Development of an Intelligent System for Compensating and Maintaining Geometric Accuracy of Five-axis Controlled Machines

Tetsuya Matsushita[*1], Tadahiro Oki[*2], Yasunori Kondo[*2], Kazuhiro Okuda[*2] and Harumitsu Senda[*1] (OKUMA Corporation)

1. Overview

As downsizing of industrial products has been intensified recently, their parts have become more complicated. In order to make such parts, more five-axis controlled machine tools are used, the accuracy of which is required to be high. However, it is difficult to achieve high accuracy in five-axis machining because it is susceptible to errors due to fixtures or machine structure. One of the main factors in such errors is a geometric error related to the locations of axes. Five-axis machines have thirteen geometric errors. Although these geometric errors are made as small as possible in the manufacturing process of machines, they change slightly when machines are installed in customers' workshops because of a change in the condition of the machines. They also change while customers use the machines because of changes in environmental temperature (thermal deformation). In addition, they change over time because of changes in the condition of the floors and other factors. Therefore, geometric errors need to be corrected in a short time when necessary in the environment where machines are used. In order to solve this problem, we developed an intelligent system with which a five-axis controlled machine tool measures and compensates its geometric errors and maintains high accuracy.

2. Technical Details

The configuration of the intelligent system is shown in Fig.1. This system consists of the following main technologies:

(1) Automatic measurement of geometric errors

A five-axis machine automatically measures its geometric errors with a datum sphere and a touch probe, which is a sensor used for in-process measurement of the positions and dimensions of workpieces. Eleven geometric errors including errors related to linear axes as well as those related to rotary axes are identified. Machine operators only need to do an easy setup and operation, in which they set a datum sphere on the table, move a probe just above the sphere and press a few keys and the start button. After this process, automatic measurement is carried out and completed in about ten minutes. Fig. 2 shows the process of measurement. With this technology, measurement accuracy is stable and does not depend on operator's skill.

(2) Compensation for geometric errors

Errors in the position and orientation of a cutting tool relative to a workpiece due to geometric errors are compensated in real time. The compensation works not only in the automatic mode but in the manual mode, so that machine operators can carry out the operations from a setup to machining in the same way as they have always done.

(3) Control of thermal deformation

Based on a machine structure that simplifies thermal deformation, for example in a way that causes only expansion or contraction without tilting, a five-axis machine autonomously compensates its thermal displacement

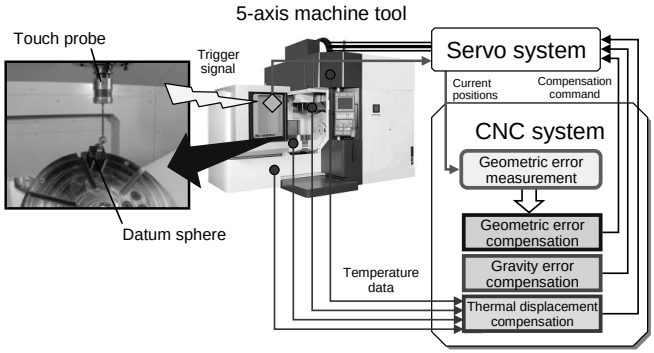

Fig. 1: Configuration of intelligent system for maintaining high accuracy

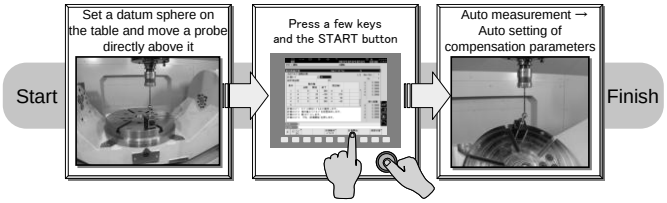

Fig. 2: Geometric error measurement process

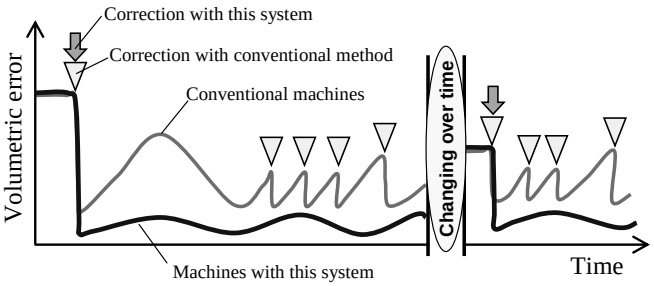

Fig. 3: Image of effect of intelligent system

due to a change in environmental temperature using temperature sensors. Highly stable accuracy is achieved under various operating conditions such as in a common workshop, with rapid temperature changes, with/without coolant and in wide working range.

With this intelligent system, machine operators only need to do an easy setup, and five-axis machines reduce the effects of geometric errors for themselves, achieving high volumetric accuracy in five-axis machining. Furthermore, they autonomously reduce the effects of the changes in geometric errors due to changes in environmental temperature, so that high accuracy is maintained for a long period of time as shown in Fig. 3.

3. Summary

This system has been launched in April 2012. Since then, it has been installed in applicable machines at a remarkably high rate, especially in the Japanese market, and contributing to improvement in machine users' productivity. In order to meet users' need for higher accuracy, we will work on the development of new technologies for improving five-axis machining accuracy further.

[*1] Member, OKUMA Corporation, Oguchi-cho, Niwa-gun, Aichi, 480-0193, Japan
[*2] OKUMA Corporation, Oguchi-cho, Niwa-gun, Aichi, 480-0193, Japan