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Edge finishing and deburring of back surfaces of microholes using micro-cutting tools

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ABSTRACT

The edge finishing and deburring of the back surfaces of micro-through holes, such as those with a diameter smaller than 1 mm, from the front surfaces by cutting are difficult and in some cases impossible with currently available tools. We have therefore fabricated micro-cutting tools by electrical discharge machining and used them for processing the back surfaces of microholes using helical tool feeding with the assistance of ultrasonic oscillation. As a result, a hole drilled using a 0.15-mm-diameter drill in a 0.2-mm-thick plate was successfully deburred and edge-finished. This is the hole with the smallest diameter whose back surface was processed from the front surface by cutting, to the best of our knowledge. The effects of ultrasonic oscillation, namely, cutting force is reduced and the generation of secondary burrs is restrained, were also observed in this study. Moreover, cutting force was further reduced with an improved geometry of the tool's cutting part.

1. Introduction

Drilling using drill tools is one of the fundamental and important machining processes that have long been widely employed in industry. Drilled holes usually require deburring and/or edge finishing such as chamfering in subsequent processes, because the generated sharp burrs or edges can cause injury to assembly workers, and because burrs sticking to a part can become loose during the operation of the product involving that part, which may eventually damage the product [1]. Edge finishing and deburring not only remove these risks, but also facilitate the fitting of parts in assembly processes and improve the appearance of a product. Although many processes such as electrochemical machining, barrel finishing, chemical etching, liquid horning, blasting, water jet machining, brushing, and magnetic abrasive machining are employed for edge finishing and deburring, these processes have disadvantages in that surfaces other than edges or burrs are removed and burrs are not totally eliminated, owing to their difficulty in precisely controlling locations where material removal is taking place. On the other hand, edge finishing and deburring by cutting using tools such as a chamfering cutter have none of these disadvantages. Moreover, if a machining center is employed, they can be carried out immediately after drilling using the same machine, considerably minimizing operation time and cost.

The edge finishing and deburring of the front surface of a hole are generally easy; however, they are also required for the back surface of a through hole. By using a conventional tool, a part with a through hole must be turned over to process its back surface, leading to an increase in the number of operation processes. Furthermore, processing the back surface of an intersecting hole is almost impossible. Special cutting tools capable of edge-finishing and deburring the back surface of such a hole from the front surface have therefore been developed and are now commercially available [2]. These tools have a mechanism that enables the outside diameters of their cutting parts to be varied. When a tool is being inserted into a hole, the outside diameter of its cutting part is smaller than the hole diameter. After the cutting part penetrates through the hole, it protrudes in the tool's radial direction and performs edge finishing or deburring. However, microtools with such a complicated mechanism are difficult to fabricate owing to their small diameters. Tools employable for holes with a diameter smaller than 1 mm are not yet available.

Because there is considerable demand for the drilling of microholes owing to the continuous miniaturization of industrial products and parts, the edge finishing and deburring of such holes are also required. In this study, we have therefore performed the edge finishing and deburring of the back surfaces of micro-through holes with a diameter smaller than 1 mm by cutting. To facilitate the fabrication of microtools, their geometries were simplified by

