INTEGRATED TUNING OF A ROBUST CONTROLLER FOR LINEAR SERVOMECHANISMS

Seong-Hwan Hong\textsuperscript{1}, Seung-Chul Kim\textsuperscript{1} and Sung-Chung Chung\textsuperscript{1,}\textsuperscript{*}
Hybrid System Design & Control LABoratory
Department of Mechanical Engineering
Hanyang University, Sungdong-Gu, Seoul 133-791, KOREA

ABSTRACT
In order to design a high-performance controller with excellent positioning and tracking performance, an optimal tuning method based on the integrated design concept is studied. DOBs, feedforward controllers and CCC are applied to control the bi-axial linear servomechanism. To derive accurate dynamic models of mechanical subsystems equipped with linear servos for the integrated tuning, system identification processes are conducted through the sine sweeping. An optimal tuning problem with stability, robustness and overshoot constraints is formulated as a nonlinear constrained optimization problem. Optimal gains are obtained through the SQP method. Experimental results confirm that both tracking and contouring errors are significantly reduced by applying the proposed controller and integrated tuning method.

KEYWORDS: cross-coupled control, disturbance observer, feedforward controller, linear motor, integrated tuning

INTRODUCTION
High-speed/precision servomechanisms are widely used in mechatronics, IT, manufacturing and FPD (flat panel display) industries. The positioning and tracking accuracy in high-speed motion is important for the fabrication of feeddrive systems. In the servomechanism with linear motors, the accuracy is affected by dynamic characteristics such as inertia variation, external load, friction, etc. To reduce such errors, feedforward controllers and internal loop compensators are required [1]. To improve the performance of the feedforward controllers, the dynamic characteristics should be precisely identified first. A disturbance observer (DOB) as an internal loop controller has been applied to improve robustness of the control system [1–5].

To improve tracking performance, a cross-coupled control (CCC) system has been used as well [4–6]. In this paper, the optimal tuning of a cross-coupled controller linked with the feedforward controller and the DOB is studied to reduce positioning and tracking errors of linear servos by using the previously developed integrated tuning methods [4,6,7–9]. In this tuning method, parameters of the mechanical subsystem are specified according to the fabricated mechanical subsystem parameters. To derive an accurate dynamic model of the mechanical subsystem of the linear servo, system identification process is conducted by the sine sweeping [10]. A velocity and acceleration feedforward controllers are applied to reduce tracking errors. A multiplicative uncertainty model is used for the DOB [1,3]. The CCC control system for an arbitrary curve, which is combined with the feedforward controller, is formulated by a state-space equation based on a series of linear motion trajectories. Finally, using the results of the optimal tuning, diagonal motion experiments are performed on a bi-axial linear servo (Fig. 1) to verify effectiveness of the proposed optimal tuning procedure. Experimental results confirm that both positioning and tracking errors are significantly reduced by applying the proposed integrated tuning method.

CROSS-COUPLLED CONTROL
In coupled control systems, contour errors are increased due to mismatched dynamic variables and loop gains. As the CCC connects orthogonal axes through feedback of contouring errors, better contouring accuracy is obtained than conventional controllers [4–5, 11]. In order to construct the CCC, time varying cross-coupling gains depending on a path trajectory should be clearly identified [4, 11]. In case of...