Simulation of an Ultrasonic Immersion Test for the Characterization of Anisotropic Materials

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Abstract

Introduction: Improving the capability of nondestructive evaluations requires the analysis of suitable models dealing with the physical and mechanical phenomena involved in the experiments. For example, ultrasonic tests may be a powerful, fast and effective method for nondestructive characterization of mechanical properties of materials. This requires the study of the related elastodynamic problems, which may present various difficulties especially in presence of complex behaviors (anisotropy, finite deformations, damage, etc.). In this context, numerical simulations may be very helpful for design experimental set-ups and for understanding the results of the tests. In particular, here we use a numerical model for simulate an immersion ultrasonic test aimed at characterizing anisotropic materials; to do this, the evaluation of ultrasonic speed of longitudinal and transversal waves in various direction is needed. The analysis is specialized to the case of fiber-reinforced composite materials with a single layer of carbon fibers (CFRP). This material may be modeled as transversely isotropic, with an axis of transverse isotropy coincident with the axis of the fibers (Figure 1). The accuracy of the numerical model has been investigated by a comparison with experimental data. Use of COMSOL Multiphysics: We used the General Form PDE interface which may solve many classical PDE, including some wave equations. The motivations of this choice are mainly two: 1) one can model the fluid (water) and the solid (fiber-reinforced composite) domains; 2) one can easily change the predefined form of the PDE for adapting it to his elastodynamic mechanical model. We used the time dependent solver for the analysis in the time domain: this approach is suitable for problems like elastic waves propagation. The parameters of the model come from ultrasonic immersion tests on samples of CFRP. Results: The analysis is focused on the determination of the speed of ultrasonic longitudinal and transversal waves through the evaluation of their time of flight. Furthermore, the numerical model allows for: 1) the identification of the areas of maximum intensity of the ultrasound beam and the measurement of the phase velocity and the phase angles (Figure 2 and Figure 3), this aims to define optimal positions of the transducers in the experiments; 2) the analysis of the effects of rotations of the specimen and/or of the transducers on the ultrasonic propagation, for improving the management of the tests; 3) the determination of planes of symmetry of the mechanical response; 4) the determination of the angles of incidence of the ultrasound beam for generating longitudinal and transverse waves with maximum energy inside the sample. Conclusion: The proposed numerical model is innovative in the field of ultrasonic NDT since it is 3D model and considers the coexistence of two phases (the fluid and the solid). The numerical results are comparable with those obtained experimentally: this validate the capability of the model for prediction and interpretation of experimental data. From this

starting point may stem a number of future applications like, for example, the analysis of ultrasound propagation in anisotropic materials with defects, damages, and initial stress (residual and/or applied).

Reference

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Figures used in the abstract

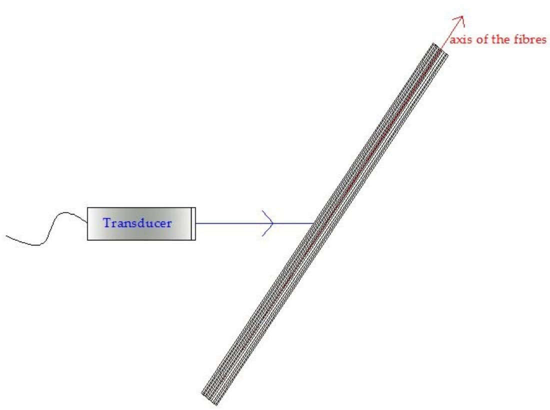

Figure 1

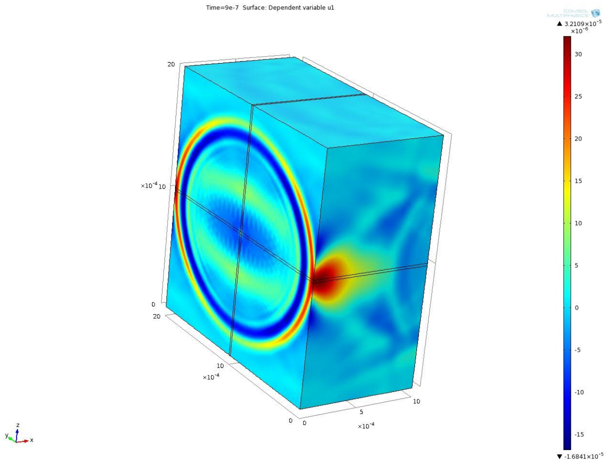

Figure 2

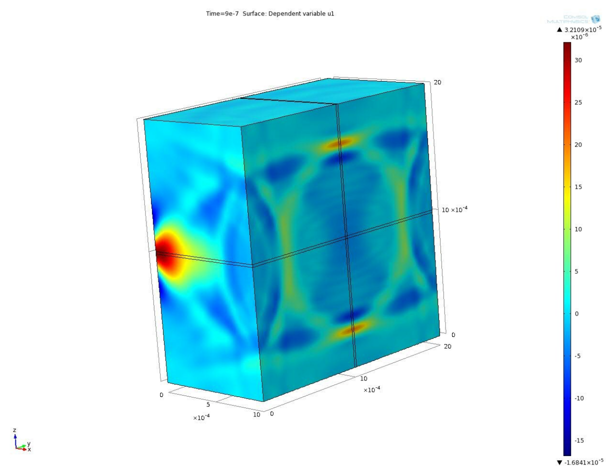

Figure 3