International Journal of Advance Research in Engineering, Science & Technology(IJAREST), ISSN(O):2393-9877, ISSN(P): 2394-2444,
Volume 2, Issue 6, June- 2015, Impact Factor: 2.125

DEVELPOMENT OF ELECTROCHEMICAL MICROMACHINING AND PROCESS PARAMETER OPTIMIZATON FOR MACHINING OF ALUMINIUM

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Abstract

The present paper deals with the analysis of ECMM process at the basic level. This study has demonstrated the ECMM process from both a theoretical and experimental point of views, based on earlier investigations. The functional aspects of ECMM set-ups and systems were understood, considering the mechanism of removal as well as the precision of the machining process for machining an Aluminium Foil using a Copper tool and Nacl electrolyte.Comparative analyses of the processing conditions governing the electrical and chemical aspects of the ECMM process were performed. The input parameters chosen were: Supply Voltage (V),Supply Current ($I_{p)}$,,Pulse Off Time(T_{off}),Pulse On Time(T_{on}).The effect of these parameters on MRR in ECMM were evaluated with the help of Taguchi method.The maximum material removal rate,i.e.MRR which is .590(mm^3/min) is obtained at 0.7A Current supply 9V Voltage supply,4µs Pulse off time and 3µs Pulse on time.The metal removal rate was considered as the quality characteristic with the concept of "larger-is-better".

KEYWORDS: *Electrochemical Machining, Micro-Machining, Electrolyte, Processing Parameter,Taguchi Method, ANOVA, MRR.*

I. INTRODUCTION

Micromachining literally means the removal of small amount of material in the range 1-999 µm. As a technical term, it also means the smaller amount of machining which cannot be obtained directly by using a conventional technique. It deals with processes capable of performing micro-manufacturing activities. This technique deals with material removal of small dimensions ranging from several microns to millimeters. This ensures developing more quality products. Manufacturing of miniaturized parts and products cannot be achieved by conventional means. Small and micro holes, slots and complex surfaces need to be produced in large numbers, sometimes in a single work piece. Sometimes when these shapes are produced by conventional machining techniques, the problem usually encountered is high tool wear, lack of rigidity and heat generation at tool work piece interface. In addition to these problems machining of three dimensional shapes becomes troublesome.

By the review of past literature it is being observed that Electrochemical Micromachining has tremendous potential on account of its versatility of applications.ECM principle is used in a wide variety of application ranging from complex shapes, complicated large metallic pieces to few microns diameter openings in silicon windows.ECM is on a surge in last few decades due to its advantages such as no tool wear, no stress/burr free machining, high MRR and ability to machine complex shapes in a wide variety of materials regardless of their hardness.ECM is an anodic dissolution process where work piece and tool are respectively anode and cathode which are separated by a flowing electrolyte. When the electric current is passed through the electrolyte using a D.C voltage source the anode work piece starts dissolving locally so that the shape of the machined surface is approximately the negative mirror image of the cathodic tool. The electrolyte which is generally a salt solution is pumped through the gap between the work piece and the tool in order to remove the machined waste and dissipate the generated heat.

A review of the past literature reveals that much work has not been done in parameter optimization in case of micro drilling in aluminium. This paper depicts the effects of various parameters on micro drilling in aluminium using Electrochemical Micromachining.

II. GAPS

- When micro shapes are produced with conventional machining techniques, the problem usually encountered is high tool wear, lack of rigidity of the process and heat generation at the tool and work piece interface. Also surface finish of machined area is very poor in conventional method. While machining of aluminium alloy using other Non-conventional processes like LBM, EDM and EBM, the value of current required is large, this can be eliminated in ECMM. In EDM, LBM and EBM, generation of heat on machining area produce thermal stresses; those can easily damage the micro machined surface especially low strength materials like aluminium. Bending of Ductile material like aluminium having small thickness can occur.

III. OBJECTIVE

- To analyze the fundamental characteristics and principles underlying the material removal mechanism in micro machining of aluminium alloy with ECMM. Then analysis of test results for investigating the influence of various parameters on material removal rate and over cut and conduct an experiment investigation for optimization of cutting condition for higher Material Removal Rate and lower Over Cut during using Taguchi design concept.

IV. EXPERIMENTAL SETUP

An Electrochemical Machining setup is being fabricated to perform the experiments. An aluminium work piece of required dimensions is fabricated and fixed on the worktable in the setup. A copper tool of dia 350µm is used for machining Nacl,i.e. the electrolyte is pumped through the machining gap. The chemical dissolution of anodic material occurs when power supply is switched on. Material is removed in form of small debris which in turn are removed by the flowing electrolyte..

FIG 1: Showing the fabricated ECMM setup

FIG 2: Showing the machining of Aluminium using Copper tool.

The MRR is determined by the volumes of the generated holes. Volume of the generated holes is measured by taking average diameters from the SEM micrographs. Machining time is observed by using a stopwatch. The MRR and average radial overcut is calculated using the following formulae;

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

$$D_{avg} = \frac{D_1 + D_2}{2}$$

'h' is height of work piece.
'D_{avg}' is average diameter of machined hole.
'D_1' and 'D_2' are the diameters of holes measured in two mutually perpendicular directions in the hole.