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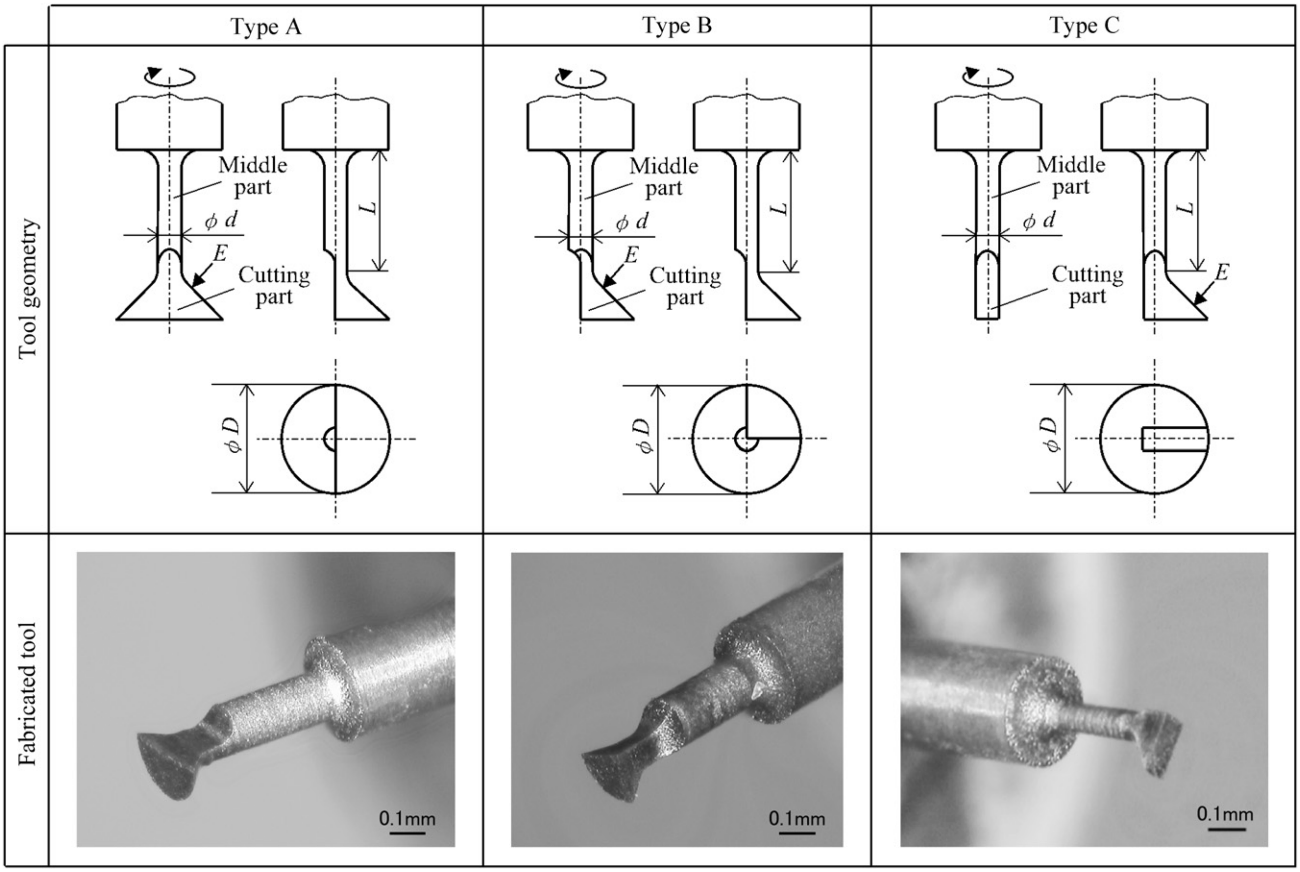

Fig. 1. Tool geometries and fabricated micro-cutting tools.

adopting helical tool feeding. Electrical discharge machining (EDM) was employed for fabricating tools because of their high hardness and micron-sized features. Furthermore, workpieces were ultrasonically oscillated with the aim of decreasing cutting force and then preventing tool breakage.

2. Experimental

2.1. Fabrication of microtools

Micro-cutting tools for the edge finishing and deburring of the back surfaces of microholes were fabricated by EDM. EDM can be used for processing hard tool blanks because any hard material, if electrically conductive, can be dealt with by EDM. The mechanical force exerted on an EDM workpiece is minute because the tool electrode and workpiece do not come in contact with each other. Furthermore, minimizing unit removal is possible under machining conditions where the electrical discharge energy is very low. These advantages facilitate the fabrication of micro-cutting tools with a high hardness and micron-sized features. Using EDM, the authors' group has fabricated many types of microtool such as drills, end mills, and turning tools, and has used them for various microcutting operations [3–6].

Wire electrodischarge grinding (WEDG) [7], an EDM method, was used for tool fabrication. A wire tool electrode is used in WEDG, similarly to in wire electrical discharge machining (WEDM). However, a wire guide supports the electrode at the machining point to reduce wire vibration in WEDG, while it does not in WEDM, leading to a high machining accuracy. WEDG can be used to fabricate straight pins several microns in diameter. In this study, WEDG was carried out on a micro-EDM machine (MG-ED72, Panasonic Corp.) that has three axes, each driven with a step feed of 0.1 μm. Its spindle system includes a V-shaped sliding bearing and a mandrel made of stainless steel. A ceramic capillary inserted in the mandrel tip guides a tool blank. The mandrel is rotated at a speed of 50 s^{-1}. The rotation runout of the mandrel is determined principally by the circularity of the cross sections of its parts in contact with the bearing surfaces. The mandrel has been fabricated such that this circularity is approximately 0.2 μm.

Three types of micro-cutting tool were fabricated. The tool geometries and fabricated tools are shown in Fig. 1. The middle parts of all three types, the diameters and lengths of which are denoted as *d* and *L*, respectively, are thinner than the cutting parts. The cutting parts are initially of circular cone shape with an apex angle of 90° and a base diameter of *D*. Removing a part of the circular cone gives the tool a cutting edge, which corresponds to the edge *E*, when the tool rotates in the direction shown in the figure. The rake angle and relief angle are both 0°. The cross sections of the cutting parts in the radial direction are D-shaped for a type-A tool, a quarter sector for a type-B tool, and nearly rectangular for a type-C tool.

2.2. Edge finishing and deburring of back surfaces of microholes

Fig. 2(a) shows the method of edge-finishing and deburring the back surfaces of microholes using helical tool feeding. Before processing, a tool is inserted into a hole until its cutting part penetrates through the hole. In the next step, the tool and hole axes are aligned, determining the position of the hole axis. This position is determined by moving the tool horizontally and by detecting the electrical contact between the tool's middle part and the inner wall of the hole, while voltage is applied across them. After the