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Research Article

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Optimizing the Electrochemical Micro Machining Parameters during Drilling of Aluminium Alloy

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Abstract-

This paper presents the effects of parameters of micro ECM on material removal rate (MRR, mm^3/min) and overcut (µm) during micro machining of aluminium alloy. A micro ECM setup has been fabricated for this purpose. A copper micro tool having mean diameter 327µm is used for experimentation. NaCl solution is used as electrolyte. It is noted that for the micro machining of aluminium alloy on micro ECM, the maximum material removal rate (MRR) is 0.533mm^3/min is obtained at 0.5A supply current, 10V supply voltage, 2.5µs pulse off time, and 5µs pulse on time. It is noted that for the micro machining of aluminium alloy on micro ECM, the minimum over cut is 0.074mm which is at 0.2A supply current, 4V supply voltage, 2.5µs pulse off time, and 3µs pulse on time.

Keywords: Micro ECM, Aluminium alloy, overcut, material removal rate, Taguchi L_9 orthogonal array

I. Introduction

The micro manufacturing techniques have wider applications in various fields like electronic devices, actuators, sensors, semi-conductors, aerospace, medicine, ultra precision and miniature parts manufacturing industries. Micro machining of hard and difficult materials like ductile material aluminium alloy sheet with conventional methods results in subsurface damage and bending of the work piece [1]. Nonconventional machining processes can be utilized in micro machining. All the nonconventional techniques remove material by utilizing the energy either mechanical or chemical or thermal or electrical energy so that there is no chance of bending of workpiece.

From the review of published available literature, it is found that Micro Electrochemical Machining seems to be more advantageous. It offers several advantages such as higher machining rate, good surface finish, better precision, control and capability to machine wide range of materials because removal material takes place by electrochemical anodic dissolution [2, 3]. A low DC voltage is applied between the micro tool (cathode) and the work piece (anode), which are separated by a continuous flow of electrolyte. The dissolution products i.e. sludge, gas bubbles, and heat can be flushed away from the Inter Electrode Gap (IEG) by continuous flow of electrolyte during machining. The Micro Electrochemical Machining process permits micro machining of micro groove, micro drilling, micro punches, micro dimple array, 3D complex shape, etc on chemical resistant materials irrespective of their hardness and toughness, with high aspect ratio which are widely used in space, automobile, biomedical, electronics, computers printed circuit boards, surgical implants, optics; and MEMS applications [4-8].

A review of literature on Micro Eectrochemical Machining reveals that these studies do not report the effect of operating parameters on the quality of micro drilled holes on aluminium alloy. This paper is reported effect of various process parameters of fabricated Micro ECM during micro machining of aluminium alloy.

II. Experimental Planning

A fabricated Micro Electrochemical Machining setup is utilized for experimental investigation. Aluminium alloy is used as work-piece materials. The aluminium alloy samples are utilized to prepare 20mm x 20mm x 2mm size of work-piece by shaping and surface grinding operation for experimentation.

The aluminium alloy is first clamped on fixtures in machining chamber which is fixed on the table of the micro ECM. Then the Electrolye is made to flow between the tool electrode and workpiece i.e in to the machining chamber. Machining is done on the workpiece using copper electrode of 327µm diameter. The chemical dissolution of metal is occurred when power supply is on. The material starts removing in form of small micro debris during chemical dissolution process.

Fig. 1: Micro Machining of Aluminium Alloy at Micro ECM

The material removal rate (MRR) is determined based on volume of the hole generated. Volume of micro holes are determined by taking average diameters of the hole from SEM micro graphs. Machining time is measured by stop watch in minutes. The over cut is determined by gap in between micro tool and micro hole. The MRR (mm^3/min) and average radial overcut (µm) are calculated using relation as follows.

$$MRR = \frac{\frac{\pi}{4} \times (D_{avg})^2 \times h}{\text{Machining Time}}$$

$$\text{overcut} = \frac{D_{avg} - d_{avg}}{2}$$

'h' is height of work piece.
'D_{avg}' is average diameter of machined hole.
'd_{avg}' is average diameter of micro tool

III. Results and Discussions

The effects of process parameters of developed Micro Electrochemical Machining setup such as supply current, supply voltage, pulse on time, and pulse off time on MRR (mm^3/min) and overcut (µm) during micro machining of aluminium alloy are analysed through various graphs.

