INTRODUCTION
Precision machinery equipped with ballscrews is widely used in the manufacturing, machine tool and semiconductor industries. Friction is very nonlinear at velocity reversals. Tracking errors due to friction degrade positioning accuracy according to operating speed. At low speed operation, the friction force is a hysteresis function of the position in the presliding regime. For high speed motion, the friction is a nonlinear function of velocity in the sliding regime.

To compensate for friction forces, model-based feedforward compensator, disturbance observer (DOB), adaptive control, repetitive control have been studied in linear servos [1~3]. For good feedforward control using the control structure shown in Fig. 1, exact identification of friction is required first. However, friction estimation error deteriorates the control system performance. Unmodeled friction and hysteresis change of the dynamic friction degrade the feedforward control performance. Inner loop controllers with torque estimators shown in Fig. 2 have been applied for the disturbance rejection [4].

HYBRID CONTROLLER
At very low speed, friction of the presliding regime depends upon junction deformation. It consists of time varying hysteresis loop. For designing accurate servos, dynamic friction compensation through the feedforward controller is required. On the other hand, Coulomb and viscous frictions are dominant at the high speed region. Static friction model with Coulomb, viscous and Stribeck effects should be identified accurately. Then, they should be compensated completely through a hybrid controller at the high speed motion.

In this paper, the static and dynamic friction models are to be identified at the whole speed range. Generalized Maxwell-slip model [5] will be used for the dynamic friction model. A hybrid controller composed of the model based feedforward friction compensator and the model free internal loop controller linked with the modified Kalman filter shown in Fig. 3 is to be proposed for the friction compensation in the ballscrew servo. For accurate identification of friction models at low and high speed regions effectively, a special experimental setup shown in Fig. 4 have been fabricated.

In order to identify parameters of the static and dynamic friction models, lots of time and efforts are required. An automatic friction parameter gathering method linked with the hybrid controller will be devised through connection between the xPC target and the experimental setup. In addition, accurate servo modeling will be conducted for better friction identification. Performance of the proposed hybrid friction controller will be verified at low/high-speed tracking and velocity reversals.

REFERENCES

FIGURE 1. Model based Feedforward Friction Control System.

FIGURE 2. Observer based Inner Loop Friction Control System.

FIGURE 3. Hybrid Friction Control System with Modified Kalman Filter.

FIGURE 4. Experimental Setup of the Ballscrew Servo.