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A Fully Coupled Model for Actuation of Higher Order Modes of Lamb Waves

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Lamb waves have proven to be a valuable tool for structural health monitoring (SHM) of plate-like structures susceptible to degradation. It is well-known that the multi-modal propagation characteristics provide both challenges and opportunities. Piezoelectric transducers are widely used in SHM applications because of their low cost, small profile and strong electromechanical coupling. Properly designing a piezoelectric transducer to excite a particular mode is of great importance to successful SHM practice. The mode tuning capability of piezoelectric transducers has been studied both theoretically and experimentally in the literature for exciting A0 and S0 modes. However, the tuning characteristics of higher order Lamb waves have been studied far less. Also, the transducer is usually modeled separately from the waveguide and their coupling is typically through the in-plane surface tractions. This assumption may induce inaccuracy if the dynamics of actuator are not negligible. The presence of the transducer can also interact with the waves being generated or received, especially if the transducer footprint is substantial. Additionally, the driving circuit is not usually included in the current actuator-waveguide model and thus the power of excited waves cannot be evaluated. In this work, a fully coupled finite element analysis model created for general Lamb wave excitation using piezoelectric transducers is developed. The model comprises three components, electrical driving circuit, piezoelectric element and linear elastic waveguide. The design of the piezoelectric transducer, i.e. width and thickness, for higher order Lamb wave mode excitation is performed for both aluminum and CFRP plates. The design is optimized for both mode tuning capability and power delivery. Experiments are carried out to verify the design.

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