称号及び氏名	博士（工学） Wiroj Thasana
学位授与の日付	平成27 年3 月31 日
論　文　名	「A Study on Estimation of Three-Dimensional Surface Roughness and Tolerances Based on Virtual Machining Systems Considering Kinematic Motion Deviations （運動偏差を考慮した仮想加工システムに基づく3次元表面あらさおよび精度の評価に関する研究）」
論文審査委員	主査　　杉村　延広 副査　　三村　耕司 副査　　大多尾　義弘

論　文　要　旨

In the last decade, changes in the machine industries are constantly exploring systems and methods to increase the quality and the reliability of the products and to decrease the costs of the machining operations. Machining processes on the Computer Numerical Control (CNC) machine tools for generating products with high accuracy and complicated geometries are inherently complex, and lead to use empirical methods for process developments. In particular, process parameters such as machining speeds, feed rates and tooling are usually selected based on handbooks and trial-and-error prototyping. However, these methods do not guarantee the process parameters which satisfy the required quality.

Various types of CNC machine tools are now being designed and applied to machining processes of complicated machine products. The machining accuracy is one of the most important characteristics of the CNC machine tools for generating products with high accuracy and complicated geometries. Accuracy can be defined as the degree of agreements or conformance of the finished parts with the required dimensional and geometrical characteristics. Errors, on the other hand, can be understood as any deviation in the positions of the tool’s cutting edges from the position theoretically required to produce workpieces of the specified tolerance.

Kinematic deviations are concerned with the relative motions of several moving machine components that need to move in accordance with precise functional requirements. These are strongly influenced by the geometric deviations of the components, such as guide ways and bearings of the machine tool components. Therefore, it is now required to clarify the relationships between the kinematic motion deviations of the machine tools and the geometric deviations of the components, from the viewpoints of the design and the manufacturing of the machine tools and their components.

The objective of the present research is to propose an estimation of 3D surface roughness and tolerances based on virtual machining in boring and turning processes including kinematic motion deviations of the CNC machining centers and the CNC turning centers, and to establish mathematical models representing the kinematic motion deviations of the machining centers based on geometric tolerances of the components.

A set of points on the bored and turned faces are obtained through the simulations. The model proposed represents the boring and turning processes based on both the shape generation motions and the cutting tool geometries. The individual motions are mathematically described by combining 4 by 4 transformation matrices including the kinematic motion deviations. Emphasis is given to the modeling and analysis of the boring and turning processes of the single point tools. A systematic method is also proposed to verify the 3D surface roughness and tolerances of the bored and turned faces based on the simulation results.

The dissertation is composed of six chapters, and the outlines for each individual chapter are as follows.

Chapter 1 provides a brief introduction of the historical background of the research, and clarifies the necessity and objective of the research.

Chapter 2 reviews the background and importance of the conventional methods and new approaches for analysis kinematic motion deviations and the geometric deviations, virtual machining, 3D surface roughness and 3D tolerances based on the literature survey, new areas for research are identified and proposed.

Chapter 3 discusses the virtual machining model representing the virtual machining centers for the boring processes and virtual turning centers for the turning processes, which include the kinematic motion deviations. The bored and turned faces generated are obtained as a set of points and evaluated to investigate the effect of various process parameters on the geometry of the parts. Once the part is verified virtually, the performance of the machining process parameters to generate a part that meets the required quality specifications can be investigated for estimation the 3D surface roughness and tolerances based on the simulation results.

Chapter 4 discusses the estimation of 3D surface roughness of produced by virtual boring and turning machining processes. The estimation of 3D surface roughness estimated both the 2-dimensional (2D) and 3D through the boring and turning process simulations with kinematic motion deviations. A model is proposed to represent the kinematic motions of the cutting edges against the workpieces, taking into consideration the kinematic deviations of the machining centers and the turning centers. Details of the virtual machining module are proposed to estimate the geometric deviations of the machined face based on the kinematic motions of the cutting edges. A proposed model is applied to the simulation of the simple boring and turning process, the geometries of the machined faces are estimated, based on the cutting conditions, the tool geometries and the kinematic deviations of the boring and turning processes. A method is also proposed to estimate both the 2D and 3D surface roughness based on the boring and turning process simulation with the kinematic motion deviations. Case studies are shown with examples of the generated faces by boring and turning process simulations considering kinematic deviations in order to estimate the 3D surface roughness.

Chapter 5 discusses the estimation of 3D tolerances including kinematic motion deviations. In the beginning, a mathematical model of kinematic motion deviations of machine tools is discussed on the basis of the geometric tolerances. The shape generation motions are bases for analysis of machine tools including both the linear tables and rotary tables. The 3D tolerances of boring and turning processes are analysed based on the machine tool models including kinematic motion deviations. A systematic method is proposed in this section to simulate the shape generation processes in both the boring and turning operations, to estimate the geometric dimensioning and tolerancing of both bored and turned faces, based on the machining parameters. The shape generation motions with deviations are mathematically described by combining 4 by 4 transformation matrices. A set of points on the bored and turned faces are generated through the simulations, and an assessment surface is obtained as the datum reference to estimate the 3D tolerances, based on the points generated by the boring and turning process simulations.

Chapter 6 provides the conclusions for the whole research work.

審　査　結　果　の　要　旨

本論文の目的は、実際に加工を実施する前に、加工条件に基づいて加工製品の表面あらさおよび幾何学的な誤差を推定するとともに、高精度部品の加工を実施する際の加工条件の設定などを支援することである。そのために、機械加工の基本となる穴の中ぐり加工および円筒面の旋削加工のためのシミュレーションシステムを開発し、加工形状の評価を行う手法を提案し、次のような成果を得ている。

(1) 工作物に対する工具の相対運動を表現するモデルの中に、工作機械の組立誤差および位置決め誤差の項を導入し、中ぐり加工および旋削加工における形状創成過程のシミュレーションを行う手法を提案した。

(2) シミュレーションで求めた加工部品の表面を表す点群から、部品の表面あらさを求める手法を提案し、ケーススタディにより手法の有効性を明らかにした。特に近年加工面の評価に用いられている3次元表面あらさを評価する手法を提案した。

(3) 加工面の評価を行うために、シミュレーションで求めた加工部品の表面を表す点群から円筒度を評価する手法を提案し、ケーススタディによりその有効性を明らかにした。

円筒度は、幾何学的な誤差を3次元空間上で評価する手法であり、加工形状の評価に重要な項目である。

(4) マシニングセンターにおける回転テーブルおよび直線テーブルの案内面の公差と加工部品に対する工具の運動偏差との関係を、形状創成理論に基づいて解析し、運動偏差に大きく影響する案内面を明確にしている。

以上の諸成果は、工作機械の設計および機械加工条件の設定を行う上での新しい知見であり、機械加工の支援システムの開発に寄与するものである。また、申請者が自立して研究活動を行うに必要な能力と学識を有することを証したものである。