Inspection of Micro-Drilling Processes by using the On-Machine vision

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Abstract: In order to inspect burrs and machining quality in micro-drilling processes, a cost-effective method using an image processing and a shape from focus (SFF) methods on the machine tool is proposed. As the on-machine vision units are incorporated with the CNC function of the machine tool, direct measurement and condition monitoring of micro-drilling processes are conducted between drilling processes on the machine tool. Stainless steel and hardened tool steel are used as specimens and twist drills made of carbide are used in experiments. Validity of the developed system is confirmed through experiments.

Keywords: Burr, CCD Camera, Condition Monitoring, Hole Quality, Illumination Unit, On-Machine Measurement, Shape from Focus, Zoom Lens

1. Introduction

Micro-drilling processes have been widely used to produce micro holes such as micro dies and molds, fuel injection nozzles, watches, bearings and printed circuit boards, etc. And it has more attention in a wide spectrum of precision production industries.

The burr (height, width) and hole quality (oversize, location error) have a significant effect on assembly of precision components. Fast and accurate measurements of burr geometry and hole quality are important for the condition monitoring of micro-drilling processes. In order to measure burr and hole quality, measurement systems such as SEM (Scanning Electron Microscope) and confocal microscopes have been used [1-2]. However, these measurement systems are very expensive. They are difficult to apply condition monitoring of drilling holes between micro-drilling processes. In addition, they are not cost-effective.

In this paper, a machine vision technique using the SFF method [3] is applied to measure the micro-drilling burrs and hole quality. In order to obtain clear images and reduce noise due to reflection, a novel illumination unit is devised using the LED array and a halogen lamp. Experiments are conducted with twisted carbide drills, and stainless and hardened tool steel specimens.

2. Hole Quality

Experiments are conducted to investigate the effectiveness of drilling processes by measuring the hole quality after machining. Two aspects, location error and oversize of the hole, of drilling quality are measured. Depending on type of drills and drilling processes, it may occur that the drill walks on the surface of the workpiece before entering the part. Whirling of the drill edge at the time of penetration into the workpiece degrades hole quality as well.

The drilled center location of a hole is determined by the position where the drill comes to a stop after walking. The location error deviated from the desired center location is called the location error of the hole \( E_L \), as shown in Fig. 1. Actual diameter is calculated by evaluating the result of least squares technique after scanning the edge through the edge detection and image processing. And location error is measured by the difference between the actual hole center and the desired hole center with comparing the CNC position and image coordination.

In all drilling operations, diameter of the hole is predetermined by the diameter of a drill bit. However, some variation in hole size from the nominal (tool) value is expected to occur even under the best drilling condition because of tool wear and the whirling. The amount of deviation between the actual hole diameter and the nominal diameter is called diameter deviation \( \delta d \), as shown in Fig. 1.

Fig. 1 Location error and diameter deviation.