

INFLUENCE OF PROCESS PARAMETER ON HOLE SIZE IN MICRO DRILLING USING ECM PROCESS

R.Karthik

Dhanalakshmi Srinivasan College of Engineering, Coimbatore, Tamil Nadu, INDIA

R.Arul

Dhanalakshmi Srinivasan College of Engineering, Coimbatore, Tamil Nadu, INDIA

N.Karthick

Dhanalakshmi Srinivasan College of Engineering, Coimbatore, Tamil Nadu, INDIA

Abhijith Prasad

Dhanalakshmi Srinivasan College of Engineering, Coimbatore, Tamil Nadu, INDIA

Sunil Kumar

Babu Banarasi Das University, Lucknow (U.P.) India

Abstract.

The increasing demand for compactness and more wide variety of functional capabilities in each merchandise these days have made manufacturers to try for newer machining techniques. Different styles of micro-machining strategies are used for producing miniature elements and additives. Micro machining refers to material removal from 1 μm to 999 μm . Electrochemical machining is able to machining a wide variety of electrically conductive materials which include tough and difficult-to-machine materials. This non-contact micro-fabrication process does no longer set off residual stress or cause device tool wear. When applied to produce micro-operations, it's far referred as electrochemical micro-machining (EMM). In this experiments it has been performed to analyze the impact of voltage on response parameters like material removal rate and shape accuracy of EMM process. Micro-holes were drilled on stainless steel-304 plate and a strip of composite material the usage of stainless-steel electrode of diameter 380 μm with insulated walls as tool. The experiments have been conducted varying the voltage while maintaining input parameters like current, pulse on/off time, electrolyte and electrolyte concentration at a steady level. The outcomes have been as compared and studied.

Key words: Micro-ECM, Voltage, SS-304, Composite, Machining Rate and Over Cut

1. INTRODUCTION

When conventional machining processes are applied in the micro-fabrication range many problems are caused such as heat generation at the tool-workpiece interface, rigidity of the tool, tool wear. Hence many non-conventional machining techniques like Electro discharge machining (EDM), Electro chemical machining(ECM), Electron beam machining (EBM), Laser beam machining (LBM) and many other combinations of these methods are tried in industries. Electrochemical micromachining which has many inherent advantages in one of the popular micromachining techniques [1].

1.1 Principle of Electrochemical Machining

Electrochemical machining is also called as a reverse-electro plating process. In this method the work piece to be machined is kept as anode and the machining tool is made the cathode with a salt solution flowing around the electrodes as electrolyte completing the electrolytic cell. The tool and the work piece are located in such a way to have a gap between them. The tool shape is the exact inverse of the feature to be machined. Hard and electrically conductive materials can be machined to required shape electrolytically by using ECM as the process involves only anode dissolution method & the rate of machining does not depend on the hardness of materials. Principle of Faraday's law of electrolysis governs this process.

2. EXPERIMENTAL SETUP

2.1 Various Units of Machining Setup

The machining set-up of micro-ECM consists of various sub units like Machining Chamber, Work holding platform, Tool feeding device, Control system, Electrolyte Recirculation System with filter and D.C Pulse Power System.



Fig:1 Machining set up of micro-ECM

3. EXPERIMENTAL DETAILS

3.1 Calculation

Machining Rate = Thickness of the specimen / Time taken for machining

Overcut = Radius of the tool electrode – Radius of the hole drilled

3.2 Machining SS-304

Experiments have been conducted in the micro-ECM setup to observe the process and its performance. Work Piece Material: Stain diameter less Steel (SS-304, 100 μm thickness as Anode), Tool Material : Stainless Steel (380 μm dia., 50 mm length as Cathode), Sodium Nitrate powder was mixed with distilled water to prepare electrolyte. Machining Parameters are:

Electrolyte	: Aqueous solution of Sodium Nitrate (NaNO_3)
IEG	: 40 Micrometers
Voltage Levels	: 5 to 9 Volts

Current : 1 Amp
 Electrolyte Concentration: 25 gm/Lit

Table : 1 Experimental readings for machining SS-304

S.No	Voltage (V)	Electrolyte Concentration (gm/lit)	Pulse Time (ms)		Hole Radius (µm)	Machining Rate (µm/s)	Radial overcut (µm)	Machining Time (in sec)
			ON	OFF				
1	5	25	17.5	2.5	270.85	0.0944	80.85	1059.2
2	6	25	17.5	2.5	310.9	0.1125	120.9	888.6
3	7	25	17.5	2.5	312.26	0.1357	122.26	736.6
4	8	25	17.5	2.5	350.34	0.161	160.34	621
5	9	25	17.5	2.5	375.86	0.2304	185.86	434

3.3 Machining Composite:

Workpiece : Al7075-87%+Al₂O₃-6%+Borosilicate Glass powder-7% (400 µm thickness)

Tool : Stainless Steel electrode

Electrolyte : Aqueous solution of Sodium Nitrate (NaNO₃)

IEG : 40 Micrometers

Voltage Levels : 5 to 9 Volts

Current : 1 Amp

Electrolyte Concentration : 25 gm/Lit

Below 10V there was no machining for a long time and hence it was kept as the minimum level and increased 12V gradually.

