IDENTIFICATION OF THERMAL CHARACTERISTICS IN THE BALLSCREW ASSEMBLY

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INTRODUCTION

Precision machinery consists of feed drives and structural elements. In the ballscrew driven feed drive system, its accuracy depends upon thermal and geometric errors of ballscrews. The thermal error is originated from internal and external heat sources. Frictional heat generated from support bearings, ballscrew nuts and motors are internal heat sources. Ambient temperature variation is external heat source. To estimate thermal behavior of a feed drive system driven by ballscrews, frictional heat generation mechanism between balls and grooves of ballscrews should be identified accurately [1-3]

In the ballscrew driven precision machinery, to remove backlash and increase nut stiffness, preload is applied to ballscrews through a nut spacer, bigger balls, etc. As the ballscrew rotates, heat is generated because of slip between balls and grooves, viscous friction due to shear stress of lubricant, and rolling contact friction. Support bearings generates frictional heat as well. In addition, environmental temperature variation as an external heat source changes temperature distribution of the ballscrew. In this paper, to identify thermal characteristics according to preload, lubricant, thrust force and size of ballscrews, experimental setup equipped with hydraulic cylinder, loadcells, torque meters, contact and noncontact temperature sensors, LVDTs and so on is to be fabricated according to the schematic and CAD diagrams shown in Fig. 1. After dividing the ballscrew assembly with several lumped elements such as motor, support bearing #1, screw shaft #1, nut, screw shaft #2 and support bearing #2, a multi-input and multi-output (MIMO) thermal system is constructed. Taking motor speed, thrust force, and ambient temperature as inputs, and temperature measurements of shaft, nut, bearings and motor as outputs, transfer matrix of the thermal MIMO system in discrete domain is obtained. Using data acquisition results obtained from many operating conditions and weighted parameter estimation algorithms [4], thermal characteristics of the ballscrew assembly can be identified well.

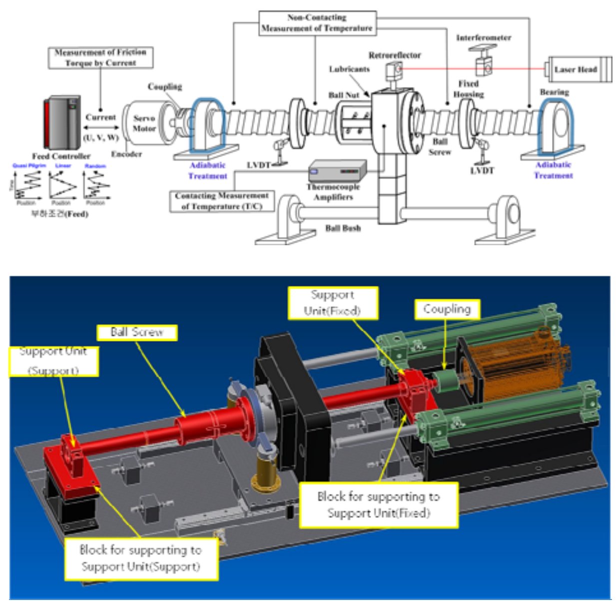

FIGURE 1. Experimental setup for measurement of ballscrew thermal characteristics.

THERMAL CHARACTERISTICS

Assuming temperature of the ballscrew nut area is uniform, heat balance equation of a lumped control volume of the nut area with internal and external heat sources is given by

$$C_h \frac{dT(t)}{dt} = \dot{Q}_{in} - \dot{Q}_{out} \tag{1}$$

where internal and external heat sources are as follows:

$$\dot{Q}_{in} = \phi \omega M_f = \phi(\frac{2\pi N}{60})M_f$$
$$\dot{Q}_{out} = \alpha_m A\,[T(t) - T_o(t)] \quad (2)$$

In Eq. (2), N , M_f , α_m and A are rotational speed, frictional torque, convection coefficient and surface area of the ballscrew, respectively. Single-input single-out (SISO) transfer function is given by

$$G(s) = \frac{T(s)}{\dot{Q}_{in}(s)} = \frac{1}{\alpha_m A}[\frac{1}{\tau s + 1}];\ \tau = \frac{C_h}{\alpha_m A} \quad (3)$$

Nut temperature is given by

$$T(t) = L^{-1}[G(s)\dot{Q}_{in}(s) + \alpha_m A G(s) T_o(s)] \quad (4)$$

In Eqs. (1)~(4), A, C_h and ω are known parameters according to operating conditions. Comparing measured input-output variables with Eq. (4), we can estimate ϕ, α_m, M_f and $\dot{Q}_{in}$ for the SISO lumped ballscrew nut area model.

Applying the above SISO relationship to several lumped elements such as motor, support bearing #1, screw shaft #1, nut, screw shaft #2 and support bearing #2, a MIMO thermal system is constructed. Taking motor speed, thrust force, and ambient temperature as inputs, and temperature measurements of shaft, ballscrew nut, bearings and motor as outputs, transfer matrix of the thermal MIMO system in discrete domain is obtained as follows:

$$G_{ij}(s) = \frac{T_i(s)}{\dot{Q}_{in,_j}(s)} \quad (5)$$

Using data acquisition results obtained from Fig. 1 under many operating conditions and weighted parameter estimation algorithms [4], we can identify thermal characteristics of the ballscrew assembly.

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