V. RESULTS AND DISCUSSION

The effects of various parameters namely; 1)SUPPLY VOLTAGE(V),(2)SUPPLY CURRENT(I_P),(3)PULSE OFF TIME(T_{off}),(4)PULSE ON TIME(T_{on}) on the output parameters, i.e. MRR are being analyzed using TAGUCHI METHOD and ANOVA with the help of Minitab software.

Table 1: Micro ECM machining parameters and their ranges.

S.No	Parameters	Range	Units
1	Supply Voltage (V)	4-10	(V)
2	Supply Current (I_P)	0.2-0.8	(A)
3	Pulse Off Time (T_{off})	2.5-6.5	(µs)
4	Pulse On Time (T_{on})	3-7	(µs)

Table 3:Results of MRR,S/N ratio for MRR

Minitab - nitin1.MPJ - [Worksheet 1 ***]

↓	C1	C2	C3	C4	C5	C6	C7
	SUPPLY CURRENT	SUPPLY VOLTAGE	PULSE OFF TIME	PULSE ON TIME	MRR	SNRA1	MEAN1
3	0.3	9	6.5	7	0.481	-6.3571	0.481
4	0.5	3	4.5	7	0.258	-11.7676	0.258
5	0.5	6	6.5	3	0.290	-10.7520	0.290
6	0.5	9	2.5	5	0.422	-7.4938	0.422
7	0.7	3	6.5	5	0.232	-12.6902	0.232
8	0.7	6	2.5	7	0.415	-7.6390	0.415
9	0.7	9	4.5	3	0.590	-4.5830	0.590

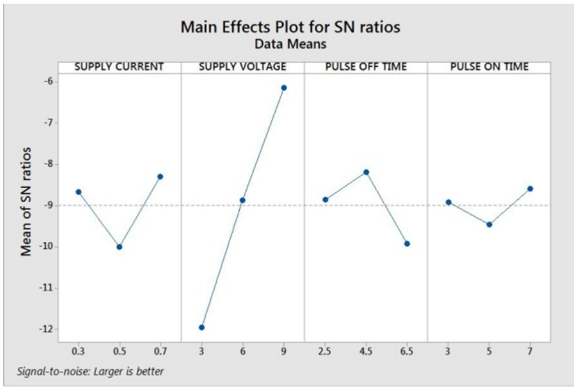

Fig 3: Graphs showing the effects of parameters on MRR

A. Observations for MRR:

SUPPLY CURRENT-The mean value of S/N ratio first decreases when the value of supplied current is from 0.3 to 0.5 A and then it increase for supply current value of 0.5 to 0.7A.

SUPPLY VOLTAGE-The mean value of S/N ratio increases for the entire range of supplied current from 3V to 9V.

PULSE OFF TIME-The mean S/N ratio first increases in the range of pulse off time from 2-4µs and then it decreases in the range of 4-6µs.

PULSE ON TIME-For this parameter the mean value of S/N ratio behaves similar to supply current parameter. It first decreases in the range of 3-5µs and then increases for values ranging from 5-7µs.

B. ANOVA RESULTS

Table 6:Showing the results obtained by application of Anova method for MRR

MATERIAL REMOVAL IN ECMM

Expt. No. ↓	→ Repetition 1	2	3	Mean	Variance	Sum of Squares of reciprocals	SN Ratio (Larger-the-Better)	S/N Ratio (Mean)	B*B	C*C	D*D	
1	0.268	0.244	0.28	0.264	0.000336	21.7372924	-13.3720545	-11.56792	0.071824	0.059536	0.0784	0.2097
2	0.402	0.414	0.353	0.389667	0.001044	10.02375502	-10.0103044	-8.186135	0.161604	0.171396	0.124609	0.45760
3	0.477	0.497	0.47	0.481333	0.000196	6.485207448	-8.11923873	-6.351081	0.227529	0.247009	0.2209	0.69543
4	0.258	0.291	0.226	0.258333	0.001056	23.20541358	-13.6558931	-11.75639	0.066564	0.084681	0.051076	0.20232
5	0.318	0.283	0.271	0.290667	0.000596	17.99566543	-12.5516791	-10.7321	0.101124	0.080089	0.073441	0.25465
6	0.43	0.464	0.372	0.422	0.002164	8.639682946	-9.36497805	-7.493751	0.1849	0.215296	0.138384	0.5385
7	0.229	0.259	0.208	0.232	0.000657	28.54515258	-14.5553237	-12.69024	0.052441	0.067081	0.043264	0.16278
8	0.392	0.419	0.434	0.415	0.000453	8.756413274	-9.42326251	-7.639038	0.153664	0.175561	0.188356	0.51758
9	0.613	0.498	0.659	0.59	0.006877	4.498029509	-6.530223	-4.58296	0.375769	0.248004	0.434281	1.05805
				0.59	0.006877	4.498029509	-6.530223	-4.58296	0.375769	0.248004	0.434281	1.05805
SUM	3.387	3.369	3.273	0.371444			-104.11318	-8.602123				5.15483