Table : 2 Experimental readings for machining composite

S.No.	Voltage (V)	Pulse Time (ms)		Electrolyte Concentration (gm/lit)	Machining Time (in sec)	Hole Radius (µm)	Machining Rate (µm/s)	Radial overcut (µm)
		On	Off					
1	10	17.5	2.5	25	2016	420.35	0.0950	230.35
2	11	17.5	2.5	25	1943	457.46	0.1141	267.46
3	12	17.5	2.5	25	1722	340.33	0.1270	150.33

4. RESULTS AND DISCUSSION

4.1 Effect of Voltage on Machining Rate and Overcut:

Machining Rate: Figure shows the influence of voltage machining rate. When voltage is increased ions from the workpiece are removed forcibly. Machining voltage is a major factor in controlling material removal rate and they have a direct relationship. The trend is same for both SS-304 and the Composite.

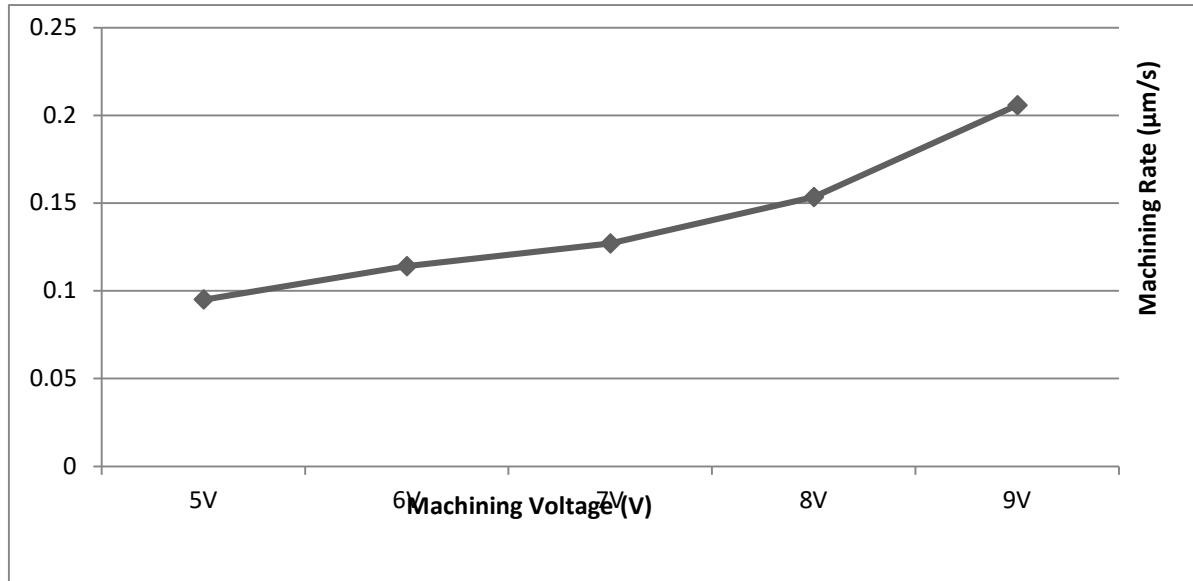


Fig: 2 Effect of Machining Voltage on Machining Rate (SS-304)

