Dynamic analysis of axially preloaded piezoelectric actuators with non-smooth behavior

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Abstract

Piezoelectric actuators are of prime importance in the ultra-precision driving and positioning. During operation, brittle piezoelectric ceramics are usually protected from tensile stresses by mechanical preload via elastic mechanisms. The contacts of the preload mechanisms with the piezoelectric stacks exist discontinuity even impact when the driving voltage encounters impulsive changes, resulting in highly nonlinear dynamics and undesired vibration. This study intends to capture the non-smooth behavior and propose an accurate modelling methodology. First, the piezoelectric stack is treated as a force generator characterized with mass-spring-damping properties, and the influence of preload on output performance is taken into consideration. Second, contact force between the preload mechanism and the piezoelectric stack is explored according to preload condition, and then nonlinear dynamical model of the piezoelectric actuator is proposed. Finally, the dynamic response of a piezoelectric actuator is simulated when an asymmetric saw-tooth voltage is applied. The results show that the stiffness of the elastic mechanism and the preload force should match the piezoelectric stack to meet different drive requirements.

Keywords: Piezoelectric actuator, mechanical preload, contact, nonlinear dynamics