Electrochemical Discharge Machining Process of Pyrex Glass with Workpiece Vibration

X. Kang, J. Wu, J. Zhu, W. Zhao
State Key Laboratory of Mechanical System and Vibration, School of Mechanical Engineering, Shanghai Jiao Tong University, China

xmkang@sjtu.edu.cn

Abstract

Electrochemical Discharge Machining (ECDM) is a promising micromachining method to process non-conducive materials such as glass and ceramic. In this paper, a new ECDM machining method with workpiece vibration is proposed, and the effect of workpiece vibration on ECDM machining performance is studied. By comparing of the diameters, roundness and depths of the holes machined by common ECDM and ECDM with workpiece vibration, it could be found that workpiece vibration can improve the shape accuracy and machining efficiency.

1 Introduction

Microcrystalline glass is widely used in microelectronic systems and microelectronic mechanical systems for its characteristics of high temperature resistance, corrosion resistance, transparent, insulation and the ability of anode joint with the silicon. In the industrial field, microcrystalline glass can be used in optical fibre micro-porous, medical implantable components or drug transport part, micro chemical reactors, micro nozzles and optical lenses.

Electrochemical discharge machining (ECDM) is a kind of non-conventional machining method which combines the technologies of electrical discharge machining (EDM) and electrochemical machining (ECM). Though ECDM can be traced back to the middle of 19th century, it was until the last 20 years that ECDM attracted lots of research interests due to its ability of machining non-conducive brittle materials.

When the machining depth is beyond a certain depth (typically 300μm), ECDM become difficult because of the shortage of the electrolyte in the gap between the tool and the workpiece. Chih-Ping Cheng utilized a magnetic field-assisted method to improve the ECDM micro-hole drilling performance. R. Wüthrich added vibration to the tool electrode in the gravity-feed ECDM micro-hole drilling process. The experimental result showed by adding vibration to the tool electrode with amplitude of 10μm and frequency of a few Hz, the machining time of gravity-feed ECDM could be reduced by half. This method, however, needs a set of complex facilities to realize tool vibration.

This paper proposed a new method in which the workpiece was fixed on a high frequency vibration table. By using this method, it would be easier to evacuate the machining debris from the machining zone and to refresh the electrolyte in the machining gap between the workpiece and tool electrode.

2 Experimental set up and procedure

2.1 Experimental set up

The experiment setup was based on a micro-EDM machine tool which was designed and developed by our laboratory. The travel ranges of three-axis precision servo are 200mm×120mm×100mm and the resolution of each servo axis is 0.1 μm. The electrolyte working slot was fixed to the high-frequency vibration table, thus, the vibrating action was applied directly on the electrolyte solution rather than the tool electrode. Figure 1 shows the schematic of the ECDM with wokpiece vibration.

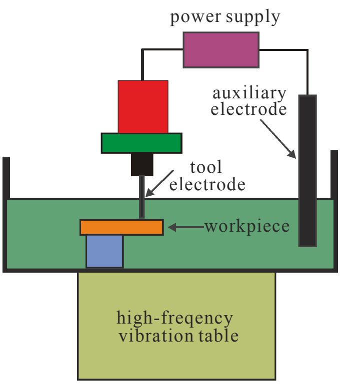


Figure 1: Schematic of ECDM with workpiece vibration

The high frequency vibration table includes three parts: the voice coil motor, the vibration table structure and the vibration flat diaphragm. The voice coil motor has the advantages of small size, low weight, and quick response, and it can also acquire high acceleration and high speed oscillation. Table 1 lists the ECDM machining parameters with workpiece vibration.

Table 1: Machining parameters of ECDM with vibration

Tool electrode	Tungsten , diameter:500μm
Auxiliary electrode	Graphite
Electrolyte	NaOH (30%wt)
Workpiece	Pyrex glass with a thickness of 1mm

2.2 Experiment procedure

The experimental results showed that the vibration table can work steadily when the frequency was 100Hz or 300Hz. At the frequencies of 100Hz or 300Hz, the vibration amplitudes of the worktable under different currents were measured by KEYENCE LK-G30 sensor. The results are listed in Table 2.

