An innovative approach to improve surface quality using hybrid micro-EDM and micro-ECM

M.D. Nguyen, M. Rahman, Y.S. Wong
National University of Singapore (NUS), Singapore

dang@nus.edu.sg

Abstract

Micro-EDM is an advantageous machining process for micro-fabrication. However, it generates uneven surfaces due to the overlapping discharge craters. This paper presents an innovative approach to improve the surface finish of fabricated micro-shapes by combining micro-EDM and micro-ECM in the same process. A significant reduction of surface roughness ensuing from material dissolution is demonstrated by the experimental results. Micro-holes and micro-shapes with mirror-like surface, less than 20nm R_a, are produced.

1 Introduction

Micro-EDM is highly feasible for micro-fabrication owing to its negligible cutting force and high machining accuracy. However, the machined surface is uneven due to the overlapping of discharge craters [1]. Furthermore, it also undergoes thermally-damaged layers such as white layer and heat affected zones. Those inherent properties inhibit the capability of micro-EDM for micro-tooling production in which surface finish is a crucial factor. This paper presents a novel hybrid micro-EDM and micro-ECM process to enhance surface quality of fabricated micro-shapes. In this method, electrical discharge and electrochemical reaction could occur in the same process by exploiting deionized water in a new perspective. Experiments are performed to identify the feasibility of this hybrid process.

2 Principle of simultaneous micro-EDM and micro-ECM (SEDCM)

To combine micro-EDM and ECM in the same process, the fluid used must provide enough dielectric strength for sparks and sufficient conductivity for electrochemical reaction. To fulfil these requirements, this study uses deionized water with low resistivity. When the process begins, the short voltage pulses are supplied to the electrode and workpiece. Then, the electrode goes down to reduce the machining gap (Fig. 1a). When the gap reaches the critical value, the sparks occur as shown in Fig. 1b. Material is removed from the workpiece by melting and vaporization. Hence, the surface is covered with overlapped discharge craters and it is rather rough. Due to the material removal by the sparks, the gap width between electrode and workpiece increases. With the supplied voltage pulses, the electrochemical reaction occurs owing to the slight conductivity of deionized water (Fig. 1c). Material is dissolved from the workpiece and its surface roughness decreases. Thanks to the usage of short voltage pulses, the dissolution of material is localized within a certain distance which is marked with dotted line. After a second, the electrode is lowered down further and the process repeats the cycle (Fig. 1d).

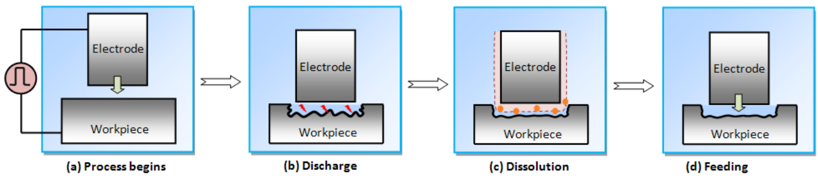

Figure 1: Principle of SEDCM

3 Experimental details

The experiments were carried out on the DT-110 machine tools using ∅75µm tungsten electrode. The SUS304 workpiece has 100µm thickness. To generate short voltage pulses, an in-house developed short pulse generator is used. The main machining conditions are summarized in Table. 1.

Table 1: Machining conditions

Dielectric fluid	Deionized water 0.4MΩcm
Voltage (V)	60
Resistor (Ω)	220
Capacitor (pF)	265
Frequency (kHz)	0 (DC regime), 100, 300, 500
Duty cycle (%)	from 15% to 70%
Tool rotation (rpm)	500
Feedrate (µm/s)	from 0.2 µm/s to 10 µm/s

4 Results and discussions

Fig. 2a shows the micro-hole fabricated by conventional micro-EDM whereas Fig. 2b exhibits the hole machined by SEDCM using 500kHz pulses with 30% duty cycle. In Fig. 2a, the micro-hole surface is observed to be covered by overlapped discharge craters; especially, the recast material can be visibly seen at its rim. On the contrary, the lateral surface of micro-hole machined by SEDCM is found to be smooth and free of crater (Fig. 2b). This shows that SEDCM could yield better surface finish because the uneven material layer generated by micro-EDM is dissolved by the electrochemical reaction. As a result, the diameter of hole generated by SEDCM is slightly larger than that of hole generated by conventional micro-EDM. This is in accordance with the experimental results: the machining gap of SEDCM is around 8μm while it is less than 6μm for conventional micro-EDM.