3.1 Effects of various parameters of developed ECMM setup on MRR

Figure 2 represents the investigated results obtained during micro machining of aluminium alloy by utilizing micro ECM. The results i.e. MRR and S/N ratio were obtained at variation of Supply Current i.e. from 0.2 to 0.8A, Supply Voltage i.e. from 4 to 10V, Pulse off time i.e. from 2.5 to 6.5µs, and Pulse on time i.e. from 3 to 7µs.

↓	C1	C2	C3	C4	C5	C6	C7
	Supply Current	Supply Voltage	Pulse OFF	Pulse ON	MRR	SNRA2	
1	0.2	4	2.5	3	0.268	-11.4373	
2	0.2	7	4.5	5	0.387	-8.2458	
3	0.2	10	6.5	7	0.513	-5.7977	
4	0.5	4	4.5	7	0.209	-13.5971	
5	0.5	7	6.5	3	0.282	-10.9950	
6	0.5	10	2.5	5	0.533	-5.4655	
7	0.8	4	6.5	5	0.288	-10.8122	
8	0.8	7	2.5	7	0.381	-8.3815	
9	0.8	10	4.5	3	0.490	-6.1961	
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Fig. 2: Results of MRR, S/N ratios of MRR

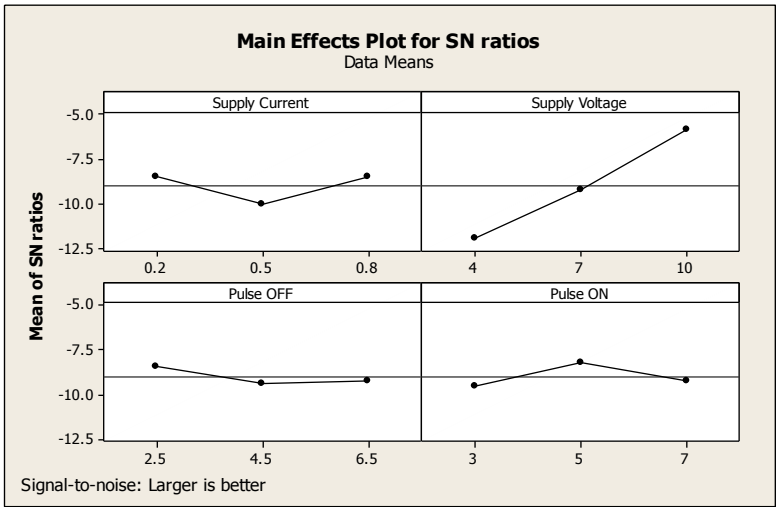

Fig. 3: Showing the effect of Micro ECM Parameters on Mean of S/N ratio of MRR

Figure 3 shows effect of various micro ECM parameters on the mean of S/N ratio of material removal rate plotted utilizing the machining results obtained. From the figure, it is observed that the mean value of S/N ratio of MRR is decrease by increasing the supply current from 0.2 to 0.5A and after that the value of S/N ratio of MRR is increase by

increasing the supply current from 0.5 to 0.8A. The mean of S/N ratio of material removal rate rises constantly by increasing the value of supply voltage from 4 to 7V and from 7 to 10V. The value of S/N ratio of MRR is decrease by increasing the pulse off time from 2.5 to 4.5µs and after that value of S/N ratio of MRR is slightly increase by increasing the pulse off time from 4.5 to 6.5µs. The mean of S/N ratio of MRR is increased by increasing the pulse on time from 3 to 5µs after that the mean of S/N ratio of MRR is decreased by increasing the pulse on time from 5 to 7µs.

