3D Ultrasonic Simulations For Pulse Echo And Pitch Catch Testing

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Abstract

Ultrasonic nondestructive testing (NDT) is extensively used in fields like medicine, oil and gas, and aerospace to inspect materials without causing damage. However, developing experimental setups and prototypes can be costly and time-consuming. This study employs advanced computational modeling to simulate ultrasonic wave propagation, providing a cost-effective alternative to physical prototyping.

A COMSOL 3D multiphysics model is utilized to simulate ultrasonic acoustic transducers in a water tank. The model couples a piezoelectric transducer with an elastic wave model via a piezoelectric effect coupling module. The interaction between the acoustic wave in the elastic medium and the fluid is modeled using an acoustic-structure boundary coupling. Simulation results are compared with experimental data from the Acoustic Intensity Measurement System (AIMS) tank to validate the model. This comparison helps understand the impact of frequency, material properties, and piezoelectric transducer design on acoustic wave propagation, reducing the need for extensive physical prototyping and thereby cutting costs and improving efficiency.

Key modeling techniques include defining element mesh size based on compressional and shear velocities to ensure accurate simulation results. Strategies for simplifying the model to reduce computational load without compromising accuracy are explored, such as reducing the number of elements and using symmetry. The study also examines the impact of different boundary conditions on the simulation. It compares hard wall boundary conditions versus specified impedance boundary conditions and the use of absorbing layers to minimize reflections and reduce model size. These techniques enhance simulation efficiency and ensure reasonable runtimes. Numerical errors, a common challenge in complex simulations, are addressed by providing methods for identifying and mitigating these errors, ensuring reliable simulation results. This modeling work aids in designing acoustic transducers and sensors for various applications, streamlining workflows, and significantly reducing prototyping costs.

In summary, this comprehensive modeling approach advances ultrasonic NDT technology, offering valuable insights into transducer design and enhancing efficiency in the development process. By leveraging simulation, the study provides a powerful tool for improving ultrasonic testing while reducing costs and development time.

Figures used in the abstract

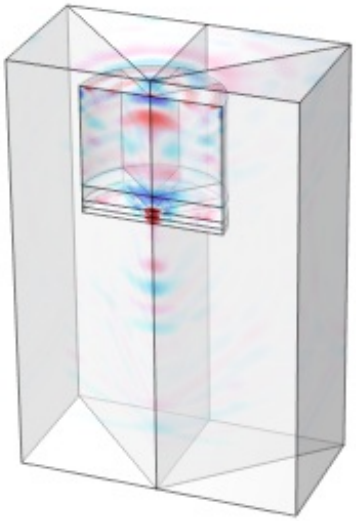

Figure 1 : Acoustic wave propagation in elastic medium and fluid.