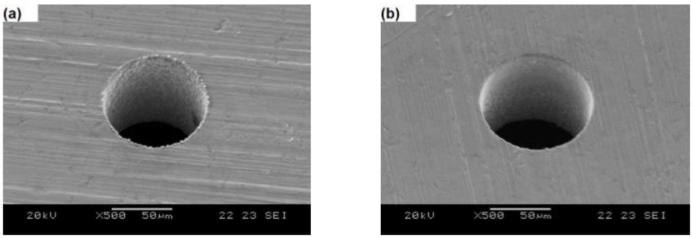

Figure 2: Micro-holes fabricated by conventional micro-EDM (a) and SEDCM (b)

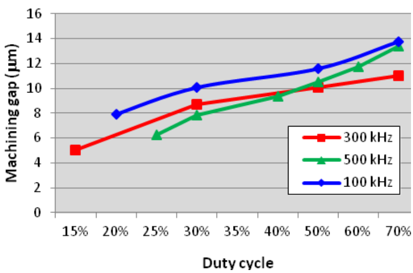

Figure 3: Variation of machining gap corresponding to different pulse parameters

In order to investigate the effect of different pulse parameters, the experiments were performed using pulses with different frequencies of 100, 300 and 500 kHz. It is observed that with smaller duty cycle, the diameter of micro-hole tends to decrease.

Similarly, at higher frequency used, the micro-holes are also smaller. This can be seen with the reduction of machining gap in Fig. 3. This phenomenon can be explained by using the double-layer model [2]. The smaller the machining gap, the better the accuracy. Hence, this confirms that short voltage pulses are effective in localizing material dissolution whereby the machining accuracy could be attained.
To investigate the enhancement of surface finish, triangular micro-cavities are fabricated as shown in Fig. 4. In case of conventional micro-EDM (a), overlapping discharge craters with 3-4 μm diameter could be seen on the machined surface. On the contrary, a relatively smooth surface with no visible crater is obtained by using SEDCM (b). In case of conventional micro-EDM, the R_a is around 175nm whereas it is only less than 20nm for SEDCM. This demonstrates that SEDCM could produce micro-shapes with better surface quality.

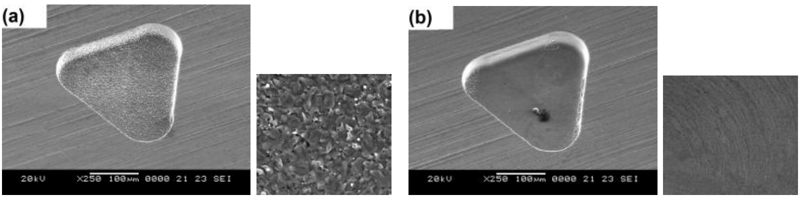

Figure 4: Micro-cavities fabricated by conventional micro-EDM (a) and SEDCM (b)

5 Conclusions

The following conclusions can be drawn from this study:

a. Micro-EDM and ECM could be combined by using low-resistivity deionized water.
b. SEDCM could enhance the surface finish of fabricated micro-shapes.
c. Short voltage pulses are effective in localizing the material dissolution zone and improve the dimensional accuracy of SEDCM.

References:

[1] W. Kurnia et al., Surface roughness model for micro electrical discharge machining, *Proc. Inst. Mech. Eng., Part B: J. of Eng. Manufacture* 223:279-287.
[2] R. Schuster et al., Electrochemical Micromachining, Science 289:98-101.