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学位（博士）論文要旨

(Doctoral thesis abstract)

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論 文 題 目 (Title)	Positioning accuracy improvement of multi-tasking machine tool having a swivel spindle by compensating influence of the identified inherent geometric deviations (同定された固有の幾何誤差の補正によるスイベル式主軸を有する複合加工機の位置決め精度向上)

論文要旨（2000 字程度）
(Abstract(400 words))
※欧文・和文どちらでもよい。但し、和文の場合は英訳を付すこと。
(in English or in Japanese)

With the increasing demand for industrialization and automation, multi-tasking machine tools have been widely used in machining components with complex geometric structures and sculptured surfaces. However, the positioning accuracy of the tool center point is inevitably hard to be guaranteed since the movement of the multi-tasking machine tool having a swivel spindle is complicated. This study focuses on compensating the identified inherent geometric deviations of the swivel spindle and the turning table to reduce their influence on the positioning accuracy of the machine tool.

In Chapter 1, the development of the multi-tasking machine tool is introduced and the errors which will influence the positioning accuracy of the machine tool are analyzed.

In Chapter 2, according to the theory of form-shaping system, the geometric deviations existing in the multi-tasking machine tool with a swivel spindle head in a horizontal position are defined. Then, a mathematical model to simulate the simultaneous three-axis motions is proposed. And the simulation both in the cylindrical coordinate system and in the Cartesian coordinate system is carried out. From the simulation results, it is confirmed that to eliminate the influence of the mounting errors of workpiece side ball on the measured results, measurements for B axis should be

performed in Cartesian coordinate system and those for C axis should be performed in cylindrical coordinate system. The relationship between the geometric deviations and the eccentricities of trajectories is established. It is found that the circular trajectories of the B axis X direction, B axis Y direction, C axis radial direction and C axis axial direction are adequate to identify the geometric deviations by designing an appropriate measuring procedure.

In Chapter 3, current compensation methods for the rotary axis of five-axis machining center are discussed firstly. Then, the flowchart of the compensation algorithm is determined and the formulae to generate the modified NC code are derived according to the special topological structure of the targeted machine tool by using the homogenous transformation matrix. It can be concluded that it is suitable to compensate the geometric deviations in a simple way without any iteration.

In Chapter 4, at first, the circular trajectories of four measuring patterns are analyzed in three views of the space, respectively. Then, a measuring procedure by using ball bar is designed based on the analysis of the influence factors on each circular trajectory. After that, the measuring procedure is applied in a multi-tasking machine tool, and the geometric deviations are identified by using the measured eccentricities of trajectories. Finally, according to the proposed compensation method in Chapter 3, the NC code is modified to measure the trajectories of four measuring patterns again. By comparing with the trajectories before and after compensation, it is confirmed that the position error of TCP is reduced significantly after the compensation. It is found that the geometric deviations of the swivel spindle and the turning table can be compensated effectively. However, the geometric deviations of the milling spindle cannot be compensated by this method.

In Chapter 5, at first, a simple measuring procedure using a touch-trigger probe is devised to identify the geometric deviations. Then, the formulae to calculate the geometric deviations are derived by analyzing the influence of the geometric deviations on the measurements for the respective rotations of B and C axes. Finally, the measuring procedure and the calculation method are applied in a multi-tasking machine tool, same as the ball bar measurement of Chapter 4. It is confirmed that the identified values obtained by these two measurement instruments are similar. Therefore, the identified values from the proposed method are reliable and can be used for compensation.

In Chapter 6, the main achievements in this study are summarized.