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Ultrasonic Scattering and Absorption Imaging for the Reinforced Concrete using Adjoint Envelope Tomography

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Seismic and ultrasound tomography can provide rich information about spatial variations of elastic properties inside a material rendering this method ideal for non-destructive testing. These tomographic methods primarily use direct and reflected waves, but are also strongly affected by waves scattering at small-scale structures below the resolution limit. As a consequence, conventional tomography has the ability to unveil the deterministic large-scale structure only, rendering scattered waves imaging noise. To image scattering and absorption properties, we presented the adjoint envelope tomography (AET) method that is based on a forward simulation of wave envelopes using Radiative Transfer Theory and an adjoint (backward) simulation of the envelope misfit, in full analogy to full-waveform inversion (FWI). In this algorithm, the forward problem is solved by modelling the 2-D multiple nonisotropic scattering in an acoustic medium with spatially variable heterogeneity and attenuation using the Monte-Carlo method. The fluctuation strength ε and intrinsic quality factor Q^{-1} in the random medium are used to describe the spatial variability of scattering and absorption, respectively. The misfit function is defined as the differences between the full squared observed and modelled envelopes. We derive the sensitivity kernels corresponding to this misfit function that is minimized during the iterative adjoint inversion with the L-BFGS method. This algorithm has been applied in some numerical tests (Zhang et al., 2021). In the present work, we show real data results from an ultrasonic experiment conducted in a reinforced concrete specimen. The later coda waves of the envelope processed from the 60 KHz ultrasonic signal are individually used for intrinsic attenuation inversion whose distribution has similarity to the temperature distribution of the concrete block. Based on the inversion result of intrinsic attenuation, scattering strength is inverted from early coda waves separately, which successfully provides the structure of the small-scale heterogeneity in the material. The resolution test shows that we recover the distribution of heterogeneity reasonably well.