別紙４－１（課程博士（英文））

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Department	Student ID Number	D159106	Supervisors	NAOKI UCHIYAMA NOBUMASA SEKISHITA
MECHANICAL ENGINEERING				
Applicant's name	YOGI MULDANI HENDRAWAN			

Abstract (Doctor)

Title of Thesis	Iterative Learning Reference Trajectory Modification for Contouring Performance Enhancement of Industrial Machine Tool Feed Drive Systems (工作機械送り駆動系の輪郭制御性能向上のための繰返し学習に基づく参照軌道修正)

Approx. 800 words

In industrial applications, highly accurate mechanical components are generally required to produce advanced mechanical and mechatronic systems. Most of them are produced by CNC (computer numerical control) machine tools. A fundamental motion in CNC machine tools is a drive axial movement to track a desired trajectory. Not only tracking errors in each drive axis but also contour errors, which are directly related to the machined shape of a workpiece, and therefore it must be considered in controller design. Although most existing contouring controllers are based on feedback control and estimated contour error, it is generally difficult to replace the feedback controller in commercial CNC machines tools. In order to improve the contouring performance for commercial CNC machine tools, this thesis presents an iterative learning contouring controller (ILCC) design with two contour error estimation approaches.

The proposed method is implemented in three types of CNC machine tool feed drive systems. First, a laboratory biaxial feed drive system is used to prove the proposed methods performance (chapter 3) with estimated contour error compensation. Then, an ILCC is applied to a three axis commercial CNC machine tool (chapter 4) by improve contour error estimation. Last, a machine tool with a linear motor mechanism is used as an advanced machine tool (chapter 5). All the description of the physical system configuration and system parameters are explained in chapter 2.

An iterative learning contouring controller (ILCC) by considering both tracking and contour errors is proposed in chapter 3. The proposed control iteratively modifies the reference trajectory of each drive axis to reduce the contour error. The proposed controller can be directly applied to commercial machines currently in use without any modification of their original controllers. The proposed method has been experimentally verified through a biaxial feed drive system on a sharp-corner trajectory which normally leads to a large contour error around the corner due to the discontinuity. Comparison with a conventional iterative learning contouring controller (CILCC) was done so as to evaluate its performance. Experimental results have shown that the contour error converges within a few iterations, and the maximum contour error can be reduced by about 49.2 % as compared to the CILCC. The limitation of this method is only

effective for a low curvature trajectory. It needs more iterations to track a high curvature trajectory.

An iterative learning contouring controller (ILCC) by considering the actual contour error compensation (ACEC) and the Bèzier reposition trajectory (BRT) is proposed in chapter 4 to improve the previous method in chapter 3. While the ACEC enhances tracking performance for a high curvature trajectory by compensating the reference input with an actual contour error value, the BRT enables smooth velocity transitions between discrete points in the reference trajectory. For the performance analysis, the proposed controller was implemented in a commercial three-axis CNC machine tools and several experiments were conducted based on typical 3D sharp-corner and half-circular trajectories. Experimental results showed that the proposed controller could reduce the maximum and mean contour errors by 45.11 % and 54.48 % on average, compared to ILCC with estimated contour error. By comparing to ILCC with ACEC, the maximum and mean contour errors are reduced to 20.54 % and 26.92 %, respectively.

To prove the effectiveness of the proposed method in an advanced commercial CNC machine tool system, it is implemented to a CNC machine tool with a linear motor mechanism in chapter 5. A design of iterative learning contouring controller (ILCC) by considering actual contour error compensation (ACEC) enhances the contouring performance of linear motor CNC machine tool feed drive systems. The proposed control iteratively modifies the reference trajectory of each drive axis to reduce the contour error. The proposed controller can be directly applied to a commercial CNC machine tool with a linear motor mechanism currently in use without any modification of their original controllers. The effectiveness of the proposed method has been experimentally verified with a rhombus trajectory. Experimental results showed that the proposed controller could reduce the maximum and mean contour errors by 94.58 % and 88.67 % on average, compared to original controller. Concluding remarks and future works are described in chapter 6.