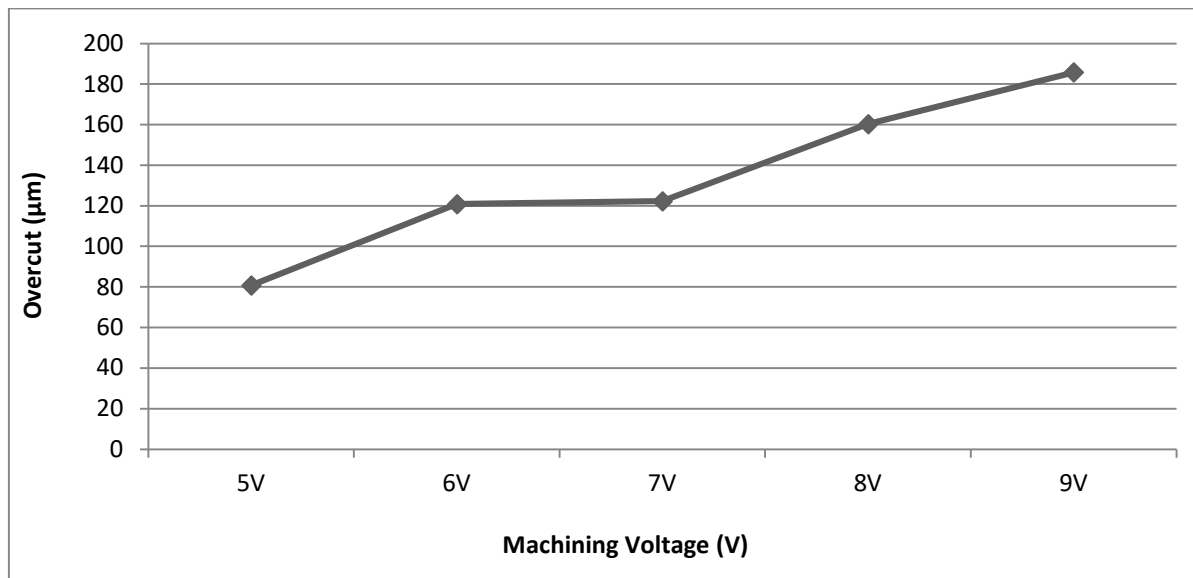


Fig: 3 Effect of Machining Voltage on Overcut (SS-304)

Overcut: Overcut is one of the indicators of machining accuracy. Generally voltage has a negative influence on overcut for any material as increase in voltage increases stray cut around the hole. But

in case of composite workpiece the overcut shows a decreasing trend from 11V to 12V. This is due to new insulation coating given on side walls of the tool. As thinning of insulation on side walls of tool may also cause stray cut, new coating is given after two or three machinings. Sledge formation between electrode gap also causes overcut and during pulse off-time it is removed from the gap thus making pulse on/off time a major controlling factor.

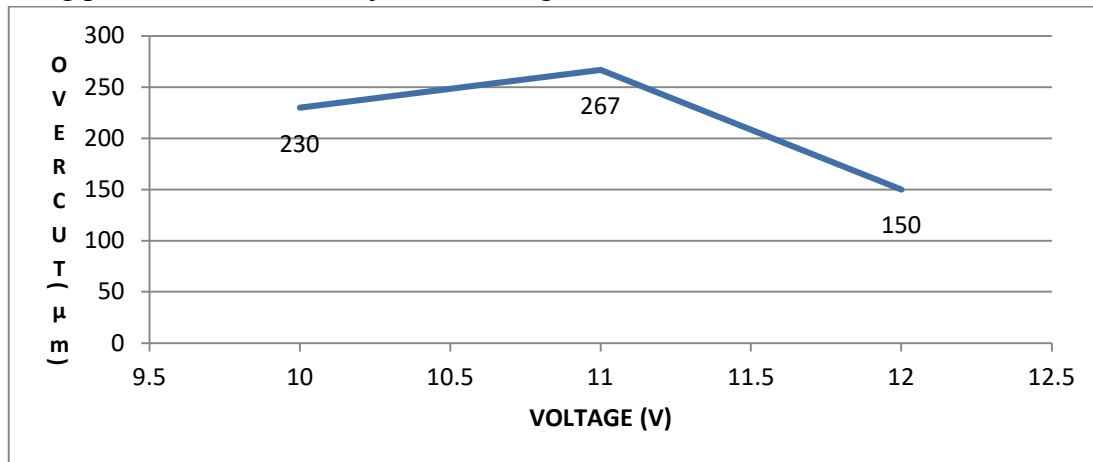


Fig: 4 Effect of Machining Voltage on Overcut (Composite)

4.2 Comparison: The initial level of machining voltage differs from material to material. In case of SS-304 it was 5V and for the composite 10V. It is due to the fact that the composite is inhomogenous and contains different materials with different ionic dissolution rate electrochemically.

4.2 Micrograph of the drilled hole:

The figure shows optical microscope image of drilled hole.