Response Table for Signal to Noise Ratios
Larger is better

Level	Supply Current	Supply Voltage	Pulse OFF	Pulse ON
1	-8.494	-11.949	-8.428	-9.543
2	-10.019	-9.207	-9.346	-8.174
3	-8.463	-5.820	-9.202	-9.259
Delta	1.556	6.129	0.918	1.368
Rank	2	1	4	3

Fig. 4: Ranking of micro ECM Parameters by Response of S/N ratio

Figure 4 shows the ranking of micro ECM parameters for optimizing the material removal rate. It can be observed that Supply voltage has the largest effect on the material removal rate of micro machining of aluminium alloy by micro ECM machining. The Pulse off time has the smallest effect on the material removal rate.

3.2 Effects of various parameters of developed ECMM setup on Overcut

↓	C1	C2	C3	C4	C5	C6	C7
	Supply Current	Supply Voltage	Pulse Off	Pulse On	Over Cut	SNRA1	MEAN1
1	0.2	4	2.5	3	0.0740	22.6154	0.0740
2	0.2	7	4.5	5	0.1065	19.4530	0.1065
3	0.2	10	6.5	7	0.2915	10.7072	0.2915
4	0.5	4	4.5	7	0.1590	15.9721	0.1590
5	0.5	7	6.5	3	0.2215	13.0925	0.2215
6	0.5	10	2.5	5	0.3890	8.2010	0.3890
7	0.8	4	6.5	5	0.1740	15.1890	0.1740
8	0.8	7	2.5	7	0.2740	11.2450	0.2740
9	0.8	10	4.5	3	0.3315	9.5903	0.3315
10							

Fig. 5: Results of overcut, S/N ratios of overcut

Figure 5 represents the investigated results obtained during micro machining of aluminium alloy by utilizing micro ECM. The results i.e. overcut and S/N ratio were obtained at variation of Supply Current i.e. from 0.2 to 0.8A, Supply Voltage i.e. from 4 to 10V, Pulse off time i.e. from 2.5 to 6.5µs, and Pulse on time i.e. from 3 to 7µs.

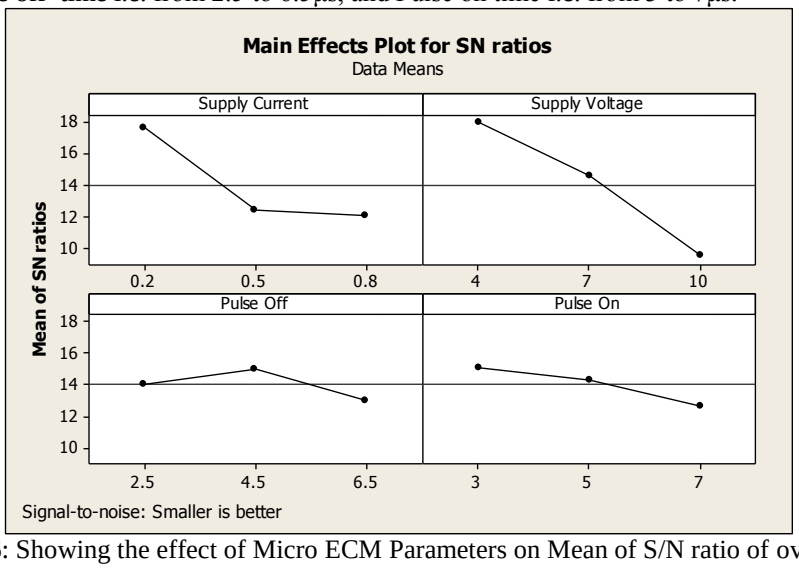

Fig. 6: Showing the effect of Micro ECM Parameters on Mean of S/N ratio of overcut

