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Setting errors compensation of a workpiece located by industrial robots

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Abstract
From the nature of ultraprecision machining, all sorts of very small errors greatly affect the machining accuracy due to the miniaturization and complexity of objects to be machined. The error causes affecting the machining accuracy are tool configuration, tool/workpiece setting, machine tool, material to be machined, cutting condition and so on. Among them, slight setting errors may have critical influence on the machining accuracy. Thus, this study aims at developing a novel compensation method of workpiece setting errors located by industrial robots in order to avoid human factors, promote the automation of setting and improve the efficiency of ultraprecision machining. According to the proposed method, it enables to accurately identify the workpiece configuration and position by on-machine measurement with nm resolution. From an experiment, it is found that the proposed compensation method has a potential to contribute to fully automated setting for conducting ultraprecision machining.

Ultraprecision machining, Setting errors, On-machine measurement, Industrial robot

1. Introduction

According to the needs of high performance devices, a development of highly integrated ultraprecision machining technology is strongly required in order to fabricate the tiny and complicated shapes with high accuracy. To meet the requirements, the authors have developed some cutting methods to fabricate the microparts by means of diamond cutting tools installed on a multi-axis ultraprecision machining center [1]. From the nature of ultraprecision machining, however, all sorts of very small errors such as machine tool and material to be machined greatly affect the machining accuracy due to the miniaturization and complexity of objects to be machined. Among them, slight setting errors may have critical influence on the machining accuracy.

The authors have been studying compensation of tool setting errors to conduct multi-axis control ultraprecision machining [2]. In the proposed compensation method, some simple grooves are firstly created on a workpiece. Then, the setting errors are calculated by measuring the groove shape and the positional relation between grooves, which are affected by the coordinate value of the actual tool position. Compensated NC data are finally generated based on the estimated setting errors. Moreover, by using an on-machine contact-type measurement device to measure the grooves, it enables to automate the compensation procedure of the tool setting errors and to shorten the compensation time [3].

Thus, this study aims at developing a novel compensation method of workpiece setting errors located by industrial robots in order to avoid human factors, promote the automation of setting and improve the efficiency of ultraprecision machining. According to the proposed method, it enables to accurately identify workpiece configuration and position by on-machine measurement with nm resolution. From an experiment, it is found that the proposed compensation method has a potential to contribute to fully automated setting for conducting ultraprecision machining.

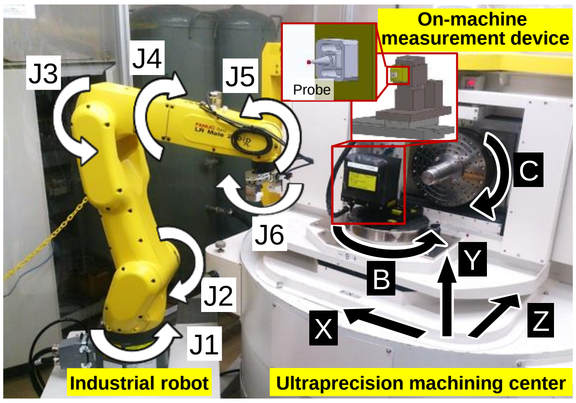


Figure 1. Ultraprecision machining center equipped with on-machine measurement device and industrial robot

2. Experimental setup

Figure 1 illustrates a 5-axis control ultraprecision machining center ROBOnano Ui and an industrial robot LR Mate 200iD (FANUC corp.) used in the study. The machining center is equipped with three translational axes (X, Y, Z) and corresponding two rotational axes (B, C). The resolutions of the translational axes and the rotational axes are 1 nm and 0.00001 degrees, respectively. The robot is a 6-axis vertical articulated robot with the approximate size and reach of human size (911 mm). The repeatability is 30 µm and the maximum allowable mass is 7 kg.

In order to measure workpiece configuration and position, a contact type on-machine measurement device is mounted on B table of the machining center beside a turbine spindle. On the other hand, a workpiece is set up on C table. The device NANOCHECKER (FANUC corp.) has 1 nm resolution and is controlled by NC controller. Then, the displacement of the probe which contacts the workpiece surface is recorded together with machine coordinates in a PC. It is confirmed that the performance is little different from commercial contact type measurement equipment.

