Data-driven identification of linear viscoelastic models using frequency-dependent ultrasound measurements

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Abstract

Any time-harmonic numerical procedure on computational acoustics requires the choice of an adequate model for the constitutive law of the vibro-acoustic material. In the particular case of linear wave propagation in a viscoelastic material, common model assumptions are the classical Maxwell and Kelvin-Voigt models or the more recent fractional derivative viscoelasticity models. Typically, once the frequency-dependent constitutive model is fixed, their parameters are estimated to fit the available experimental measurements with the mechanical response of the mathematical model. This modeling methodology for viscoelastic materials suffers potentially from the epistemic uncertainty of *a priori* unsuitable model selection.

On the contrary, in the present work, the mathematical modeling of linear viscoelastic materials and, consequently, the choice of their frequency-dependent constitutive laws, are performed based uniquely on the available ultrasound experimental measurements without imposing any functional parameter dependency. This data-driven methodology requires the numerical solution of an inverse problem at each frequency of interest.

The acoustic response of a thin layer of viscoelastic material due to the time-harmonic excitations generated by a transducer has been computed numerically. In these numerical simulations, the non-planar directivity pattern of the transducer has been taken into account. In addition, to avoid the numerical pollution errors at high-frequency regime and to reduce the computational cost solving each inverse problem, the acoustic pressure field has been approximated by using a plane wave discretization. The proposed methodology on the selection of the viscoelastic model is illustrated using echo reduction and insertion loss ultrasound measurements in an underwater environment.