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A Generalized Equivalent Loading Model for Piezoelectric Elements

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Typically, an active structural health monitoring system (SHM) consists of an integrated network of actuator/sensor piezoceramic elements that inject and receive ultrasound pulses into the host structure collecting information about structural health. Although numerical simulation has been used extensively in understanding and aiding in the design of such systems, analytical models are still the primary vehicle for understanding actuation and sensing mechanisms. Being based on simplified assumptions it suffers from certain limitations with respect to its extension to SHM systems. The main assumption of equivalent loading is neglecting the mechanical coupling by replacing the piezoceramic with equivalent load(s). The present work addresses two of the limitations of this assumption, namely the effect of the thickness of the piezoceramic element on the equivalent load in dynamic setting at high frequency. This study is done via a novel formulation based on earlier work considering Lamb waves as a propagating carrier wave with superimposed modes which is not limited to isotropic media and the inclusion of the generalized loads are done via the reciprocity relation. The model results are compared with the numerical simulation results using commercial finite element software (ANSYS) for a wide range of frequencies. The applicability of the model to frequencies as large as 0,5 MHz is demonstrated. The effect of the loading on the energy partitioning between Lamb fundamental modes, without the need for prior adjustment comes as the first advantage of the presented model over the classical integral transform based models, thus enabling a direct relation for mode tuning. The second advantage is the easy inclusion of the finite frequency content of the excitation through Fourier transform, relaxing the assumption of harmonic waves propagation that prevails in the classical models enabling a more realistic signal to be modeled.

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Ключевые слова:

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