Finite element analysis with experimental validation of the piezoelectric actuation of a cantilever beam

Concepts using the finite element method are defined for the piezoelectric PZT material and the adhesive bonding. Experimental results validate the numerical ones. Expertise is gained in the optimized conditions for dimension, geometry and positioning of the actuator.

Cu-Hai Nguyen

One of the focuses in the EMPA innovation program "Adaptive Material Systems" is to investigate the electromechanical interaction between piezoelectric actuators and vibrating mechanical structures. This preliminary project explores the flexural actuation of a cantilever beam in aluminum by a thin plate made of piezoelectric PZT (Lead-Zirconate-Titanate) ceramic material.

Finite element calculations are made with ANSYS, which has been chosen for its coupled-field capabilities. As the PZT-plate is polarized in its thickness direction but operates in the plane dimension, its input material properties are orthotropic and consist of stiffness, dielectric and piezoelectric matrices. The piezoelectric effect results in elongation and compression of the two surfaces (electrodes) of the PZT-plate, proportional to the electrical voltage and pulsating at the excitation frequency. When this PZT-plate is bonded to the beam, it transmits a pulsed bending moment into the beam, which then vibrates at the same frequency. At coincidence with one of the beam natural frequencies, resonance occurs with much extended beam vibration amplitude. The finite element analysis takes into account a physical adhesive bonding between actuator and beam, as well as beam damping conditions. A voltage of ±10 V_{peak} at an excitation frequency growing stepwise up to 5000 Hz is applied. Fig. 1 shows results for the third flexural vibration Eigenmode at 330 Hz of the Al-beam, with a maximum vibration amplitude of about 30 µm at its free end.

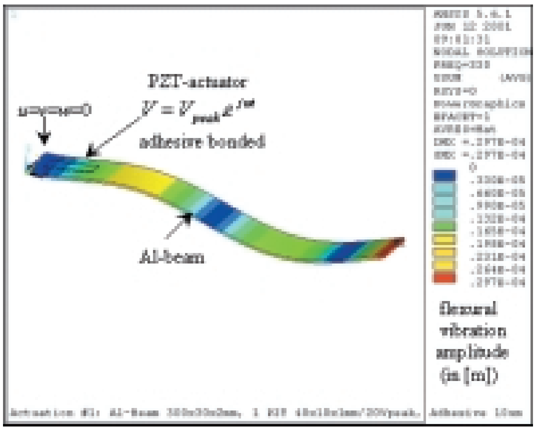

Fig. 1: *Example of finite element results for the PZT-actuated third flexural vibration Eigenmode of the Al-beam.*

Validation of the numerical results is made through parallel conducted measurements using the experimental setup shown in Fig. 2, under different configurations for the PZT-actuator. The length of the actuator has to be appropriate to vibrate the beam at all its eigenfrequencies, but its position on the beam has less influence. Comprehension of its role and impact as flexural wave guide into the beam is extended by an analytical study conducted within the main project "Multicoupling".

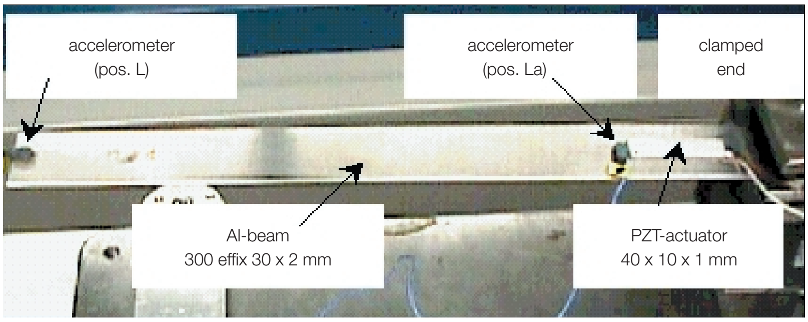

Fig. 2: *Experimental set-up of the PZT-actuation of the Al-beam.*

Contact: *cu-hai.nguyen@empa.ch*
References: *C.H. Nguyen, 6. Swiss CAD-FEM (2001)*