Machining Voltage 9V, Pulse On-Time 17.5ms, Electrolyte Concentration 25gm/l

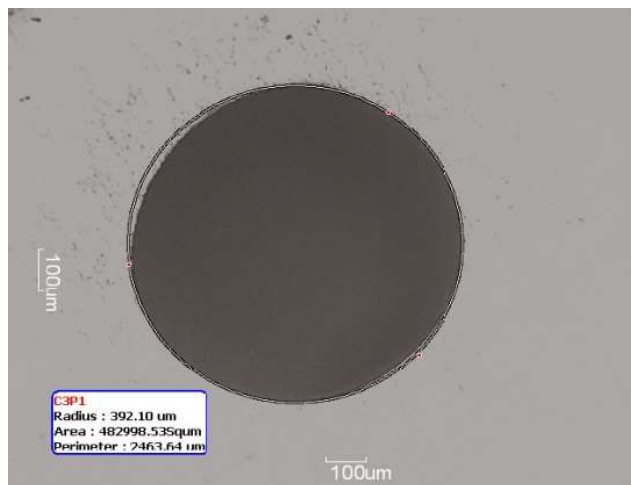


Fig: 5 Micrograph

5. CONCLUSION

The electrochemical micromachining experiments conducted on two different materials show that the range of input parameters differ from material to material and have to be decided for specific

materials only by conducting preliminary experiments. Electrochemical micromachining of composite materials would require further research on a wide range of materials and compositions to optimize various inputs for a specific material that affect the performance of the machining process.

REFERENCES

1. Rajurkar K.P., Levy G., Malshe A., Sundaram M.M., McGeough J., Hu X., Resnick R., DeSilva A. Micro and nano machining by electro-physical and chemical processes. *CIRP Ann.-Manuf. Technol.* 2006;55:643–666.
2. Jo C.H., Kim B.H., Chu C.N. Micro electrochemical machining for complex internal micro features. *CIRP Ann.-Manuf. Technol.* 2009;58:181–184.
3. D'Urso G., Giardin C., Quarto M., Maccarini G. Cost Index Model for the Process Performance Optimization of Micro-EDM Drilling on Tungsten Carbide. *Micromachines.* 2017;8:2514.
4. Wang C.J., Chen G., Luan D., Zhang P. Effect of Laser Power on the Quality of Drilled Micro Hole Using $\text{Cu}_{50}\text{Zr}_{50}$ Amorphous Alloys Foils. *Micromachines.* 2014;5:1061–1068.
5. Schuster R., Kirchner V., Allongue P., Ertl G. Electrochemical micromachining. *Science.* 2000;289:98–101.
6. Kim B.H., Park B.J., Chu C.N. Fabrication of multiple electrodes by reverse EDM and their application in micro ECM. *J. Micromech. Microeng.* 2006;16:843.
7. Lee E.S., Baek S.Y., Cho C.R. A study of the characteristics for electrochemical micromachining with ultrashort voltage pulses. *Int. J. Adv. Manuf. Technol.* 2007;31:762–769.
8. Ryu S.H. Micro fabrication by electrochemical process in citric acid electrolyte. *J. Mater. Mach. Technol.* 2009;209:2831–2837.
9. Yong L., Zheng Y., Yang G., Peng L. Localized electrochemical micromachining with gap control. *Sens. Actuators A Phys.* 2003;108:44–148.
10. Liu G., Li Y., Chen X., Ma X., Zhu X. Side-Insulation of Tool Electrode and Application in Micro ECM. *Electromach. Mould.* 2009;4:28–31.
11. Park B.J., Kim B.H., Chu C.N. The effects of tool electrode size on characteristics of micro electrochemical machining. *CIRP Ann.-Manuf. Technol.* 2006;55:197–200.
12. Wang J., Chen W., Gao F., Han F. A new electrode sidewall insulation method in electrochemical drilling. *Int. J. Adv. Manuf. Technol.* 2014;75:21–32.
13. Kim B.H., Na C.W., Lee Y.S., Choi D.K., Chu C.N. Micro electrochemical machining of 3D micro structure using dilute sulfuric acid. *CIRP Ann.-Manuf. Technol.* 2005;54:191–194.
14. Liu Y., Cai H., Li H. Fabrication of micro spherical electrode by one pulse EDM and their application in electrochemical micromachining. *J. Manuf. Process.* 2015;17:162–170.

15. Ahn S.H., Ryu S.H., Choi D.K., Chu C.N. Electro-chemical micro drilling using ultra short pulses. *Accuracy Eng.* 2004;28:129–134.
16. Wang M.H., Zhu D., Xu H.Y. Use of Micro-helix Electrodes in Improving Performance of Micro-ECM. *Mech. Sci. Technol.* 2006;3:024.
17. Liu Y., Huang S.F. Experimental Study on Electrochemical Drilling of Micro Holes with High Aspect Ratio. *Adv. Mater. Res.* 2014;941:1952–1955.