Electrochemical machining of STS304 using electrode tool fabricated by 3D printing

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1. Introduction

Electrochemical machining (ECM) is a non-contact, special machining process that has the advantage of machining difficult-to-machine materials without wear on electrode tools [1].

However, the heat, slurry, and bubbles generated in the ECM become an impediment to machining [2], In order to increase the machining efficiency, research is being conducted on the method of analysis using simulation, the method of generating ultrasonic wave on the electrode tool during the execution, or the method of increasing the machining efficiency by applying pulses [3].

Since the ECM processes the workpiece according to the shape of the electrode tool, the fabrication of the electrode tool is an important factor for improving the machining efficiency.

Koyano used Selective laser sintering (SLS) to make the electrode tool, and to improve the machining efficiency by removing the projected part of the electrolyte through the porous fabrication on the machining surface of the electrode tool.

The advantage of 3D printing is that you can quickly create the desired geometry through 3D design. Therefore, in this study, electrode tool is fabricated by using 3D printing of fuse deposition modeling (FDM) method. An acrylonitrile butadiene styrene (ABS) material filament was used to fabricate the electrode tool. The ABS material, which is commonly used in FDM, has better heat resistance and strength than poly lactic acid (PLA). However, there is no electric conductivity, which is a necessary condition for ECM. To solve this problem, a metal 3D printer can be used to produce a conductive electrode tool, but the manufacturing cost increases. Lyubimov fabricated an electrode tool with prototyping technology for electrode tool fabrication, and produced an electrode tool with electro conductive properties using galvanic and vacuum deposition on a plastic electrode tool.

In this study, we also compare the machining performance through the ECM using a metal conventional electrode tool and a conductive coated electrode tool.

2. Experimental setup and method

Experiments were conducted to verify the machining performance of silver paste coated electrodes. We also compare the performance of the fabricated electrode tool with that of the copper electrode tool. The diameter of all electrode tool was 5.5mm and the electrolyte-feeding hole was 3mm. The silver paste was applied once, and the portion except the machined portion was coated with insulation. ECM performed experiments through uniaxial transfer using a precision actuator with a resolution of 2μm. The processing conditions are shown in Table 1. The electrolyte solution used in the ECM was an NaNO3 aqueous solution suitable for machining, and the electrolyte temperature was set at about 30℃ using a heat pipe. The workpiece used were STS304 with a size of 25×25mm and a thickness of 5mm. The current density used in the ECM was 6.31, 8.4, 10.5, 12.6, 14.7, 16.8A/cm2 and the on-off time was controlled by applying a pulse to the duty factor of 50%. The gap between the workpiece and the electrode tool is 0.06mm, the target machining depth is 1 mm, and the machining speed is 2μm/s.

Fig. 7 is a schematic of the ECM processing. The electrode tool is the cathode (-) and the workpiece is the anode (+) for the electrochemical reaction. The electrolyte is pumped through the electrolyte-feeding hole of the electrode tool and the electrolyte is reused through filtering.

Table 1 Experimental conditions

Metal electrode	Cu
Conductive coating electrode	Silver paste
Electrolyte	$NaNO_3$
Electrolyte temperature	30℃
Target Machining depth	1mm
Machining speed	2 ㎛/s

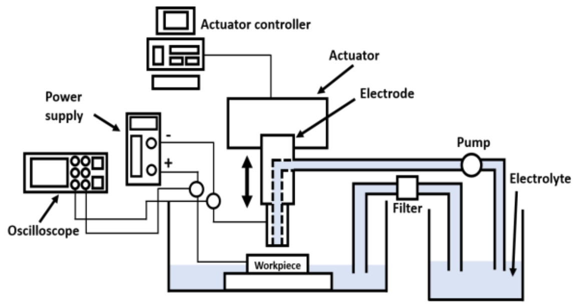

Fig.1 Schematic diagram of electrochemical machining

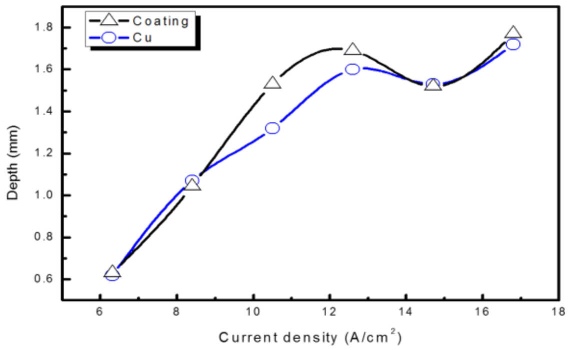

Fig.2 Comparison of machined depth of Cu electrode tool and Coating electrode tool according to current density

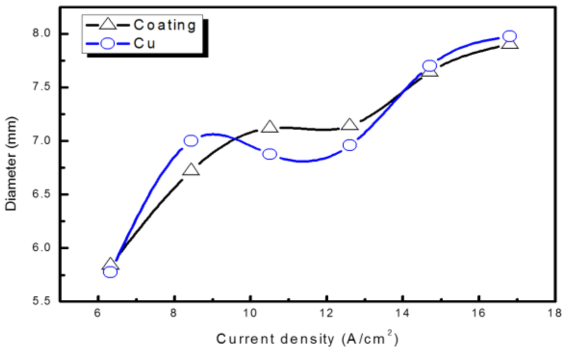

Fig.3 Comparison of machined diameter of Cu electrode tool and Coating electrode tool according to current density

3. Results

The ECM according to the change of the current density was performed using the silver paste coated electrode tool and copper electrode tool. Fig. 8 is a graph showing the depth after ECM of the copper electrode tool and the conductive coated electrode tool with the change of current density. ECM results with copper electrode tool 0.6mm machined at a current density of 6.31A/cm2 and not machined to the target depth. It is machined above the target depth to a depth of 1.32mm at a current density of 10.5A/cm2. Under the experimental condition, the maximum current density of 16.8A/cm2 was applied and the deepest 1.72mm was machined. The result of ECM with the conductive coated electrode tool was machined from 6.31 A/cm2 to 0.53mm and not machined to the target depth. At a current density of 10.5A/cm2, the depth was machined to 1.43mm. At a current density of 16.8A/cm2, the workpiece is machined to 1.67mm and machined beyond the target depth. The experimental results show that at low current density, the depth is not machined to the target machining depth, but as the current density increases, the machining depth increases and machining is actively performed. Fig. 9 is a graph of machining diameter by current density. A copper electrode tool was applied at a current density of 6.31A/cm2. The diameter was 5.84mm, which is about the same as the diameter of the electrode tool. However, as the current density increased, the diameter increased. The machining was performed with a current density of 16.8A/cm2 the machining diameter was measured to be 7.9mm, which is 1.6 mm larger than the tool diameter. Applying a current density of 6.31A/cm2 to the conductive coated electrode tool increased the machining diameter to 6.3mm and increased as the current density increased, as was the case with the copper electrode tool. After applying a current density of 16.8A/cm2, the machining diameter of the workpiece measurement results were 7.8mm machined similar to a copper electrode tool.

4. Conclusions

It is confirmed that the ECM can be carried out by applying the conductive coating to the 3D printed electrode tool of the ABS material. It can be seen that the metal electrode tool and the conductive electrode tool can be sufficiently used as the electrode tool by comparing the machining performance according to the change of the current density. By using this conductive coating, the electrode tool can be fabricated at a lower cost than the metal material, and the conductivity of the product can be imparted without any special process. Complex shapes be created easily and rapidly and are suitable for ECM use.

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