

# Micro Pin Fabrication by ECM with Ultra-low Concentration Electrolyte

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## Abstract

In this study, a method to obtain tungsten carbide pins with diameters from 14 to 60  $\mu\text{m}$  in 11 to 12 min by ECM with ultra-low concentration electrolyte was proposed. In order to improve the machining accuracy, workpiece rotation and ultrasonic washing during machining were adopted. It was found that thinner pins with better axial symmetry were obtained with the rotation and ultrasonic washing.

## 1 Introduction

Tungsten carbide is widely used as the material for micro tools, although it is known as one of the typical difficult-to-cut materials. Grinding processes and electro-discharge machining are generally used in tungsten carbide machining, but the machining speed is slow and tool wear is high. Meanwhile there is no tool wear in electrochemical machining (ECM). Furthermore, metallic material can be machined with ECM regardless of the material hardness. Although tungsten carbide can be machined using sodium hydroxide solution in electrochemical machining [1], the electrolyte is harmful to operators and causes environmental problems, since solid sodium hydroxide or solutions of sodium hydroxide may cause chemical burns, permanent injury or scarring if it contacts unprotected human.

In order to solve these problems and expand its application range, the authors present an environmentally-friendly, high precision and low-cost method of electrochemical micro-machining by using mineral water as an ultra-low concentration electrolyte ( $2.49 \times 10^{-6}$  wt%) [2]. However, the reproducibility of the machining shape is poor for the micro pin fabrication. The main reason is considered to be byproduct in the gap area and the material attached on the pin surface disturbs the flow of the electric current. In this study, the effect of the byproduct removal by means of workpiece rotation and ultrasonic washing was proposed and its effectiveness was experimentally investigated.

## 2 Experimental set-up

The schematic of the system for micro pin fabrication is shown in Figure 1. It consists of an XYZ stage, a rotating spindle and a high-voltage power source required for the high-resistance electrolyte. The workpiece is mounted in the rotating spindle whose position can be controlled in the X, Y, Z directions. A commercially available ultrasonic washing machine is used as the electrolyte tank. Because of ultrasonic washing and rotating spindle effect during machining, the bubbles and other byproducts are effectively removed from the gap area, and the fabrication process becomes stable. Also, the highly precise constant current provided by the power source guarantees the same dissolved mass per unit time. The workpiece rotation improves the pin's axial symmetry. Layout of the micro pin and tool is shown in Figure 2. The workpiece faces the SUS304 tool plate, and the bottom surface of the

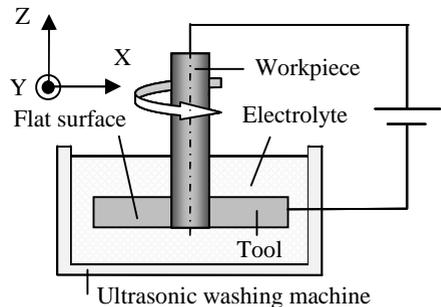


Figure 1: Set-up for fabricating micro-pin

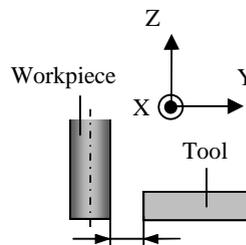


Figure 2: Layout of work and tool

tool and the end of the workpiece lie at the same height. The physical properties of the mineral water used in experiments are shown in Table 1 and the compositions of the mineral water are shown in Table 2.

Table 1: Physical properties of mineral water used in experiments

Electric conductivity [S/m]	0.014
pH	7
Water hardness	33.1

Table 2: Composition of mineral water (mg per 100ml)

Na	1.25
Ca	0.85
K	0.10
Mg	0.29

tool and the end of the workpiece lie at the same height. The physical properties of the mineral water used in experiments are shown in Table 1 and the compositions of the mineral water are shown in Table 2.

## 3 Effect on fabricated shape by rotation and ultrasonic washing

Micro pins were machined with a constant current under the machining conditions shown in Table 3. Experiments under the following four situations were carried out

to investigate the effect of rotation and ultrasonic washing; without rotation and ultrasonic washing, with only rotation, with only ultrasonic washing, and with both rotation and ultrasonic washing. Figure 3 shows the fabricated micro pins under different situations. Though attached products on micro pins reduced due to the workpiece rotation and ultrasonic washing, they were not removed completely. Therefore, ultrasonic washing was conducted again after machining. It is found that the fabricated pin has non-uniform diameters in the cases without the rotation and ultrasonic washing (Fig. 3(a)) and with only rotation (Fig.3 (b)). The reason is thought to be that the current density tends to concentrate on the area with big curvatures, due to the existence of the byproducts in the gap area and the attached products on the pins, thus causing the pin to be machined locally. Even in the situation of non-rotation, the pin was also fabricated at the area which didn't face the tool in shown Figure 3(a).

