Proposal of Electrolyte Suction Tool Electrode for Machining Area Confinement and Gap-width Detection

K. Endo, W. Natsu
Tokyo University of Agriculture and Technology, Japan

summer@cc.tuat.ac.jp

Abstract

Since the machining takes place in a wide area where the machining current flows in ECM, it is difficult to confine the machined area. Additionally, in order to feed the tool electrode appropriately during machining, the gap-width detection is necessary. In this research, in order to confine the machining area and detect the gap-width, the tool electrode which is capable of not only circulating electrolyte beneath the tool electrode but also detecting the gap-width by the suction pressure was proposed. It was found the suction pressure indicates the gap-width and the pressure signal can be used to control the tool electrode feed. In addition, the machining area was confined successfully.

1 Introduction

Since the electrochemical machining (ECM) is a contactless and electrochemical machining method, ECM is suitable to machine hard-to-cut materials and the machining force is negligibly small. However, it is difficult to confine the machining area during machining, because machining takes place not only beneath the tool electrode but also around the surrounding area. For this reason, various researches about the tool electrode for a higher machining accuracy have been reported [1-3], although most of them have their drawbacks. On the other hand, the gap-width detection and proper tool feed are necessary to prevent electrical short-circuits during machining and to obtain a higher machining accuracy. In this paper, in order to feed the tool electrode properly, a new type of ECM tool which is capable of not only circulating electrolyte beneath the tool electrode but also detecting the gap-width by measuring the suction pressure was proposed.

2 Experimental setup

In this research, a tool electrode shown in the Fig.1 was designed to circulate the electrolyte just beneath the tool electrode. This tool electrode consists of an inner and an outer cylinder; both of them are made of brass. The electrolyte flows from a narrow aperture formed by the two cylinders, due to the suction through the center hole of the inner cylinder. In this way, the electrolyte is circulated beneath the tool electrode. The tips of both cylinders are tapered to circulate the electrolyte through the whole tip surface of the tool electrode. This enables the machining in the depth direction. The principle of the circulation is shown below: when the tool electrode approaches the workpiece, sectional area of the flow channel becomes narrower. In the narrower flow channel, the air flows faster between the tool electrode and workpiece. This makes the pressure lower between the tool and workpiece. Therefore, the electrolyte is suctioned from the aperture, and starts to circulate. No electrolyte flows towards the outer periphery with this method. In order to decrease an air inflow from outside of the tool, the outer cylinder of the tool is projected from the inner cylinder by 0.05mm. The dimensions of the tool and specifications of the suction pump are shown in Table1 and 2.

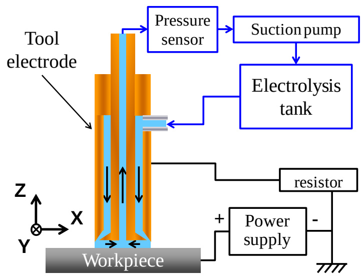

Fig.1 Schematic of experiment device

3 Relationship between the gap-width and the suction pressure

The electrolyte flows from the aperture, runs through the gap, and is suctioned through the hole of the inner cylinder. The cross-section of the flow channel changes with the gap-width. This means the suction pressure varies depending on the gap-width. Thus, the gap-width can be estimated by the suction pressure. From Fig.2, it is found that the suction pressure changes corresponding to the gap-width before machining. In particular, the suction pressure varies greatly when the

Table 1 Tool dimensions

Diameter of outer cylinder	10 mm
Length of outer cylinder	45 mm
Diameter of inner cylinder	9 mm
Diameter of center hole	3 mm

Table 2 Specification of pump

Maximum vacuum	47.99 kPa
Maximum capacity	0.6 L/min

gap-width is smaller than 100 μm. However, in the hole machining, the surface geometry of the workpiece is different from a flat surface. Since the surface geometry of the workipiece affects the flow channel shape, the relationship between the gap-width and the suction pressure may change with the machining process. In order to know the change in the relationship between the suction pressure and the gap-width with the machining process, experiments were performed on the hole machining at various machining depth: 100, 300, 500, 1000 μm. After these experiments, the effect of the machined depth on the pressure-width was investigated by measuring the suction pressure at each condition. The results are also shown in Fig. 2. It is found that, although the pressure-width relationship changes greatly with the machining depth at the first stage, the relationship remains the same after the tool feed is larger than 300 μm.