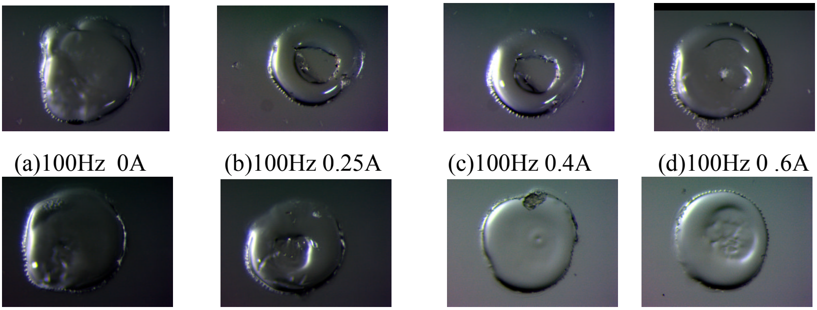
Table 2: amplitudes in different current values in condition of 100Hz and 300Hz

100Hz	current value (A)	0.1	0.2	0.25	0.3	0.4	0.5	0.6
	Amplitude (μm)	1.4	4.4	7.3	10.5	14.1	18.6	22.1
300Hz	current value (A)	0.1	0.2	0.25	0.3	0.4		
	Amplitude (μm)	1.2	3.1	5.5	7.2	8.3		

In the machining process, the Pyrexglass workpiece was fixed in the working slot and the electrolyte level was 2mm high above the workpiece. The tip of the tool electrode located 100μm above the Pyrex glass workpiece and the tool electrode conducted the feeding motion with a speed of 5μm/s after the high frequency vibration table and the pulsed power supply was open. The machining process was maintained for 150 seconds for each hole with different current values. The machining voltage was 45V, 500Hz and 50% duty cycle ratio.

3 Result and discussion

The machined holes were observed by stereo microscope and the diameter of each holes were measured. The measuring result indicated that the vibration can decrease the hole diameter from 700μm to about 600μm. This result showed that the vibration helped the machining debris ventilate from the machining gap, which inhibited sidewall discharge to some degree. The roundness of the holes was also improved, because the vibration increased the stability of discharge machining. Figure 2 shows the photographs of the machined holes under different machining conditions.



(a)100Hz 0A (b)100Hz 0.25A (c)100Hz 0.4A (d)100Hz 0 .6A

(e)300Hz 0A (f)300Hz 0.2A (g)300Hz 0.25A (g)300Hz 0. 3A

Figure 2: Holes under different workpiece vibration parameters

From the experimental result, it can be seen that the optimal vibration condition was a vibration frequency of 300Hz and a current of 0.3A current (7.2μm).

Acknowledgement:

This paper is supported by National Natural Science Fund of China under grant number 51175336.

References:

[1] Rolf Wüthrich, Philippe Mandinb. Electrochemical discharges—Discovery and early applications. ElectrochimicaActa, 2009, Vol. 54 : 4031 – 4035 Zhi-Ping

[2] Zheng, Kun-Ling Wu， et al. Feasibility of 3D Surface Machining on Pyrex Glass by Electrochemical Discharge Machining (ECDM). AEMS07, Nagoya Nov. 2007: 28-30.

[3] M Jalali, P Maillard, and R Wüthrich. Toward a better understanding of glass gravity-feed micro-hole drilling with electrochemical discharges, J. Micromech. Microeng., **19** (2009) 045001 (7pp)

[4] Chih-Ping Cheng, Kun-LingWu, et al. Magnetic field-assisted electrochemical discharge machining, J. Micromech. Microeng. 20 (2010) 075019 (7pp)

[5] Wüthrich, B Despont, P Maillard and H Bleuler. Improving the material removal rate in spark-assisted chemical engraving(SACE) gravity-feed micro-hole drilling by tool vibration, J. Micromech.Microeng. 16 (2006) N28–N31