Adaptive Controller for Precision Machining Process

Author: Elizabeth C. M. Wu
Sponsored By: Industry Affiliates of the LMA

Abstract— This work proposes the use of an adaptive controller in the machining of mirror quality surfaces using diamond turning machines. An outline of the controller is presented as well as issues to be considered in the design process. The performance of the controller will be verified by computer simulation and experimental tests. Further validation of the control algorithm will also be conducted.

Introduction

Precision manufacturing processes are commonly used nowadays in the machining of mirror quality surfaces for applications such as laser mirrors, polygon mirrors and magnetic discs. Since chemical mechanical polishing techniques are only suitable for surface finishing of flat or spherical surfaces, diamond turning machining is the choice technique for effective finishing of complex and sculptured surfaces.

The precision machining process has different characteristics compared to the conventional process. The sub-micron accuracy in the precision process often requires sophisticated metrology equipment and advanced signal processing techniques. The physics of several precision processes are not fully understood and process parameters change constantly. Issues such as crystal orientation of material, sensitivity to thermal and environmental changes and geometrical interaction between tool and workpiece, which are generally overlooked in conventional machining, have to be carefully considered in precision processes.

The required accuracy in precision manufacturing is often achieved by use of process parameters determined offline and by manual or limited feedback control of the process. However, as the lower limit for the surface finish tolerances decreases, online estimation of parameters and a better control system is required. The use of a pc-based adaptive controller is suggested in this work, since this technique is well suited for processes with varying parameters.

Controller Architecture

The outline of the single point diamond turning machine is shown in Figure 1. A linear encoder measures the position of the cross-feed table. A capacitance gauge measures the position of the diamond tool. An AE sensor is used to monitor the machining condition.

Figure 2 shows the basic architecture of the proposed adaptive controller. It is composed of two loops. The first one is the basic feedback loop of controller and process. The second one is responsible for the real-time estimation of process parameters using the information from sensors and for adjusting the controller according to changes in the process. This is an automated way of process modeling and design. The adjustment mechanism is an online solution to a controller design problem for a process with known parameters. The estimator can be based on a conventional recursive algorithm or it can be an expert system in which the changes in parameters are defined following a set of rules and previously collected data. Different sampling rates can be used for the controller and the estimator.

Due to the nature of the controller, several issues have to be considered. The adjustment mechanism has to be designed so it updates the controller in a way that the resulting closed-loop system is always stable. Since the controller design is performed in real time, the computer implementation of the controller and its design algorithm has to be properly made to reduce computational delays. The estimator has to be designed to obtain a model of the process that is relevant to the task of control system design and also has to keep track of the changes in the process. Therefore the data used by the estimator have to be carefully filtered and we have to consider how much old data must be used to make the estimation.

Although some of these issues can be solved by careful theoretical design of the control system, most of them will have to be approached in an ad hoc manner and the performance of the improved control system will be verified by simulations and experimental tests.

Future Work

Only the basic architecture of the controller was presented. Detailed design of the controller will be conducted, followed by computer simulation and finally physical implementation, testing and validation of the control system.

References
[1] Lee, Y. and Dornfeld, D. A., "Application of Open Architecture Control System in Precision Machining," *31st CIRP International Seminar on Manufacturing systems*, Berkeley, CA, May 1998.
[2] Nakao, Y., "Precision Control of Single Point Diamond Turning Machine using Intelligent Controller," *Laboratory for Manufacturing Automation Research Reports*, UC Berkeley, 1998.
[3] Astron, K. J. and Wittenmark, B., "Adaptive Control", 2nd edition, Menlo Park, CA, Addisson-Wesley Publishing Company, Inc., 1995.

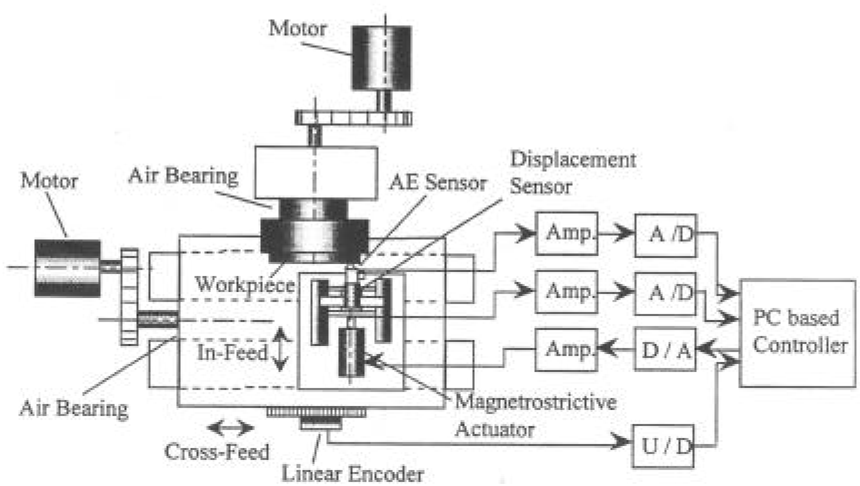

Figure 1. Outline of Single point Diamond Turning Machine

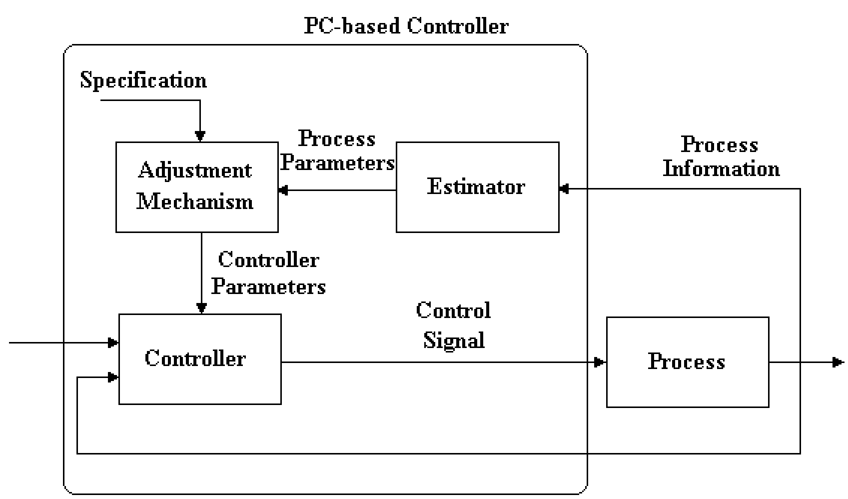

Figure 2. Block Diagram of the Controlled System