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Ultrasonic Testing of a Nuclear Fuel Cladding Pipe, Modelization with a Hybrid Method and Experiments

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Nuclear Fuel cladding pipes are long and thin tubes made of zirconium-alloy whose purpose is to confine the fissile material in a nuclear reactor. During their 3 year cycle in the reactor's core they must maintain their integrity while enduring severe stresses (heat, corrosion and irradiation). Nondestructive evaluations are performed at several stages of the manufacturing process. ASTM International provides recommendations regarding the Ultrasonic Testing (UT) of zirconium cladding pipes at the end of the production line[1]. The recommended setup is a pulse-echo immersion testing at frequency higher than 5 MHz where transverse and longitudinal calibration notches are used for defining alert levels with sufficient margins. AREVA NP's project is to build a numerical model of this UT in order to enhance the selectivity of the tests and reduce the cost of over-quality. This model is based on the hybridization of a semi-analytic method and a Finite Difference Time Domain (FDTD) method. They are used in conjunction with a time domain reciprocity equation which allows to back-propagate the signal from a line close to the metallic pipe as well as around a potential crack (fig. 1). Results for two positions of the back-propagation line are compared with an experimental signal recorded in a water tank (fig. 2). The flaw used in this study case is a rectangular longitudinal calibration notch. This result is the first step towards an efficient computation of received signals for many different crack positions and geometries.

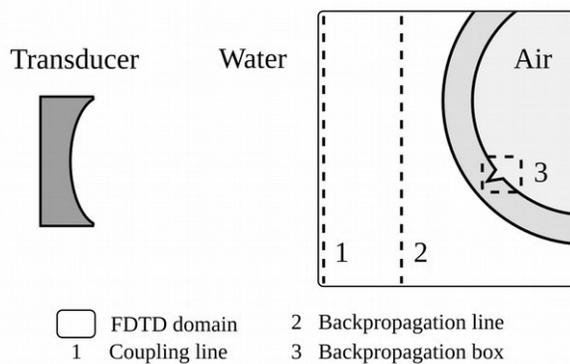


Figure 1. Numerical domains

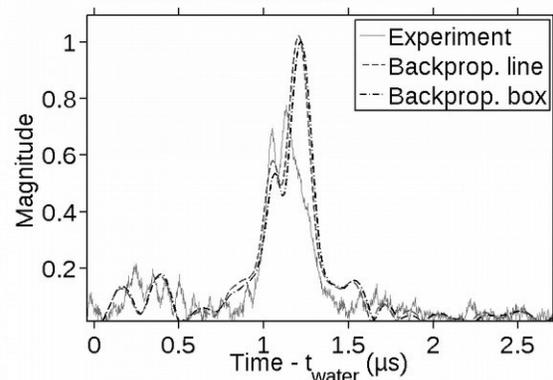


Figure 2. Received signals

References:

1. ASTM B811-13e1, Standard Specification for Wrought Zirconium Alloy Seamless Tubes for Nuclear Reactor Fuel Cladding, ASTM International, West Conshohocken, PA, 2013, www.astm.org