Table 3-Response table for ranking of parameters acc.to their effects on MRR

Response Table for Signal to Noise Ratios
Larger is better

Level	SUPPLY CURRENT	SUPPLY VOLTAGE	PULSE OFF TIME	PULSE ON TIME
1	-8.709	-12.009	-8.900	-8.889
2	-9.926	-8.785	-8.184	-9.462
3	-8.304	-6.145	-9.854	-8.588
Delta	1.622	5.864	1.670	0.874
Rank	3	1	2	4

Table 3-Response table for ranking of parameters acc.to their effects on MRR

From the ranking table it can be observed that Supply voltage has the largest effect on MRR in ECMM process and the Pulse on time ha the minimal effect on MRR during machining of aluminium foil using ECMM process.

Table 7:Showing the ANOVA for S/N data

ANOVA of S/N Data

SOURCE		SS	DOF	V	P	F-Ratio
CURRENT		62.0994349	2	31.04972	27.73797	4.255062
VOLTAGE		145.865883	2	72.93294	65.15396	9.994751
PULSE OFF		1.31920338	2	0.659602	0.589249	0.090392
PULSE ON		14.5942486	*	*	*	*
ERROR		14.5942486	2	7.297124	6.518818	
T		223.878769	8		100	
SST	45.56663947					
CF	1292.875458					

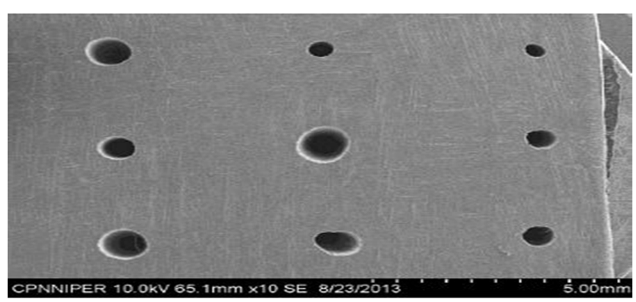

Figure 5: Shows micrographs of micro holes produced by EMM.SEM images show that the better machined holes drilled with lower values of supply current and voltage.

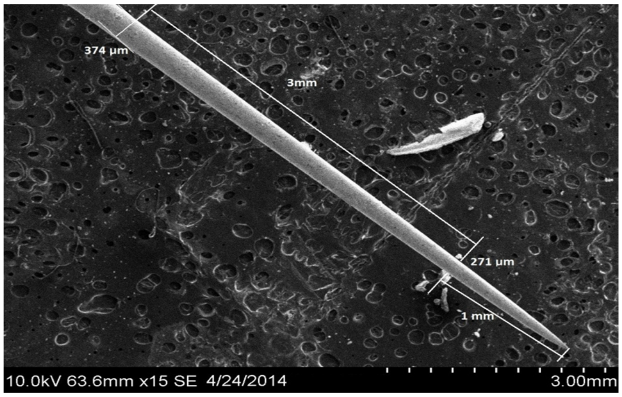

Figure 6:SEM image of the Copper tool.

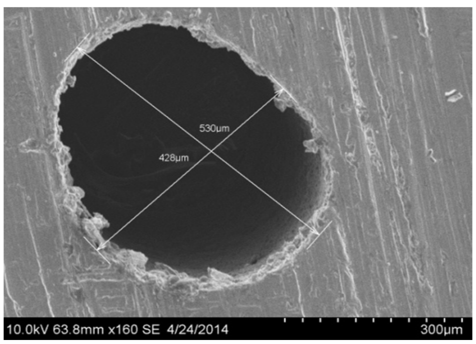

Figure 7:SEM image of upper surface of drilled hole through first run

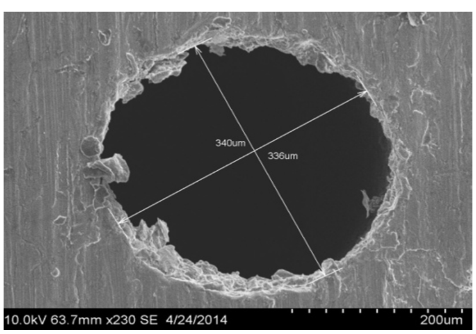

Figure 8:SEM image of lower surface of drilled hole through first run

CONCLUSIONS:

1.) It is noted that the maximum value of MR, i.e 0.590 mm^3/min is obtained at 0.7A current,9 Volts,4µs Pulse off time and 3µs Pulse on time.

2.) It is observed that optimum parameters for higher MRR are 0.7A current,9 Volts supply,4µs Pulse off time and 3µs Pulse on time under the condition 'LARGER IS BETTER' for S/N ratio.

3.) Supply voltage is the most significant factor with a percentage contribution of approx 82% and the pulse on time has the least contribution in S/N ratio as obtained from the ANOVA method.

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