Integrated design methodology for high-precision/speed servomechanisms

M-S Kim1 and S-C Chung2*

1Department of Mechanical Design and Production Engineering and
2School of Mechanical Engineering, Hanyang University, SungdongGu, Seoul, Republic of Korea

The manuscript was received on 4 June 2004 and was accepted after revision for publication on 5 May 2005.

DOI: 10.1243/09544060/SX31634

Abstract: An integrated design method for a high-precision/speed servomechanism including interactions of mechanical and electrical subsystems is proposed in this article. On the basis of the multiobjective optimization method, a non-linear optimal design procedure of the mechanical subsystem is performed simultaneously through the design process of the electrical subsystem satisfying the desired performance. Mechanical and electrical constraints have been formulated according to design requirements. Both mechanical and electrical parameters are considered as design variables. Validity of the integrated design problem is verified on the different application areas. Parametric studies of the design variables have also been conducted in this article. Case studies show that the integrated design method for an x-y positioning system satisfies the desired high-precision/speed performance.

Keywords: Abbe offset, contour error, digital control, mechatronic system, multiobjective optimization, PTP motion, stability, servomechanism, x-y positioning system, z transform

1 INTRODUCTION

Information storage devices such as HDDs, DVDs, and CD-ROM drives have increased the need for high-precision/speed servomechanisms. Servomechanisms of assembly equipments in the semiconductor industry demand high-speed motion of 120 m/min peak speed and 30 m/s² rated accelerations. In addition, high-speed machine tools require servomechanisms providing >40 m/min feedrate and 20 m/s² peak accelerations [1]. Demanding specifications exceed the axis motion capabilities of conventional ones. It is indispensable to devise a special design concept to fabricate high-precision/speed servomechanisms.

Servomechanisms are typical mechatronic systems composed of mechanical and electrical subsystems. Performance of the mechatronic system depends upon interactions of those subsystems [2]. According to the component design methodology

[3], which focuses on the design or optimization of each subsystem, it is impossible to obtain the optimum performance of the mechatronic system because of the assumption of independence between components.

Ziegler and Nichols [4] developed the tuning method of PID controllers most generally used in industrial components. Chiu and Tomizuka [5] formulated the contouring control problem in the 'task' coordinated frame to improve the contouring performance of servo controllers. Koren [6] introduced the cross-coupling controller to push the actual position onto the desired path. Ebrahimi and Whalley [7] studied simulation, modelling, and analysis of the mechanical subsystem of servomechanisms. However, limitations of performance depend not only on specifications of mechanical subsystems, but also on characteristics of electrical subsystems. Simultaneous optimization of the electrical and mechanical subsystems has to be performed to obtain the optimal performance.

Some systematic approaches for the integrated design concept for various mechatronic systems have been reported so far. Chang and Chung [8] have studied the integrated design methodology for