Fast Nanometer Positioning System by Combining Fast Resonant Mode and Accurate Piezostack Direct Drive

A. Santoso, J. Peirs, F. Al-Bender, D. Reynaerts
KU Leuven, Department of Mechanical Engineering, Belgium
Anindito.Santoso@mech.kuleuven.be

Abstract

Product design and production technology in general have been showing great trends towards miniaturization. Several products which follow this direction are: mobile phone, semiconductor chips, and tablet PC. In order to support these growing industries, fine positioning systems are crucial as an enabling technology for the manufacturing, inspection, or operation of the products.

The ultrasonic piezomotor of KU Leuven is designed for fine positioning with sub-micrometer accuracy. To operate the motor, its contact point is first preloaded against the target slider. The piezos are then excited by an electrical signal to create an elliptical vibration of the contact point. This vibration translates to stick and slip operation and results in a macroscopic velocity of the slider. However aside from its attractive offer, e.g. high speed and no electromagnetic field, the motor is also known for its nonlinearity; varying characteristic depending on its contact materials; material wear; and dependency on operating temperature. These can form a barrier for applications targetting nm and sub-nm positioning.

To tackle the limitations of ultrasonic piezomotors, the Multi-Drive system has been developed which combines the high speed capability of ultrasonic piezomotors (resonant mode) with the fine positioning capability of piezostacks (direct-drive mode).. The two modes are operated simultaneously

with capability of **speed above 100 mm/s** and **positioning accuracy of 2 nm**. For the resonant mode, combination of **phase control** and **amplitude control** is applied to compensate for its nonlinearity. For the direct-drive mode we apply our custom **Maxwell Slip algorithm** which enables **hysteresis compensation of two piezostacks working in collaboration**. The performance of each mode when individually and simultaneously operated is evaluated by an experiment.

The resonant mode excitation signal mainly consists of two high-frequency sines with adjustable amplitude and phase difference. The amplitude control produces lower heat dissipation and less wear, compared to the phase control. However during amplitude control, there will be deadzone nonlinearity that limits the minimum operating voltage. This deadzone limit can vary during operation due to small variation of the preload between the motor and slider, and variation of contact material characteristics at contact spot. To overcome this situation, we propose of working in phase control when the commanded speed output is low, while vice versa working with amplitude control when higher velocity is expected.

Piezostack actuators are known to have a nonlinear characteristic in the form of hysteresis. It is a relatively complex hysteresis due to the fact that the stack follows a different loading curve at the initial time compared with later operation. In the Direct-Drive mode, two piezostacks are being utilized. One of them acts for negative direction, while the other acts for positive direction. To handle this, a modification is applied to the existing Maxwell Slip based compensation algorithm for one piezostack.

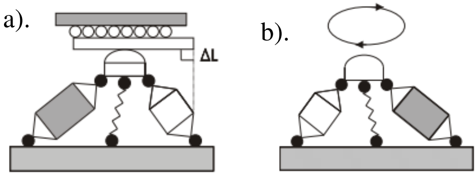

Fig. 1: *(a) Direct-drive and (b) resonant drive modes*

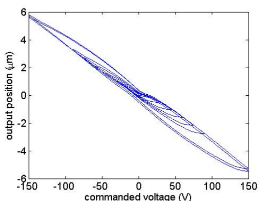

Fig. 2: *Hysteresis of two collaborating piezos*