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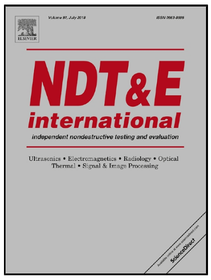

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Modeling of Delamination Detection utilizing Air-coupled Ultrasound in Wood-based Composites

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Abstract

In this work, we model ACU transmission in delaminations, with focus in the interference effects resulting from multiple ultrasonic reflections within the delamination layers and the resulting changes in the amplitude and time of flight. For this purpose, we propose a simplified analytical model, which we cross-validate with full-wave finite-difference time-domain (FDTD) simulations. Both models show a very high agreement on the predicted ultrasound waveforms, with amplitude deviations less than 0.15 dB and time deviations below 0.1 µs. The reduction of ultrasound signal amplitude at debonding was validated with experiments. A simple engineering formula in function of delamination gap and transducer frequency was sufficient to model experimental transmission values for a gap thickness range from 70 to 2000 µm with an uncertainty below 2 dB. Furthermore, consistent resonance frequencies were identified in both experiments and simulations. The use of pulsed ultrasound signals reduces undesired resonances and provides a consistent amplitude reduction across the full range of delamination gaps. Apart from interference effects, the effect of the finite size of the ultrasound transducers as well as diffraction effects were empirically investigated. As a result of these, the lateral resolution is reduced and the sound tends to propagate through the bonded region next to the delamination. Diffraction effects are strongly influenced by wood anisotropy, with lower lateral resolution in the grain direction.

- **Keywords**: air-coupled ultrasound, composite materials, debond, experiment, ultrasonic modeling