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Fabrication and experimental verification of electrochemical machining tool for complex-shaped hole

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Abstract

The demand for processing of reverse-tapered holes and other complex-shaped holes made of difficult-to-cut materials has increased in recent years. The hole processing by the electrolysis processing is thought to be suitable because there are no heat affected layer and tool wear in electrochemical machining (ECM). It has been reported that, a tool with insulated side surface had been used to process reverse-tapered holes from straight pre-drilled holes by controlling the applied voltage as well as feeding speed. However, the processing efficiency is low because the anodic dissolution occurs only in the area nearing the electrode`s end surface, also control of the power supplied or the electrode feed is necessary. To solve the problem of low processing efficiency, an ECM tool with changed conductive area ratio along the axial direction was proposed by our research group, and the effectiveness was confirmed through computer simulation. The purpose of this study is to experimentally confirm the processing possibility of the proposed ECM tool for complex-shaped holes. First, the ECM tool was fabricated by winding a copper wire over the cylindrical surface of a non-conductive shaft. The shaft with pitch-changed spiral groove was produced by a 3D printer. Then, machining experiments were carried out by inserting the fabricated tool into a pre-drilled straight hole. In order to investigate the influence of experimental conditions, the current value and processing time were changed in experiments. As the results, reverse-tapered and complex-shaped holes were shaped from a straight hole of 7mm in diameter and 45mm in depth. The experimental results showed that our proposed ECM tool is effective in processing complex-shaped holes. In addition, it was found that the processing quantity can be controlled through the current value and processing time.

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Keywords: ECM; electrochemical machining; complex-shaped hole; reverse-tapered hole; conductive area ratio

1. Introduction

In order to improve the cooling efficiency of dies, processing difficulty-to-cut materials with reverse tapered holes and complex shaped holes is in demand. Processing complex shaped holes with electrochemical machining (ECM) has attracted much attention because it has following advantages: there are no affected layers, no tool wear and good finished surface can be obtained.

Chang Hee Jo et al. [1] has controlled the forwarding speed and pulse on time using an electrode with insulated side surface to process a reverse tapered hole. Li Yong et al. [2] has controlled the applied voltage and forwarding speed with an insulated electrode and processed a reverse tapered hole. However, processing efficiency was low with the above methods because the processing was carried out only using the end surface of electrode and the control of power supply or the electrode movement is required.

Dahai Mi et al. [3] has devised a tool which is capable of control the axial processing quantity by controlling the conductive area of the electrode side surface and confirmed the effectiveness by simulation. The tool did not require a complicated control unit.

In this study, the tool electrode with controlled side conductive area was fabricated and effectiveness of the tool was examined in processing complex-shaped holes and the reverse tapered holes. In addition, the possibility of tool design by the simulation from the comparison of experimental results with simulation results was discussed. Furthermore, the influences of processing electric current and processing time, which affect the processed shape, were also investigated.

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2. Processing principle

It is known that the processing speed of ECM is determined by the current density on the workpiece surface. Therefore, it is expected that complicated shapes can be processed by changing current density on the workpiece surface.

In this study, tool electrode with tin-coated annealed copper wire wound on its side surface was designed. Pitch of the wire varies like figure 1. The tool electrode rotated during ECM and controlled processing quantity along axial direction is expected.

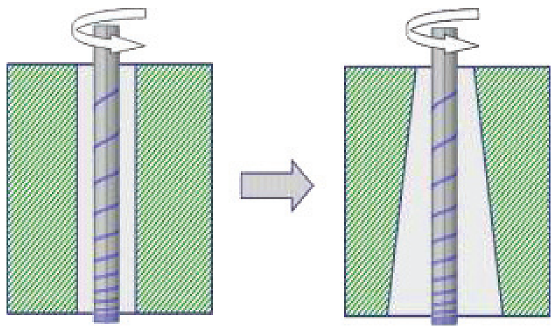

Fig.1 Concept of proposed ECM method

3. Experimental equipment

3.1. Electrolytic bath

Schematic drawing of experimental equipment is shown in figure 2. As shown in figure 2, top and bottom ends of electrode were supported in order to prevent eccentricity. Several vertical holes were processed on the workpiece in advance. Processing carried out inside the pre-drilled holes with rotation and voltage impression. Fresh electrolyte was supplied by suction of pump in order to remove sludge and heat.

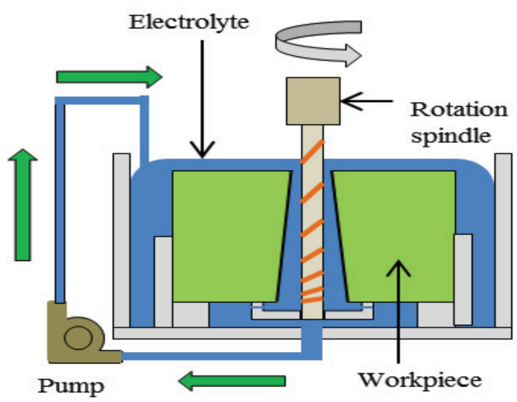

Fig.2 Experimental equipment

3.2. Tool electrode

Insulator column as tool electrode in this investigation was manufactured by 3D printer (Stratasys EDEN250). Small ditch was processed on the tool surface before winding wire, which position is the same as pitch of the wound wire. The ditch facilitates the winding of wire and help to prevent looseness.

Tin-coated soft copper wire of φ0.4mm was wound on the tool electrode along the ditch. Picture of tool electrode for the reverse-tapered hole processing is shown in figure 3. Comparison of pitches between actual and designed conductive area is shown in figure 4. As shown in figure 4, maximum difference of the shape of radial direction was approximately 0.1mm, and maximum difference of pitch was almost 1mm. Figure 5 shows appearance of the tool electrode for complex-shaped hole processing.

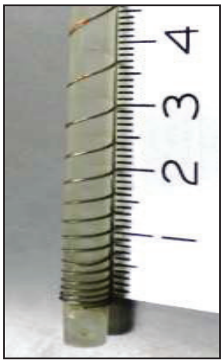

Fig.3 Tool electrode for reverse-tapered hole

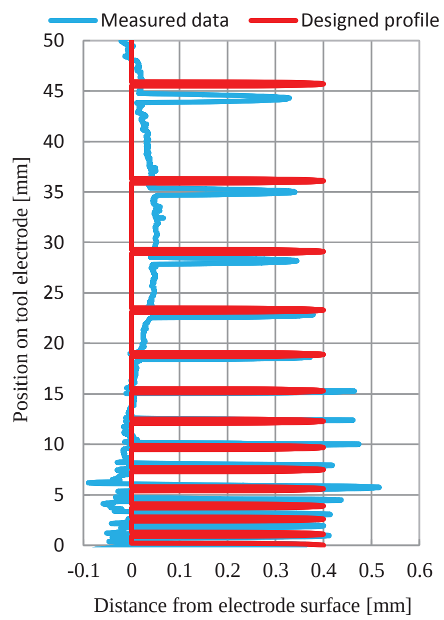

Fig.4 Designed profile and measured data of fabricated tool electrode

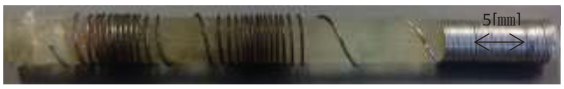

Fig.5 Tool electrode for complexed internal features hole