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EXPERIMENTAL STUDY OF FABRICATION OF STRAIGHT TOOL FOR ELECTRO-CHEMICAL MICRO MACHINING

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ABSTRACT
Electro chemical micro machining (ECMM) is an advanced form of machining process for the machining of the electrically conductive materials. Electro chemical micro machining has one of the alternatives to the conventional method for the machining of hard materials and complex shape without any residual stress and also machined to the work piece without any tool wear. ECMM has extensive used in aerospace, automotive, medical, electronic, textile and petroleum industries. The study of tool fabrication is the most important in ECMM in micro levels. In this present study, an experimental setup is used to fabricate a straight tool of copper material. In ECMM material is removed based on anodic electrochemical reaction. Therefore the tool electrode can be used for a long time, since no tool wear is expected in this process. The micro tool can be reused to generate various holes and shapes with a single tool.
The machining parameters are used as voltage, electrolyte concentration. It was found that as voltage is kept constant throughout the experiment, by Ohm's law, as resistance decreases, current (I) increases. By Faraday's laws of electrolysis as current increases, MRR increases.
KEYWORDS: *Taguchi method, Electro chemical micro Machining (ECMM), Material removal rate (MRR), electrode.*

1. INTRODUCTION
In Electrochemical micro Machining, machined surface is approximately replica of the tool [1]. Tool is used for production of micro holes and micro channels in ECMM process. In recent years, ECMM has received special attention in fabrication of micro parts. Micro holes and micro channels are used in many applications like micro dies, micro nozzles etc. In ECMM material is removed based on anodic electrochemical reaction. Therefore the tool electrode can be used for a long time, since no tool wear is expected in this process [2-3]. The micro tool can be reused to generate various holes and shapes with a single tool [4][6].

2. EXPERIMENTAL SETUP FOR TOOL FABRICATION
A schematic diagram of tool fabrication experimental process is shown in figure 1. The fabrication tool setup is made of iron frame in which machining chamber is forms of a beaker. A dummy block is placed below the machining chamber for

easy and quickly adjustment of the tool dipped height[5].

The machining chamber filled with electrolyte. Two electrode wires are dipped into the electrolyte. One electrode is connected with positive terminal and another electrode is connected with negative terminal. The gap between the electrode and depth to which electrodes are dipped into electrolyte is adjustable by using lead screw. Voltage supply is connected after preparation the complete setup. Desired tool shape is obtained with applying the voltage.

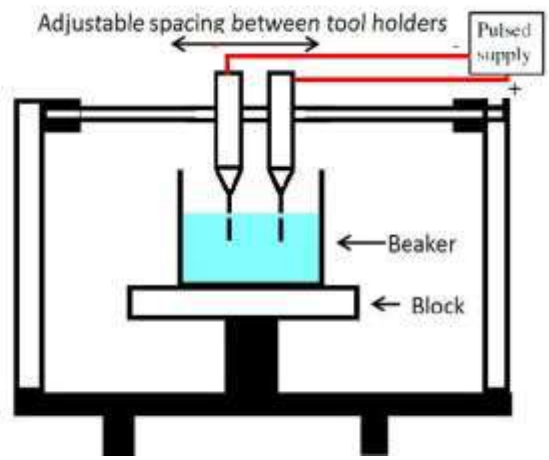

Fig. 1 ECMM Tool Fabrication Setup

3. CHEMICAL REACTIONS

Metal dissolution occurs with the electrode which is connected with the positive terminal and acts as anode terminal.

At the anode, Cu leaves 2e− and converted into Cu++. Water dissociates into (OH)− and H_2 which is liberated at cathode. Cu++ combines with 2(OH)− to form black bluish precipitates of $Cu(OH)_2$. Since other electrode is Cu with -ve potential applied, Cu ions are not formed and hence it is different from electroplating. However, if $CuSO_4$ is added to electrolyte solution, it dissociates into Cu++ and these ions are attracted to Cu electrode which leads to electroplating. Hence, process used in the experiment is ECMM which is different from electroplating[3].

Following reactions take place at cathode and anode.

At anode: $Cu \rightarrow Cu^{++} + 2e^-$ (dissolution of anode)

At cathode: $2H_2O + 2e^- \rightarrow H_2 \uparrow + 2(OH)^-$ (electrolysis)

In solution: $Cu^{++} + 2(OH)^- \rightarrow Cu(OH)_2 \downarrow$ (reaction product)

Black bluish precipitates of $Cu(OH)_2$ are formed into the electrolyte solution.

4. MACHINING PARAMETER

The experiment conducted with the following condition.

Power supply	DC
Voltage	6 Volt, 10 Volt
Concentration	30 gm/lit
Electrode wire material	Copper
Electrolyte	$NaNO_3 + H_2O$

