Non-linear position-varying control for an eccentric shaft Z-actuator with pre-tension

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Abstract

A compact eccentric shaft Z-actuator for high-precision machinery is proposed to drive a pre-tensioned body, see Figure 1, for which a simplified model is shown in Figure 2. The pre-tension force prevents play and pulls back the body to its upper end stop in case the motor is disabled. Other major advantages are (1) strong rejection of disturbance forces thanks to a large equivalent mass of the inertia, (2) low holding torque and power dissipation when the body is kept at a desired position, (3) sub-micrometer accuracy without any significant friction, and (4) compact building height.

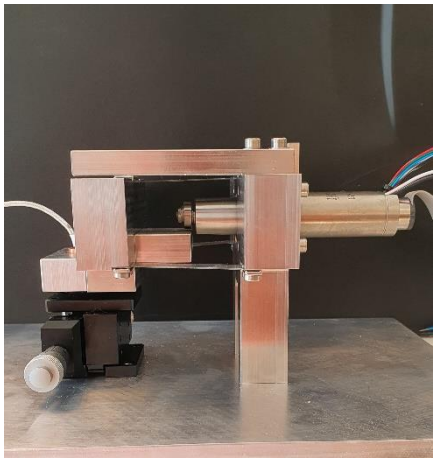

Figure 1: Eccentric shaft Z-actuator (side view).

The large ±60° stroke of the motor angle induces non-linear and position-varying system dynamics which makes feedback control challenging. Figure 3 shows some frequency response functions (FRFs) of the system from motor torque T to displacement sensor Δz at different motor angle positions. These FRFs show position-dependencies in (1) the stiffness line, (2) the mass line, and (3) the resonance frequency due to the finite stiffness of the motor coupling. A two-step feedback linearization control method is applied to solve the first two non-linearities. Loop shaping techniques and an adaptive notch filter are used to obtain robust stability against the position-varying resonance frequency. A closed-loop bandwidth of 40-80 Hz has been realized. Time-domain experiments with several reference profiles show excellent performance.

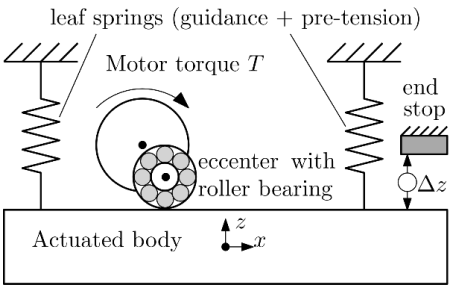

Figure 2: Simplified model (front view)

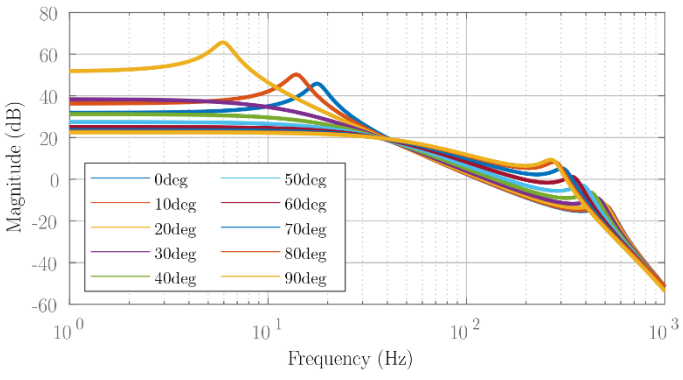

Figure 3: Frequency response functions from T to Δz at different positions.