethylene glycol and sodium bromide on titanium by using ECM. Wang et al. (2017) analyzed the effect of pulsed power supply on metal dissolving. The study shows that the breakdown time has a significant effect on metal dissolution in ECM. Thanigaivelan et al. (2017) studied the effect of process parameters such machining voltage, electrolyte concentration and pulse on time on machining accuracy. More over the tool electrode shape plays the significant effect on accuracy in Electrochemical Micro Machining (EMM). Ayyappan and Sivakumar (2014) analyzed the effect of aqueous sodium chloride mixed with potassium dichromate electrolyte and oxygenated aqueous sodium dichromate electrolyte in ECM to improve the machining rate. Tang et al. (2011) have used electrolyte temperature as a parameter to improve the efficiency of the ECM process. Skoczypiec et al. (2010) have analyzed the effect of ultrasonic vibrations to improve the electrolyte dissolution. Thanigaivelan et al. (2011) used the acidified sodium nitrate as an electrolyte which improved the machining rate and overcut significantly Mukherjee et al. (2013) have analyzed the role electrolyte in current-carrying process during ECM process. It is evident from the above literature that researchers have concentrated in machining of metals and alloys. The machining of metal matrix composites is the need of the hour due its wide application in various industries such as aerospace and automobile. In

*To whom correspondence should be addressed: Email: Phone:
this research the machining of Al 7075 composite is considered and effect of process parameters on anisotropic property of the Al7075 is studied with different condition of electrolyte.

2. METHODS

The ECM machine with the capability to vary the voltage, frequency, current and duty cycle, were considered for the study. Blind holes were drilled on X and Y plan of the Al7075 to study the anisotropic property of the composite. The thickness of workpiece (anode) is 10mm and diameter of electrode (cathode) is 500μm. The necessary gap between the tool and the work piece is maintained so as to avoid the micro spark. Sodium nitrate (NaNO₃) and acidified sodium nitrate (H₂SO₄+NaNO₃) are used as electrolyte. The electrolyte is prepared by mixing the various quantity of sodium nitrate salt with distilled water. The electrolyte is heated using IR light source and temperature of the electrolyte is maintained at 37°C. The stepper motor mechanism is used to feed the micro tool towards the workpiece. Initially the Al 7075 composite was machined by varying the parameters like the concentration of the electrolyte (NaNO₃) voltage and duty cycle while keeping the frequency of power at a constant value of 50 Hz.

3. EXPERIMENTAL

Total of 48 experiments combination are conducted on the workpiece. 24 sets of experiments are conducted with electrolyte at room temperature along X and Y plane of the workpiece and remaining 24 sets of experiments are conducted using acidified NaNO₃ IR heated electrolyte. Table 1 shows the parameter combination for blind hole machining. The parameter was varied one at a time. Each experiment is repeated twice. The blind holes are machined at constant time for one hour. Blind holes were scanned in the Scanning Electron Microscope (SEM) and the images were analyzed for surface quality.

4. RESULTS

Fig. 1 shows the effect of machining voltage for room temperature NaNO₃ electrolyte and IR heated acidified electrolyte for X and Y plan. It is clear that the machining depth is found to better across the Y plan with the infra-red heated acidified electrolyte. The depth of the hole shows the increasing trend for both plan. The use of room temperature sodium electrolyte, the depth of hole along the X plan increases gradually and reaches higher value at higher voltage. The sudden steep increase in depth is noticed between machining voltage of 11-12 V. During the machining voltage of 9-11 V the increase in current density contributes for increase in depth of blind hole. During higher voltage the current density required for material removal is more resulting in deeper blind hole.

Along the Y-plan for same experimental combinations the depth

<table>
<thead>
<tr>
<th>Sample no</th>
<th>Voltage (v)</th>
<th>Electrolyte Concentration (g/L)</th>
<th>Duty cycle (%)</th>
<th>X-Direction</th>
<th>Y-Direction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Electrolyte at room temperature</td>
<td>Acidified IR heated electrolyte</td>
<td>Electrolyte at room temperature</td>
<td>Acidified IR heated electrolyte</td>
</tr>
<tr>
<td>1</td>
<td>9</td>
<td>35</td>
<td>80</td>
<td>0.61</td>
<td>0.69</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td>35</td>
<td>80</td>
<td>0.64</td>
<td>0.73</td>
</tr>
<tr>
<td>3</td>
<td>11</td>
<td>35</td>
<td>80</td>
<td>0.67</td>
<td>0.76</td>
</tr>
<tr>
<td>4</td>
<td>12</td>
<td>35</td>
<td>80</td>
<td>1.08</td>
<td>1.21</td>
</tr>
<tr>
<td>5</td>
<td>12</td>
<td>20</td>
<td>80</td>
<td>0.84</td>
<td>0.75</td>
</tr>
<tr>
<td>6</td>
<td>12</td>
<td>25</td>
<td>80</td>
<td>0.71</td>
<td>0.79</td>
</tr>
<tr>
<td>7</td>
<td>12</td>
<td>30</td>
<td>80</td>
<td>0.89</td>
<td>0.88</td>
</tr>
<tr>
<td>8</td>
<td>12</td>
<td>35</td>
<td>80</td>
<td>1.08</td>
<td>1.21</td>
</tr>
<tr>
<td>9</td>
<td>12</td>
<td>35</td>
<td>50</td>
<td>0.76</td>
<td>0.89</td>
</tr>
<tr>
<td>10</td>
<td>12</td>
<td>35</td>
<td>60</td>
<td>0.82</td>
<td>0.95</td>
</tr>
<tr>
<td>11</td>
<td>12</td>
<td>35</td>
<td>70</td>
<td>0.95</td>
<td>1.08</td>
</tr>
<tr>
<td>12</td>
<td>12</td>
<td>35</td>
<td>80</td>
<td>1.08</td>
<td>1.21</td>
</tr>
</tbody>
</table>