Figure 6 shows effect of various micro ECM parameters on the mean of S/N ratio of overcut plotted utilizing the machining results obtained. From the figure, it is observed that the mean value of S/N ratio of overcut is decrease by increasing the supply current from 0.2 to 0.5A and after that the value of S/N ratio of overcut is again decrease by increasing the supply current from 0.5 to 0.8A. The mean of S/N ratio of overcut rises constantly by decreasing the value of supply voltage from 4 to 7V and from 7 to 10V. The value of S/N ratio of overcut is increase by increasing the pulse off time from 2.5 to 4.5µs and after that value of S/N ratio of overcut is decrease by increasing the pulse off time from 4.5 to 6.5µs. The mean of S/N ratio of overcut is decreased by increasing the pulse on time from 3 to 5µs after that the mean of S/N ratio of overcut is decreased by increasing the pulse on time from 5 to 7µs.

Response Table for Signal to Noise Ratios
Smaller is better

Level	Supply Current	Supply Voltage	Pulse Off	Pulse On
1	17.592	17.925	14.020	15.099
2	12.422	14.597	15.005	14.281
3	12.008	9.500	12.996	12.641
Delta	5.584	8.426	2.009	2.458
Rank	2	1	4	3

Fig. 7: Ranking of micro ECM Parameters by Response of S/N ratio

Figure 7 shows the ranking of micro ECM parameters for optimizing the overcut. It can be observed that Supply voltage has the largest effect on the overcut of micro machining of aluminium alloy by micro ECM machining. The Pulse off time has the smallest effect on the overcut.

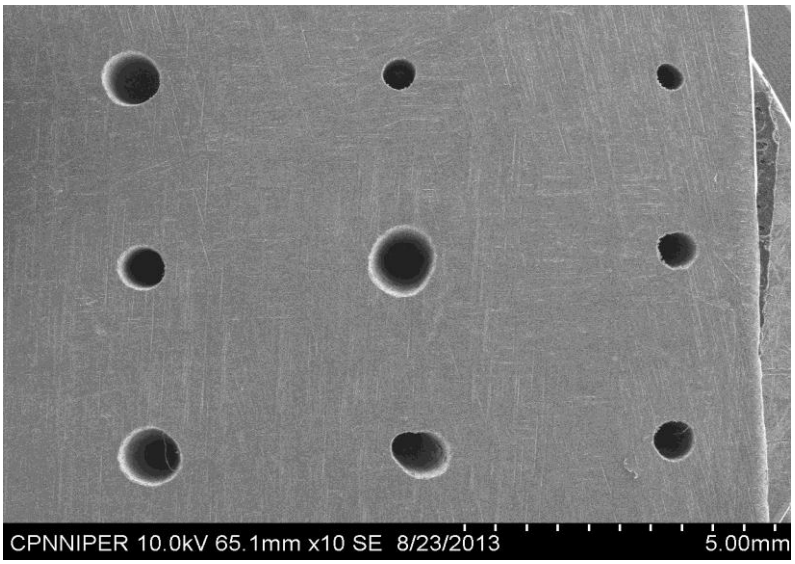

Fig. 8: SEM micro-graph of micro holes produced by Micro ECM

Fig. 8 shows SEM micro-graph of micro holes produced by micro ECM. From SEM micro-graph shows the better machined circular micro-holes produced by low supply voltage and low supply current, but overcut is produced when large supply current, large supply voltage and more pulse on time.

IV. Conclusions

- It is noted that for the micro machining of aluminium alloy on micro ECM, the maximum material removal rate (MRR) i.e. 0.533mm^3/min is obtained at 0.5A supply current, 10V supply voltage, 2.5µs pulse off time, and 5 µs pulse on time.
- It is observed that the optimum parameters for higher MRR are 0.2A supply current, 10V supply voltage, 2.5µs pulse off time, and 5µs pulse on time.
- It is noted that for the micro machining of aluminium alloy on micro ECM, the minimum over cut is 0.074mm which is obtained at 0.2A supply current, 4V supply voltage, 2.5µs pulse off time, and 3µs pulse on time.
- It is observed that the optimum parameters for lower over cut value are 0.2A supply current, 4V supply voltage, 4.5µs pulse off time and 3 µs pulse on time.

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