Study on Sensitivity of Gap-width Detection with Peak Current in Pulse ECM

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Abstract

The gap-width in pulse electrochemical machining (ECM) was detected by measuring the peak current generated in response to the applied pulse voltage, and the influence of the machining conditions on the detection sensitivity were investigated. It was found that the sensitivity was increased by using a lower concentration of electrolyte and electrolyte height. In addition, the experiment showed that the sensitivity can be maintained with the frequent removal of by-products from the gap area.

1 Introduction

It is generally known that good machining performance, such as high machining accuracy and machining speed, are obtained by using a pulsed power supply in electrochemical machining (ECM), rather than a conventional DC power supply. However, the detection and control of the gap-width in pulse ECM has not yet been realized for practical use. Although some techniques for gap-width detection in pulse ECM have been proposed [1-3], most have not reached the stage of practical use because of their complexity and low detection sensitivity. Herein, we present an easier and more practicable gap-width detection method that involves measurement of the peak current that is generated in response to a pulse voltage [4]. In order to apply this method for practical use, the change in the detection sensitivity with the machining conditions must be determined.

2 Principle of gap-width detection and the experimental device

When a pulse voltage is applied between the tool electrode and the workpiece, the current flows through the circuit with an overshoot signal at the moment of the pulse-rising period [4]. The overshoot is caused by the charging phenomenon of the double layers. Because the peak of the current waveform tends to become larger when the gap-width is shortened, the gap-width can be detected by measuring the peak current.

Figure 1 shows a schematic of the experimental device. In the experiment, two types of voltage pulses are used: a sensing pulse and a machining pulse. Because the sensing pulse is used to detect the gap-width, the voltage is set to a lower value (2V) in order to avoid the dissolution of the workpiece material during detection. The tool electrode is jumped once after a certain number of machining pulses are applied, in order to remove the by-products and the processing heat generated in the gap area. The experimental conditions used in this study are shown in Table 1.

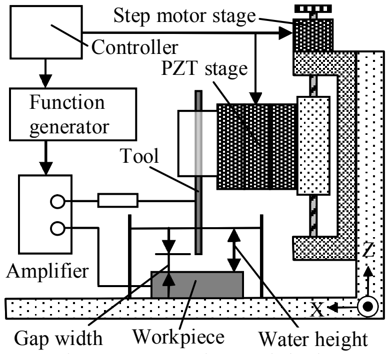

Figure 1: Experimental device

Table 1: Experimental conditions

Tool	W ϕ 300 µm	
Work	SUS plate(t=0.5 mm)	
Electrolyte	$NaNO_3aq$	
Jumping stroke	90 µm	
Pulses per sensing	800 pps	
Pulse type	Sensing	Machining
High level voltage	2 V	10 V
Low level voltage	0 V	2 V
Pulse width	5 µs	60 µs
Pulse period	10 ms	10 ms
Rise/Fall fime	7 ns	7 ns

3 Influence of electrolyte concentration and height

3.1 Influence of the electrolyte concentration

Since the electrolyte resistance changes greatly with its concentration and causes a change in the peak current, the influence of the electrolyte concentration on the detection sensitivity was investigated. In order to eliminate the influence of the by-products and the processing heat, the machining pulses were not applied during this experiment. It was found from Figure 2 that the change in the peak current with the gap-width increases when using a lower concentration of electrolyte, which indicates that the sensitivity of the gap-width detection increases with a decrease in the electrolyte concentration.

3.2 Influence of the electrolyte height

Because a change in the electrolyte height causes a change in the tool surface area in contact with the electrolyte, the influence of the electrolyte height on the sensitivity was investigated. The electrolyte height was set at 2, 3, and 5 mm, and approximately 60 µm. The height of 60 µm was realized by creating a rapid flow of the electrolyte jetted from a nozzle toward the workpiece surface. Based on the results shown in Figure 3, it was found that a higher sensitivity can be obtained by using a lower electrolyte height.

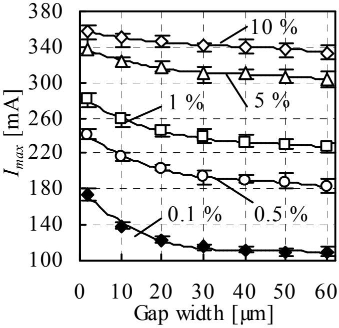

Figure 2: Relationship between the gap-width and I_{max} for different concentrations of electrolyte

4. Influence of the machining process

In the above section, the sensitivity was investigated under conditions without machining. During machining, however, by-products and processing heat generated in the gap area not only decrease the machining accuracy, but also influence the sensitivity of the gap-width detection, because the current distribution is disturbed.

To investigate the influence of machining, a machining pulse was applied during the experiment. The amount of by-products and processing heat in the gap area was adjusted by varying the interval of the tool electrode jump. The jump interval is represented by the number of machining pulses between two jumps, ppj.

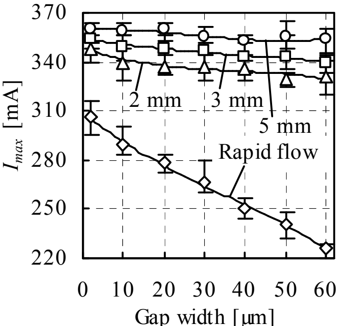

Figure 3: Relationship between the gap-width and I_{max} for different electrolyte heights

First, the tool electrode was set to the position with an initial gap-width of 10 µm. After applying 800 machining pulses, 90 sensing pulses were applied and the gap-width was detected. Once the detected signals indicated that the gap-width had become greater than 16 µm, the machining process was stopped, and the cross section of the machined hole was measured. By observing the machined depth, the change in the sensitivity could be evaluated. The measured cross sections of the machined holes for different jump intervals are shown in Figure 4. As seen in this figure, the depth of the machined holes for jump intervals of 160 and 400 ppj was about 10 µm, which is 4 µm larger than the target value, possibly because of the processing heat caused by the machining. During machining, the temperature rises as a result of generated processing heat, and leads to an increase in the electrical conductivity of the electrolyte, which then causes the detected gap-width to be narrower than the actual gap-width. Therefore, the hole is machined deeper than the target depth. Meanwhile, the machined depth is nearly the same as the target depth in the cases where the jump interval was smaller that 80 ppj. This difference is because the by-products and processing heat were effectively removed from the gap area by the frequent jump movement. Therefore, in order to maintain the detection sensitivity, short jump intervals should be used.

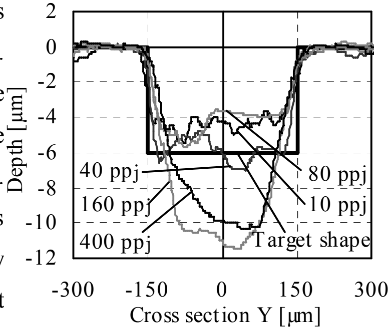

Figure 4: Relationship between the cross section of the holes and the ppj

5 Conclusions

Based on the experimental results, the following conclusions were drawn:

(1) The lower is the electrolyte concentration and the electrolyte height, the higher is the sensitivity.

(2) In order to avoid changes in the sensitivity with machining, the by-products and machining heat should be removed from the gap area frequently

Acknowledgement

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