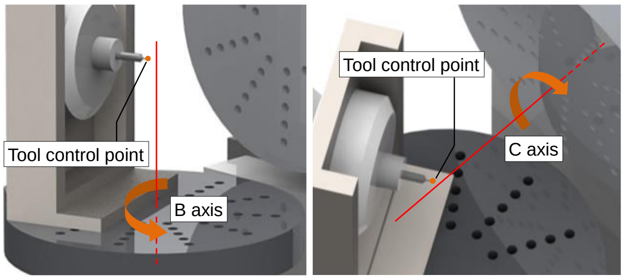


Figure 2. Example of setting errors of tool against rotational center

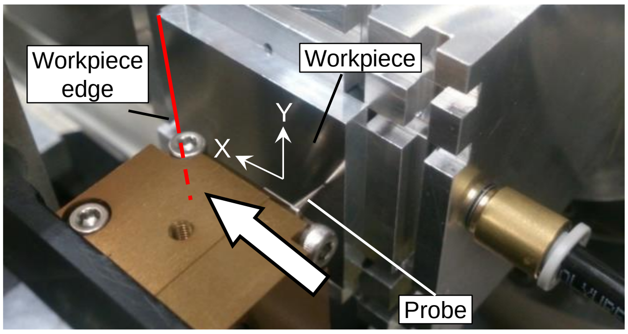


Figure 3. On-machine measurement of wokiece surface

3. Setting errors compensation of tool and workpiece

NC data is generated where tool control point would be located on the center of rotational axes as a tool initial position. However, it is extremely difficult to precisely locate the control point on the axes since the initial tool is set by rough measurement and manual adjustment, as shown in Figure 2. This results in the deterioration of machining accuracy. Thus, the compensation method is devised to reduce the influence of tool setting errors.

The proposed compensation method of tool setting errors has three stages. At the first stage, the simple grooves are created on a plane surface of soft material such as brass. At the second stage, the setting errors are calculated by detecting the positional relation between the grooves. The coordinate values of the actual tool control point can be measured by scanning the groove profiles to determine those depths [3]. At the third stage, compensated NC data are generated based on the estimated setting errors.

On the other hand, workpiece setting errors have been ignored though the workpiece is manually located on precise jigs in the same way. However, in order to achieve ultraprecision machining avoiding human factors, workpiece setting errors should be also compensated. If the compensation technique is established, the automation of setting is realized by using an industrial robot to improve the efficiency of ultraprecision machining.

Workpiece is firstly located on a vacuum type chuck fixed on C table by a robot in this study. As shown in Figure 3, the probe of on-machine measurement device follows the workpiece surface and detects the workpiece edges. Thus, the workpiece configuration and orientation are identified based on the displacements of the probe. As a result, NC data is modified to compensate workpiece setting errors.

4. Machining experiment and result

In order to confirm the above mentioned compensation method, a machining experiment is conducted by using a pseudo ball end mill made of single crystal diamond having a 0.5 mm radius, and an aluminum plate as workpiece. The workpiece dimension is 40 x 40 x 5 mm and the configuration is assumed to consist of 6 plane faces for the simplicity.

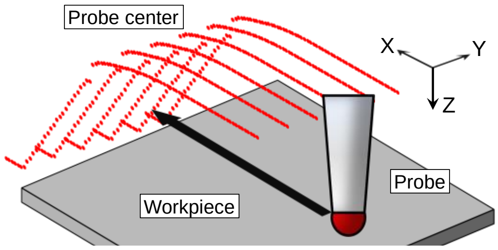
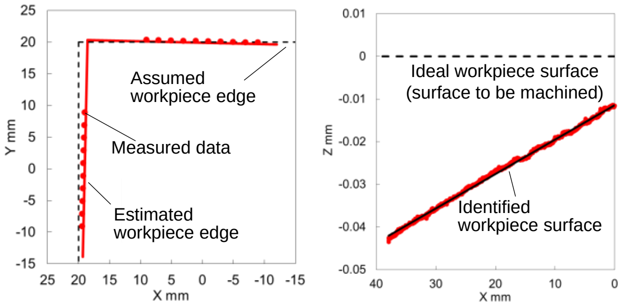


Figure 4. Probe scanning on workpiece surface to detect an edge



(a) X-Y plane (b) Z-X plane

Figure 5. Identified workpiece configuration and position

In the experiment, the robot firstly carried the workpiece to a vacuum type chuck fixed on C table. According to the assumed workpiece position, the on-machine measurement device was moved on X-Y plane to follow and identify the workpiece surface as shown in Figure 4. In particular, in order to detect a workpiece edge, the probe was fed in one (X) direction multiple times and the displacements were recorded together with machine coordinates. After that, C axis was rotated by 90 degrees to detect another workpiece edge.

Figure 5 shows the workpiece configuration and position identified by the proposed method using on-machine measurement device. Based on the above results, NC data was finally modified corresponding to the actual workpiece configuration and position by compensating workpiece setting errors within 1 µm that is the approximate accuracy of manual setting. Furthermore, actual tool control point was detected by simple grooving created on the workpiece surface. By using the actual workpiece configuration, tool setting errors would be accurately compensated.

5. Conclusion

In this study, a method to compensate workpiece setting errors located by industrial robots is proposed. By using an on-machine measurement device, it enables to identify the workpiece configuration and position on a machine tool table. From an experiment, it is found that the proposed compensation method has a potential to contribute to fully automated setting for conducting ultraprecision machining.

Acknowledgements

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