5. VARIATION IN MRR WITH TIME AND CHANGE IN TOOL DIAMETER

Variation in the wire diameter depends on the machining time. With increase in machining time wire diameter also decrease. Initial diameter (D_2) is known and diameter (D_1) at every 5 minutes (T) interval is measured by USB digital microscope. The magnification of microscope can be adjusted manually in the range of 50x to 500x. Different values of diameter readings at different places are taken at any particular instant of time and average value of diameter is taken into consideration. Average amount of volume removed from wire is calculated as:

$$V = \frac{\pi}{4} \times (D_1^2 - D_2^2) \times L \qquad (1)$$

Where, L is the length of electrode dipped in electrolyte, D_2 is initial diameter of wire and D_1 is diameter of wire at time (t). Since total time taken (t) to reach wire at radius D_1 is known and hence average MRR can be calculated by:

$$\text{Material Removal Rate} = \frac{V}{t} \qquad (2)$$

Table 1 observation of variation of diameter & MRR with time

S. No.	Time (min.)	10 Volt				6 Volt			
		Average Dia. (mm)	Change in Dia. (mm)	Material Removed (mm^3)	MRR (mm^3/min)	Average Dia. (mm)	Change in Dia. (mm)	Material Removed (mm^3)	MRR (mm^3/min)
1	0	1.4	0	0	0	1.4	0	0	0
2	5	1.32	0.08	0.126	0.025	1.36	0.04	0.025	0.005
3	10	1.26	0.14	0.385	0.038	1.28	0.12	0.226	0.023
4	15	1.03	0.37	2.687	0.179	1.11	0.29	1.32	0.088
5	20	0.85	0.55	5.937	0.297	0.96	0.44	3.04	0.152
6	25	0.68	0.72	10.174	0.407	0.79	0.61	5.842	0.234
7	30	0.54	0.86	14.515	0.484	0.63	0.77	9.309	0.31
8	35	0.49	0.91	16.251	0.464	0.58	0.82	10.557	0.302

6. RESULT & DISCUSSION

Variation of average material removal rate (MRR) with time is shown in Fig.2. At the beginning of ECM, resistance offered is more because of presence of oxidation layer and dust particles at surface, hence MRR is low initially. As dissolution time (t) increases, the resistance offered decreases. Since voltage is kept constant throughout the experiment, by Ohm's law (V = IR), as resistance decreases, current (I) increases. By Faraday's laws of electrolysis as current increases, MRR increases which is shown by curve in Fig.2.

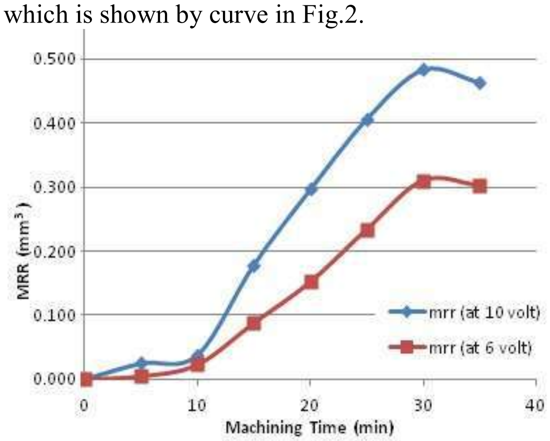

Fig. 2 Graph between Material Removal V/S Machining Time

At higher time of dissolution, MRR tries to decrease slowly before the anode completely dissolves into the solution. Since diameter is very small (60-80 μm) at the end of machining, surface area of electrode decreases. By relationship, R=ρ×L/A, resistance increases. Keeping voltage constant and by Ohm's law, current decreases and hence by Faraday's laws of electrolysis, MRR decreases which is shown by the curve in Fig.2.

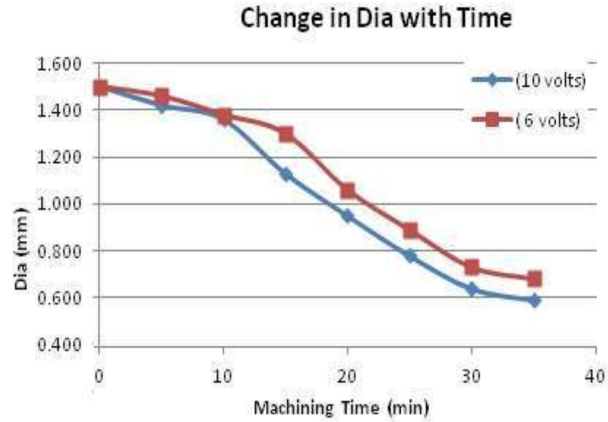

Fig 3: Variation of diameter with time

Photographs of fabricated different straight micro electrodes are given in Fig.4. In some experiments, a slight taper is observed at the tip which is further reduced by increasing dipped length (L) in electrolyte.

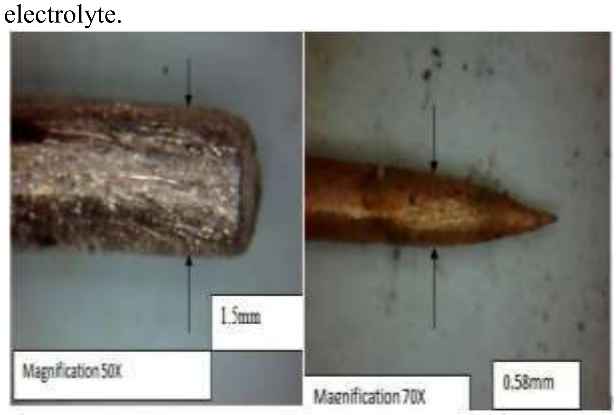

Fig. 4 Tool fabrication at 6 volt 30gm/lit $NaNO_3$ electrolyte concentration (a) Anode copper wire before machining (b) Anode copper wire after machining

7. CONCLUSION

Following conclusions are made from the present work:

1. The designed setup can be used for making micro tools and with the fabricated tool, machining of desired work piece (μ-holes and μ-channels) can be done. The minimum diameter straight tools of 50 μm have been fabricated using the present setup.
2. MRR increase with increasing the dropped height in the electrolyte.
3. Without changing the setup and tool position, the same fabricated straight tools can be used in hole drilling in mass production industries. It will maintain its positional accuracy.

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