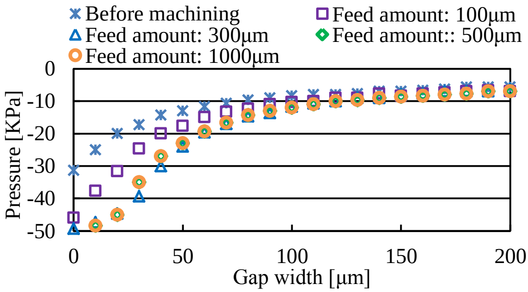

Fig.2 Pressure-width relationship

Table 3 Experimental condition

Tool material	Brass
Workpiece	SUS304
Electrolyte	10 wt% $NaNO_3$ aq
Total feed amount	100, 300, 500, 1000 μm

Table 4 Power parameters

High-level current	15 A
Low-level current	0 A
Pulse width	5 ms
Pulse period	50 ms

4 Investigation of the effectiveness by experiments

4.1 Blind hole machining with feed control

Sequence of a blind hole machining is shown below. Before the machining, a specific suction pressure was set as the threshold value corresponding to the target gap-width. The initial gap-width was then set equal to the target one. After the

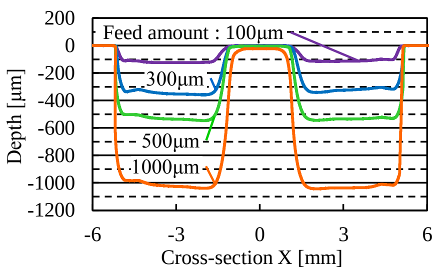

Fig.3 Cross-sectional shape of machined hole

machining current was applied, the tool was fed by 10μm immediately when the suction pressure became larger than the threshold value. This sequence was repeated until the feed amount reached the intended feed amount. In this experiment, the threshold value was set as -12kPa, this value corresponds to the target gap-width of 100 μm. Experimental conditions and power parameters are shown in Table 3 and 4. The cross-sections of machined holes are shown in Fig.3. Since both initial and target gap-width were set as 100 μm, the machined depth should be equal to the tool feed amount if the gap-width was kept to the target one. However, Fig.3 shows the machined depth was deeper than the tool feed amount under all conditions. This is because the by-products existing in the gap. During machining, muddy by-products in the gap caused an increase in the viscosity of the electrolyte. This means a larger suction pressure was needed even at the same gap-width, and thus, the gap-width increased corresponding to the threshold value.

4.2 Evaluation of the machining area confinement

Since the electrolyte is circulated only beneath the tool electrode, the hole diameter is expected not to increase with the tool feed. Therefore, the hole diameter on the workpiece surface was used for evaluation. If machining area is confined successfully, the diameter does not change regardless of the tool feed amount. Fig.4 shows the hole diameter at the each tool feed amount. The hole diameter keeps the same after the amount is larger than 300 μm. The reason for the increase in the first stage is considered to be caused by the bulging of electrolyte due to the bubbles produced in the gap. This fact shows that the machining area is successfully confined by the proposed suction tool.

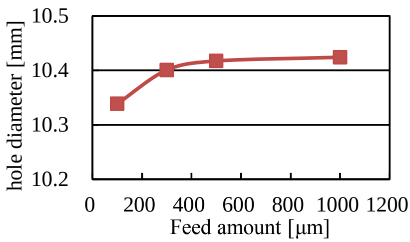

Fig.4 Hole diameter - feed amount relationship

5 Conclusions

In this study, a new type of ECM tool in order to confine the machining area and control the gap-width was proposed. The relationship between the gap-width and the suction pressure was investigated. Then, blind hole machining was performed. It was found that the gap-width can be estimated by measuring the suction pressure. In addition, after feeding the tool electrode to a certain depth, the machining area was successfully confined.

References:

[1] J. Wilson, Practice and Theory of Electrochemical Machining, John Wiley & Sons, (1971), pp. 65

[2] Di Zhu, et al., Design of electrode profile in electrochemical manufacturing process, Annals of CIRP, 52(1), (2003), pp. 169-172

[3] M. Nagano, et al., Figuring of metal mirror substrate by Numerically Controlled Electrochemical machining – Fundamental machining characteristics of coaxial nozzle type tool electrode -, proceedings of JSPE annual meeting, (2012) , pp. 343-344