This is believed to occur as the machining current also flowed in the area with a large gap width. Meanwhile, it can be

observed from Figure 3(c) that this fabricated pin has a more uniform diameter. It shows that the electric current didn't concentrate locally because of the removal of the byproducts by ultrasonic washing.

However, it is found

Table 3: Machining conditions

Electrolyte	Mineral water
Machining current [mA]	50
Machining time [min]	8
Revolution [rpm]	2850
Distance between electrodes [ $\mu\text{m}$ ]	350
Work material	$\phi 300\mu\text{m}$ WC pin
Tool material	t2mm SUS304 plate

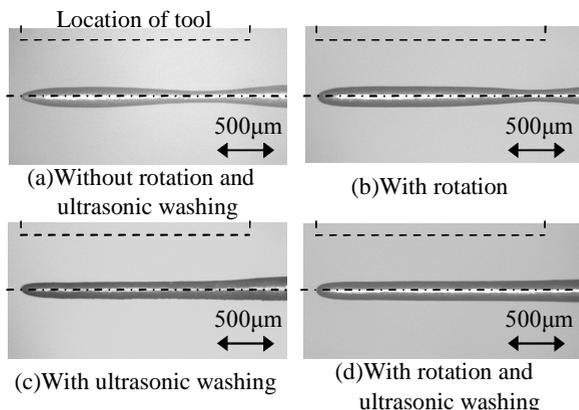


Fig.3 Micro-pin fabricated under each condition

from Figure 3(c) that the pin is a little eccentric to the central line. It is believed that a larger current flowed in the area of the narrow gap width, and the amount of machining was greater here than in other areas. Here, it can be observed from Figure

3(d) with the rotation and ultrasonic washing that the diameter along the central line becomes uniform and the shape becomes more axisymmetric. The decrease of the eccentricity was due to the workpiece rotation and the uniform machining was due to ultrasonic washing.

#### 4 Change in pin diameter with time

According to the preceding section, the localized machining is reduced greatly due to the byproduct removal by workpiece rotation and ultrasonic washing. Thus, it is hoped that the pin diameter can be made much smaller. Hence, the fabrication of the micro pin was carried out by changing the machining time under the machining conditions shown in Table 3. Workpiece rotation and ultrasonic washing were consistently conducted during machining. Figure 4 shows the pin's shape for the machining time of 11.8 min and Figure 5 shows the relation between the micro pin diameter and the machining time. The diameters were measured at the pin's end. It was found that the micro pin was fabricated with no localized machining, although the pin becomes little thinner towards the end. Also, it is found that the pin diameters become smaller in proportion to the machining time. Figure 15 shows that a micro pin with the diameter of 14  $\mu\text{m}$  can be obtained from a 300  $\mu\text{m}$  pin in 11.8 min.

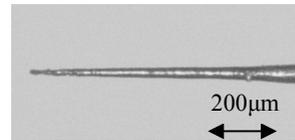


Fig.4 Micro-pin fabricated by machining time of 11.8 min

#### 5 Conclusions

During the micro pin fabrication using mineral water as the electrolyte, micro pins with higher machining accuracy and smaller diameters are obtained by applying workpiece rotation and ultrasonic washing.

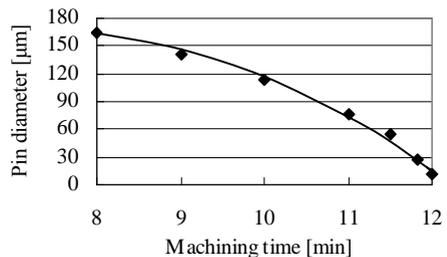


Fig.5 Relationship between machining time and pin diameter

#### Reference:

- [1] Masuzawa, T., Kimura, M., 1991 Electrochemical Surface Finishing of Tungsten Carbide Alloy, *Annals of the CIRP*,40/1:199-202.
- [2] Ye Yang, Wataru Natsu, Wansheng Zhao, Realization of eco-friendly electrochemical micromachining using mineral water as an electrolyte, *Precision Engineering* 35(2011)204-213.