Fabrication of Micro -Tool Using Electrochemical Micromachining and Study of Process Parameters

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Abstract— Recent changes in societies demand have forced us to introduce more and more micro-parts into various types of industrial products for example, the fuel injection nozzle for automobiles, miniaturized medical tools, microprobe used to measure electricity or surface properties of a test piece, integrated micro channels used as medicine delivering systems and various aeronautical requirements. In the present work, an experimental set up has been designed and developed to fabricate micro electrodes and to machine micro holes and slots using the ECMM process and to study the effect of various process parameters on it. The machining of micro holes and slots is done on copper work pieces of 60 µm and 500 µm thickness using ECMM and copper wire of dia. 200 µm as tool. The effect of process parameters such as voltage, electrolyte concentration, pulse duty ratio and feed rate on machined hole diameter have been studied. The hole dia. increases exponentially with voltage and concentration and decreases exponentially with feed rate. The fabrication of straight micro tools is done on the same set up using dipped ECM with copper wire of dia. 1.3 mm and copper sheets of 3 mm thickness and holes of various diameters as cathodes. Same method is used to fabricate step micro tools with copper wire of dia. 2 mm. The effect of process parameters namely voltage, IEG, time, pulse duty ratio and electrolyte concentration on the diameter of the micro tool is studied. The change in diameter of the tool increases linearly with voltage and time while it increases quadratically with pulse duty ratio and electrolyte concentration. The photographs of all the micro tools are taken and measured using USB microscope at 50x and 200x zoom

Key words: ECMM, USB, automobiles

I. Introduction

The needs for miniaturization of various ultra precision items utilized for producing highly precision machines and equipments necessitate the development of manufacturing processes capable of performing micro manufacturing activities. Micromachining refers to small amount of material removal that ranges from 1 to 999. Recent changes in society demands have forced to introduce more and more icro-parts into various types of industrial products for example, the fuel injection nozzle for automobiles, miniaturized medical tools, microprobe used to measure electricity or surface properties of a test piece, integrated micro channels used as medicine delivering systems and various aeronautical requirements. Slots, complex surfaces and micro-holes used to be produced in large numbers, sometimes in a single work piece, especially in electronic industries. These features are produced by using conventional machining techniques also, but the problems generally faced are, tool wear, rigidity problem of the tool and heat generation at the tool work piece interface.

II. DOE ForMicro Tool Fabrication

There are 5 process parameters chosen for the fabrication of micro tool . For 5 factors and half factorial design the value of α becomes.

The DOE and the analysis part are done by the "Design Expert 7.0.0" software.

S. No.	Process parameter	Unit	Levels				
			- α	- 1	0	+ 1	+ α
1	Voltage	V	4	8	12	16	20
2	IEG	mm	2.125 (2)	4	6	7.75	9.625 (9.5)
3	Time	min	0 (1)	2	4	6	8
4	T_{on}/T_{off} (T_{on} = 100 µs)		- 1.0625 (0.3125)	0.625	2.31 (2.63)	4	5.6875 (7.69)
5	Concentration	g/L	0 (5)	15	30	45	60

Coded Levels and Actual Values of Process Parameter. The experiments are conducted on copper work piece to fabricate micro tools in run experiments, prepared using central composite rotatable design methodology with above 5 factors. All the values given in the table are the calculated values.

Some of these values are changed slightly. These used values aregiven in the bracket.

III. Response Calculation

Run order	Std order	Factors					Response	
		A Voltage (V)	B IEG (mm)	C Time (min)	D T_{on}/T_{off}	E Conc. (gm/L)	Average change in dia. (ΔD) (mm)	Taper angle (θ) (deg.)
1	6	16.00	4.00	6.00	0.63	45.00	1.334	16.96
2	16	16.00	7.75	2.00	4.00	45.00	0.766	8.159
3	14	16.00	4.00	6.00	4.00	15.00	1.27	32.41
4	11	8.00	7.75	2.00	4.00	45.00	0.276	1.336
5	8	16.00	7.75	6.00	0.63	15.00	0.352	3.528
6	32	12.00	6.00	4.00	2.63	30.00	0.79	3.731
7	29	12.00	6.00	4.00	2.63	30.00	0.706	2.973
8	5	8.00	4.00	6.00	0.63	15.00	0.152	1.431
9	28	12.00	6.00	4.00	2.63	30.00	0.877	7.573
10	25	12.00	6.00	4.00	2.63	5.00	0.113	1.145
11	7	8.00	7.75	6.00	0.63	45.00	0.35	1.431
12	1	8.00	4.00	2.00	0.63	45.00	0.064	0
13	24	12.00	6.00	4.00	7.69	30.00	0.983	3.432
14	23	12.00	6.00	4.00	0.31	30.00	0.247	1.241
15	12	16.00	7.75	2.50	4.00	15.00	0.3	1.431
16	22	12.00	6.00	8.00	2.63	30.00	1.402	35.03
17	9	8.00	4.00	2.00	4.00	15.00	0.125	1.145
18	31	12.00	6.00	4.00	2.63	30.00	0.731	4.345
19	17	4.00	6.00	4.00	2.63	30.00	0.135	0
20	19	12.00	2.00	4.00	2.63	30.00	0.817	17.83

The calculated responses are average change in diameter (ΔD) of the copper wire and the taper angle (θ) of the fabricated tool.Theaverage change in diameter is givenas: $\Delta D = D_1 - D_2$. Measurement of the initial and final diameters of the micro tools

IV. Results And Discussion

Based on the response surface model obtained after regression analysis, the results interms of 5 process parameters namely Voltage, IEG, Time, T on/Toff and

ElectrolyteConcentration for micro electrode against the average change in dia. (ΔD) and the taperangle (θ) are plotted and discussed in the following subsections. Response curves areplotted using "Microsoft Office Excel 2007" package.

V. CONCLUSIONS AND SCOPE OF FUTURE WORK

A. *Conclusions*

A set up has been developed for fabricating micro electrodes as well as machining micro holes and slots. The effect of key process parameters have been studied over the shape of the micro electrodes fabricated. The conclusions derived from the experiments are as follows:

(1) The average change in diameter of the micro tool after the ECMM process increases almost linearly with increase in voltage and time, and increases quadratically with increase in pulse duty ratio and electrolyte concentration.
(2) For low concentration of electrolyte the average change in diameter (ΔD) decreases with increasing IEG and for high concentrations of electrolyte ΔD increases with increase in IEG.
(3) The taper angle of the micro electrode (θ) increases linearly with voltage and machining time and it decreases linearly with increasing IEG.
(4) The minimum diameter of the micro electrode obtained was 165 μm and tip radius 27 μm for the following process parameters: Voltage: 7.8 V, IEG: 6 mm, Time: 7 min, Duty Ratio: 0.8, electrolyte concentration: 30 g/L.
(5) The maximum taper angle obtained is 35.23 at the machining conditions of: Voltage: 20 V, IEG: 6 mm, Time: 4 min, Duty Ratio: 0.73 and conc.: 30 g/L.

B. *Scope for Future Work*

The concept of fabricating micro electrodes using ECMM is fairly new and hence there is enormous scope for future work. In the present work a set up has been developed for fabricating micro tools and using the same for machining micro holes and slots. It can be further modified to incorporate the rotationary and oscillatory features for the tool and their effect can be studied on the shape of tools fabricated. Including the rotationary feature for the tool fabrication can improve the shape and size of it by improving the diffusion process and flushing. Similarly, oscillation of the tool can improve the accuracy of the holes and slots machined by it.

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