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

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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 applica- tions 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 ($NaNO_3$) and acidified sodium nitrate electro- lyte. Moreover the machinability of anisotropic proper- ty 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 H_2SO_4 shows better machining rate which is nearly two times than the electrolyte at room temperature. The machining rate is better for infra-red heated elec- trolyte compared to the electrolyte at room tempera- ture. Applied voltage, Duty cycle and electrolyte con- centration 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 ma- chining 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 prod- ucts 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 in- creasing the radius of the tool resulting in uniform dis- tribution of flow field in the machining gap. Anasane and Bhattacharyya (2017) have analyzed the effect of the electrolyte namely ethylene glycol and sodium bro- mide 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 concen- tration 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 potassi- um dichromate electrolyte and oxygenated aqueous so- dium chloride electrolyte in ECM to improve the ma- chining rate. Tang et al.,(2011) have used electrolyte temperature as a parameter to improve the efficiency of the ECM process.. Skoczypiec et al. [10] have analyzed the effect of ultrasonic vibrations to improve the elec- trochemical 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 electro- lyte 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

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this research the ma- chining 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, fre- quency, current and duty cycle, were consid- ered 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 ($NaNO_3$) and acidified sodium nitrate (H_2SO_4+$NaNO_3$) are used as electrolyte. The electrolyte is prepared by mixing the various quan- tity of sodium nitrate salt with distilled water. The electrolyte is heated using IR light source and temperature of the electrolyte is maintained at 37ºC. The stepper motor mechanism is used to feed the micro tool towards the workpiece. Ini- tially the Al 7075 com- posite was machined by varying the parameters like the concentra- tion of the electrolyte ($NaNO_3$) voltage and duty cycle while keeping the fre- quency 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 electro- lyte at room temperature along X and Y plane of the workpiece and remaining 24 sets of exper- iments are conducted using acidi- fied $NaNo_3$ 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 Micro- scope (SEM) and the images were analyzed for surface quality.

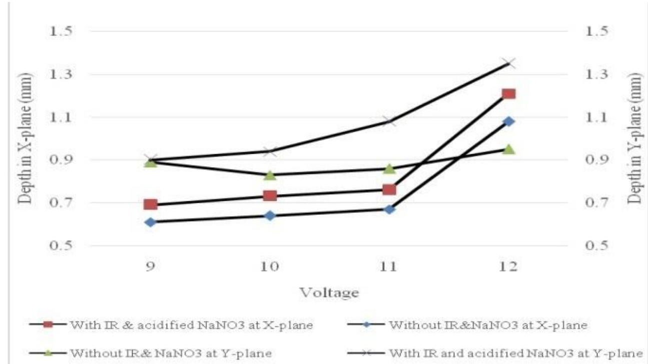

Figure 1. Influence of voltage on anisotropic structure of Al7075 at electrolyte conc.of35g/l & duty cycle 80%.

4. RESULTS

Fig. 1 shows the effect of machining voltage for room tempera- ture $NaNO_3$ 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 in- crease 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 1. Experimental Combination for machining Al7075 MMC

Sample no	Voltage (v)	Electrolyte Concentration (g/L)	Duty cycle (%)	Hole depth (mm)			
				X-Direction		Y-Direction	
				Electrolyte at room temperature	Acidified IR heated electrolyte	Electrolyte at room temperature	Acidified IR heated electrolyte
1	9	35	80	0.61	0.69	0.89	0.9
2	10	35	80	0.64	0.73	0.83	0.94
3	11	35	80	0.67	0.76	0.86	1.08
4	12	35	80	1.08	1.21	0.95	1.35
5	12	20	80	0.84	0.75	0.7	0.86
6	12	25	80	0.71	0.79	0.74	0.91
7	12	30	80	0.89	0.88	0.77	1.06
8	12	35	80	1.08	1.21	0.95	1.35
9	12	35	50	0.76	0.89	0.82	1.02
10	12	35	60	0.82	0.95	0.88	1.24
11	12	35	70	0.95	1.08	0.915	1.295
12	12	35	80	1.08	1.21	0.95	1.35

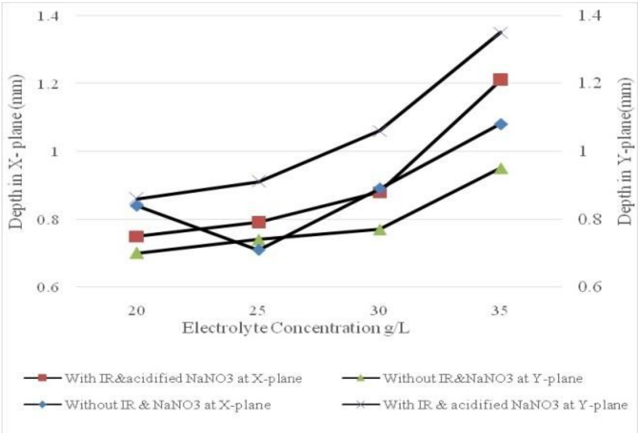

Figure 2. Influence of electrolyte concentration on aniso- tropic structure of Al7075 at 12V & 80% duty cycle

