DEVELOPMENT OF A PRACTICAL HIGH-PERFORMANCE LASER-GUIDED DEEP-HOLE BORING TOOL: BORING OF STEEL WORKPIECES

A. Katsuki¹, H. Onikura¹, T. Sajima¹, H. K. Park², J. G. Zhen² and H. Murakami³

¹Department of Intelligent Machinery and Systems, Faculty of Engineering, Kyushu University
36, 6-10-1 Hakozaki, Higashi-ku, Fukuoka, 812-8581, JAPAN
²Graduate School of Kyushu University
³Fukuoka Industrial Technology Center, Kitakyushu, 837-0901, JAPAN

1. Introduction

Axial hole deviation in deep hole drilling results in degradation of the quality and a decrease in the yield rate of products. A prototype laser-guided deep-hole boring tool with a 110mm diameter whose attitude was controlled by piezoelectric actuators was developed to prevent the hole deviation. Counter-boring of duralumin workpieces (JIS-type A2017-T4) was performed with straightness of ±10 µm over 700 mm [1]. 700 mm is the maximum machinable length of the machine tool.

On the basis of the experimental results of the prototype tool, a practical laser-guided deep-hole boring tool of 110mm diameter is produced for application and higher machining accuracy. As a result of its performance test with duralumin workpieces, it is found that the tool can be guided to bore a straight hole and be used practically under the restrictive condition that a double disk coupling is used instead of the stopper [2].

On an industrial market, steel workpieces are commonly used and are difficult to bore compared to duralumin. In this study, steel (JIS-type S45C) workpieces are used to examine performance of a laser-guided tool.

2. Experimental apparatus

In this experiment, a new multifunctional laser-guided deep-hole boring tool with a 110-mm diameter is fabricated. It can be used for boring, internal grinding and measuring hole accuracies by exchanging its leading part for each purpose [3,4]. When a deep hole is bored, the instrument to evaluate...
hole accuracies is needed. However such an instrument, in particular for extremely deep hole, is not presently on the market.

In Figs.1 and 2, a counter-boring head and an experimental apparatus are shown, respectively. The experimental apparatus consists of a counter-boring head, the front and rear actuators located on an actuator holder for its attitude control, a laser diode molded in the rear end of the holder and a rotation stopper to correct its rolling. The laser diode is used for detecting its attitude with two PSDs (Position-Sensitive Detector) set backward.

3. Experimental procedure

The experiment is performed using a horizontal drilling machine with the rotational tool-stationary workpiece system. In this experiment, three kinds of workpieces
are used (Fig.3).

(a) **Normal workpiece**

The workpiece has no special feature in shape, which causes hole deviation (Fig.3 (a)).

(b) **Thin walled workpiece**

The workpiece has a thin wall (0.8 mm after machining) between hole depths 60 and 140 mm on +X side (Fig.3(b)).

(c) **Workpiece with an obliquely prebored hole**

The workpiece has a prebored hole, which is inclined by 0.1 or 0.2 mm toward +X over 200 mm (Fig.3(c)). In the experiments, duralumin workpieces (JIS-type A2017-T4) as well as steel are used to examine the cutting state.

Cutting conditions are as follows. Rotational speed is 375 rpm, feed is 0.09 mm/rev. Cutting fluid, Sulfo-chlorinated oil (JIS type 2-13) is fed with a flow rate of 150 mL/min.

4. Results and discussions

Experimental results are shown in Figs.4 to 8. In Figs. (a) and (b), variations of tool position and hole deviation with hole depth are shown in X and Y directions, respectively.

(a) **Normal workpiece**

The tool is well guided and straight hole is bored as shown in Figs. 4 (a) and (b), respectively. However, respective female and male screw of the boring head and bar are damaged to the extent of impossibility of usage after several experiment of boring of steel workpieces. Excessive torque during boring of steel workpieces causes the boring bar a bend.
Until now, a weak boring bar (outside/inside diameters: 18 / 14 mm) is used for increasing of controllability of the boring head. Hence from now on, the practical boring tool is used instead of the multifunctional boring head [2]. Furthermore, a stronger boring bar (outside/inside diameters: 18 / 12 mm) is used for increasing of its rigidity.

(b) Thin walled workpiece

Figure 5 shows experimental results. In the region from a depth of Z=60 to 140mm, a thin wall (0.8 mm after boring) is provided, but the hole is bored straight without being affected by the thin wall.

(c) Workpiece with an obliquely prebored hole

Figure 6 shows result of boring of the duralumin workpiece with a prebored hole, which is inclined by 0.2 mm over 200 mm. In the boring of duralumin workpiece, rotational speed is 270 rpm and feed is 0.125 mm/rev.

The tool is well guided straight and hole is bored without trouble.

Figure 7 shows the boring of steel workpiece. The prebored hole is inclined by 0.2mm over 200mm. The tool is well guided straight and hole is bored without trouble until a depth of 28mm. From a depth of 28 mm, cutting torque increases by three times of normal cutting. The boring bar slips by 5 mm during boring and bends at the collet chuck, which holds it on the headstock of the horizontal drilling machine.

Figure 8 shows the case that the inclination is 0.1mm over 200 mm. Until a depth of 30mm, the tool is well guided and straight hole is bored. However the impressed voltages of Tr.6 and Tr.5 actuators become 1000 and 0V, respectively and tool is uncontrollable between the depths of 30 and 150mm (Fig.9). This problem can be resolved by arranging the heights of three actuators and by stabilizing the cutting conditions.

5. Conclusions

As a result of performance tests, it is cleared that the laser-guided tool can be guided to bore a straight hole even in the machining of steel workpieces with abnormal prebored holes. These holes are disturbances during boring.

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References