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CAVITY IDENTIFICATION WITH PIEZOELECTRIC SENSORS USING ITERATED EXCITATIONS AND A TOPOLOGICAL SENSITIVITY APPROACH

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Transient elastic or ultrasonic waves are preferred phenomena to probe elastic solids in applications such as geophysics or non-destructive testing. Embedded and unknown defects or heterogeneities are illuminated by waves propagating in the solid body considered while measurements of their scattered counterparts are collected on a subset of the external surface. Based on such boundary data, a wide range of algorithms aiming at detecting and reconstructing such scattering obstacles have been developed.

Following [3] the object of this talk is the transient wave-based detection and identification of cavities embedded in elastic solids using piezoelectric transducers. Such devices is placed in contact with the investigated elastic medium and is used both as the source of the illuminating elastic waves as well as, as the receiver of the associated echoes. In the emission regime, well chosen electric potentials are applied on the active elements of the transducer, which generates a wave propagating in the underlying solid. Alternatively, during the reception regime, electric potentials are recorded, they are associated to a displacement field generated by the mechanical waves illuminating the sensor .

This work addresses the identification problem within a comprehensive framework encompassing the modeling of the elastic wave propagation, the modeling of the piezo-electric transducer/sensor as well as the coupling phenomena induced by the use of such measurement device. A reciprocity identity associated with the transducer model [2] is derived to lay the foundations of the ensuing developments of this inverse scattering problem:

- First, an application of the reciprocity identity enables the proposition of a mathematically well defined iterative construction procedure of electric inputs generating waves expected to focus on the sought defects, without knowing a priori their position. As a consequence, the algorithm suggested is a time domain version of well-known time reversal algorithms.

- Next, the identification problem is investigated by way of an adjoint field-based topological sensitivity (TS) approach [1], whose mathematical justification relies on the considered reciprocity identity. The TS approach is a qualitative and computationally-efficient technique based upon the non-iterative computation of indicator functions of the sought defects. It can be related, in terms of implemented algorithm, to reverse time migration technique (RTM).

For simplicity of exposition, the studied configurations involve defects in the form of traction-free cavities and a set of 2D numerical examples based on the spectral finite-elements method is presented to assess the performances of the proposed approach in identifying embedded defects from electric measurements (see Figure 1).

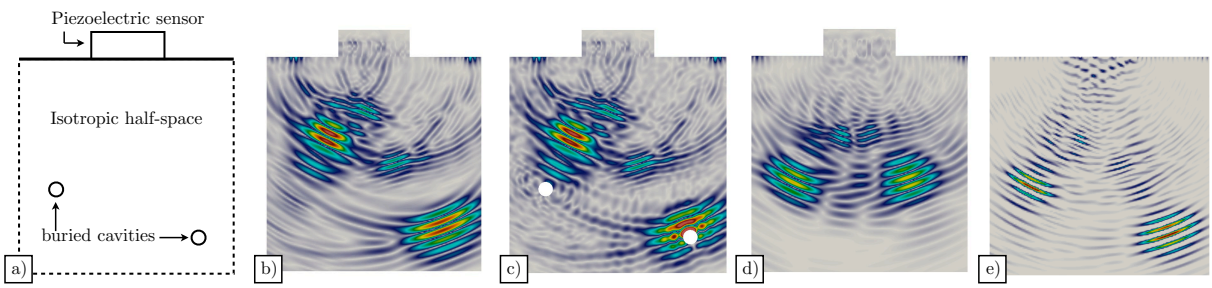

Figure 1: a) Schematic of a typical configuration where a piezoelectric sensor lays upon the probed medium. b) Snapshot of the simulated (well chosen) direct field. c) Snapshot of the (simulated) experiment in the unknown domain. d) Snapshot of the adjoint field. e) Indicator function constructed using the TS technique.

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