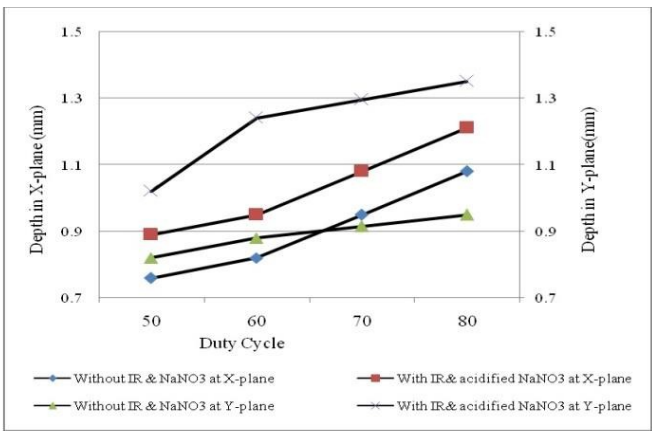

Figure 3. Influence of duty cycle on anisotropic structure of Al7075 at 12V & 80% duty cycle.

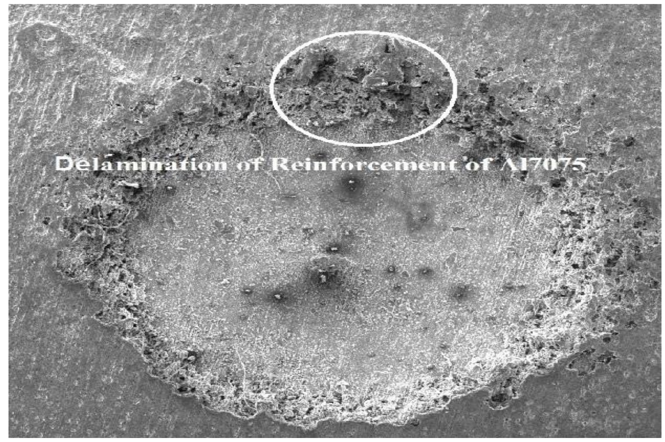

Figure 4. SEM images of surface machined with IR heated and acidified Electrolyte.

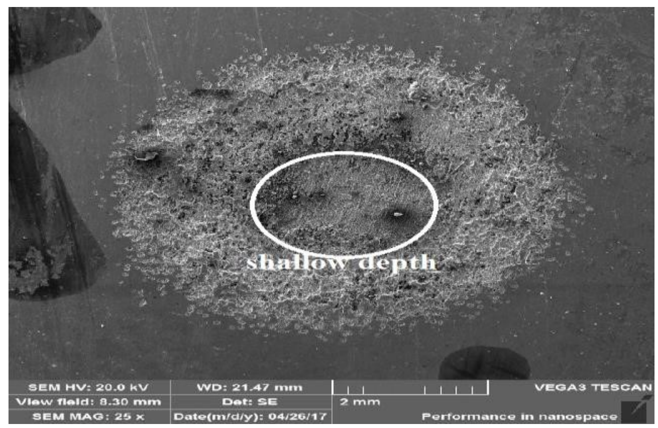

Figure 5. SEM images of surface machined with Electrolyte at room temperature

of blind hole shows insignificant effect for change in voltage. Although the depth of the blind hole is higher compared to X-plan the increase in machining voltage produced same effect on material removal. In case of acidified IR heated electrolyte the material removal along Y-plan shows the increasing trend. The increase in current density, temperature of electrolyte and sparse distribution of reinforcement contributes for higher depth along this plan. 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 the both the type of electrolyte shows the simi- lar trend and deeper blind hole witnessed at higher volt- age 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 generat- ed for room temperature at the both plan is lower com- pared to the IR heated acidified electrolyte. Under the influence of infra red heated electrolyte the machining rate is 30% higher compared to room temperature elec- trolyte 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 con- centration 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 delamination 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 ma- chining MMCs.

5. DISCUSSION

It clear from the fig.1 to 5 the machining on Y- plane of Al7075 shows better result for IR heated acidi- fied electrolyte. Based on the literature although the heated electrolyte produces undesira- ble effect on the circumference of the hole the machining efficien- cy of this type of electrolyte is found to be significant. The use of heated acidified electrolyte has a significant ef- fect on ion dis- sociation which resulted in better machin- ing 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 consid- ered for the exper- iment. Based on the conducted experiments the follow- ing results are obtained:

1. The acidified IR heated electrolyte with varying voltage shows the increasing trend for the material re- moval 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 electro- lyte the ma- chining rate is 30% higher compared to room temperature electro- lyte along Y-plane at 12V, 80% duty cycle, 50Hz frequency and 35 g/L electrolyte concentra- tion.
3. The increase in duty cycle increases the current density re- quired 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 electro- lyte may be appropriate for machining MMCs.
6. The anisotropic property has the notable effect on the ma- chining rate. The Y-plane machining shows more depth blind holes compared to machining of X- plane of Al7075.

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