Figure 1. Influence of voltage on anisotropic structure of Al7075 at electrolyte conc.of 35g/l & duty cycle 80%.
of blind hole shows insignificant effect for change in voltage. Although the depth of the blind hole is higher compared to X-plane the increase in machining voltage produced same effect on material removal. In case of acidified IR heated electrolyte the material removal along Y-plane shows the increasing trend. The increase in current density, temperature of electrolyte and sparse distribution of reinforcement contributes for higher depth along this plane. The increase in electrolyte temperature makes the electrolyte composition more concentrated resulting in higher material removal. Moreover the sparse distribution of reinforcement along the Y-plane attributes for easier removal of material. It is evident from the figure that the depth produced on X-plane for both the type of electrolyte shows the similar trend and deeper blind hole witnessed at higher voltage for IR heated acidified electrolyte. It is clear from the figure that anisotropic property of MMC shows significant impact of material removal.

The effect of electrolyte concentration on depth of the blind hole is presented in the Fig. 2. The depth generated for room temperature at the both plan is lower compared to the IR heated acidified electrolyte. Under the influence of infra red heated electrolyte the machining rate is 30% higher compared to room temperature electrolyte along Y-plane at 12V, 80% duty cycle, 50Hz frequency and 35 g/L electrolyte concentration. The increase in electrolyte concentration enhances the disso- lution process due to availability of more ions and it is also evident from figure that more depth is created at higher concentration of electrolyte. In case of IR heated acidified electrolyte the heating process evaporates the electrolyte solution and consequently increases the concentration hence the depth created at both X and Y plan is comparatively higher. The depth of hole created at the Y-plane is higher due the distribution of reinforcement in MMC. On comparing the machinability in the both the planes the Y-plane show 10% higher side for IR heated acidified electrolyte.

Fig. 3 shows the effect of duty cycle on aniso- tropic structure of Al7075 at 12V & 80% duty cycle. The increase in duty cycle increases the current density required for material removal. The IR heated acidified electrolyte shows the higher depth in Y-plane which is about 11% higher than X-plane.

Fig. 4 and Fig. 5 shows the profile of the blind hole machined by room temperature electrolyte and heated electrolyte. The SEM micrograph shown in figure 4 shows the blind hole machined at Y-plane for IR heated acidified electrolyte. The evident from the figure that heated and acidified electrolyte contributes more etching and the circumference of the blind hole shows the delamina-
tion of the reinforcement of the MMC. It is clear from the figure 5 that the depth of the blind hole produced for room temperature electrolyte at Y-plane is shallow. Hence on comparing the SEM micrographs the heated acidified electrolyte may be appropriate for machining MMCs.

5. DISCUSSION

It clear from the fig.1 to 5 the machining on Y-plane of Al7075 shows better result for IR heated acidified electrolyte. Based on the literature although the heated electrolyte produces undesirable effect on the circumference of the hole the machining efficiency of this type of electrolyte is found to be significant. The use of heated acidified electrolyte has a significant effect on ion dissociation which resulted in better machining rate of MMC.

6. CONCLUSIONS

Experiments were conducted on ECM to study the effect of heated and acidified electrolyte on anisotropic properties of the material for the machining rate. The parameters combinations like voltage, duty cycle and electrolyte concentration were considered for the experiment. Based on the conducted experiments the following results are obtained:

1. The acidified IR heated electrolyte with varying voltage shows the increasing trend for the material removal along Y-plan. The increase in current density, temperature of electrolyte and sparse distribution of reinforcement contributes for higher depth along this plan.
2. Under the influence of infra red heated electrolyte the machining rate is 30% higher compared to room temperature electrolyte along Y-plane at 12V, 80% duty cycle, 50Hz frequency and 35 g/L electrolyte concentration.
3. The increase in duty cycle increases the current density required for material removal. The IR heated acidified electrolyte shows the higher depth in Y-plane which is about 11% higher than X-plane.
4. Heated and acidified electrolyte contributes more etching and the circumference of the blind hole shows the delamination of the reinforcement of the MMC.
5. Comparing the SEM micrographs the heated acidified electrolyte may be appropriate for machining MMCs.
6. The anisotropic property has the notable effect on the machining rate. The Y-plane machining shows more depth blind holes compared to machining of X-plane of Al7075.

REFERENCES