Optimization Of Guided Wave Mode Selection For Enhanced Corrosion Detection

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Abstract

Guided wave technology offers a promising approach for non-destructive testing (NDT), particularly in the detection of corrosion in critical structures such as pipelines. This study focuses on utilizing COMSOL Multiphysics to simulate guided wave propagation for optimizing corrosion detection. The primary objective is to identify the most effective guided wave modes and understand their sensitivity relative to various defect geometries, ultimately improving the accuracy and reliability of corrosion detection. The research employs COMSOL Multiphysics, leveraging its powerful simulation capabilities to model guided wave propagation in pipes of different geometry. The study encompasses several key stages:
1. Model Setup
• Developing a comprehensive 3D model of the test structure, incorporating realistic geometries and material properties
• Introducing various types of corrosion defects, including uniform thinning, pitting, and crack-like flaws, to evaluate their impact on guided wave propagation
2. Mode Selection
• Simulating different guided wave modes, such as Lamb waves and shear horizontal (SH) waves, across a range of frequencies in the time domain by using the structural mechanics module
• Utilizing dispersion curves to identify optimal wave modes that offer the best trade-off between sensitivity and attenuation
3. Sensitivity Analysis
• Performing a parametric study to assess the sensitivity of each wave mode to the presence and geometry of corrosion defects by using batch processing on a cluster/ server
• Quantifying the influence of defect size, shape, and location on the amplitude and phase of the guided waves
4. Validation
• Comparing simulation results with experimental data obtained from ultrasonic testing on samples with known corrosion defects.
• Refining the simulation parameters to improve accuracy and correlation with empirical observations
The simulations reveal that different guided wave modes exhibit varying levels of sensitivity to specific defect geometries. Key findings include:
• Lamb Waves are particularly sensitive to uniform thinning and large-area corrosion but exhibit higher attenuation, limiting their effective range.
• Shear Horizontal Waves demonstrate superior sensitivity to localized defects such as pitting and cracks, with lower attenuation, making them suitable for long-range inspection.
The parametric study highlights the critical influence of frequency selection on defect detection capabilities. Lower frequencies provide deeper penetration and better detection of subsurface defects, while higher frequencies enhance the resolution for surface and near-surface anomalies.
The results underscore the importance of selecting the appropriate guided wave mode based on the specific characteristics of the structure and the expected defect types. By understanding the

interaction between guided waves and defect geometries, inspectors can tailor their NDT strategies to achieve higher detection accuracy. The study also identifies potential limitations and areas for further research, such as the impact of environmental conditions on wave. This research demonstrates the effectivity of COMSOL Multiphysics in simulating guided wave propagation for corrosion detection. By identifying the most sensitive guided wave modes and understanding their interaction with different defect geometries, the study provides valuable insights that can enhance the reliability and precision of NDT methods.

Reference

JL.Rose, Ultrasonic Guided Waves in Solid Media. Cambridge University Press; 2014.

K. F. Graff, Wave Motion in Elastic Solids, Dover Publications Inc., 2003

Figures used in the abstract

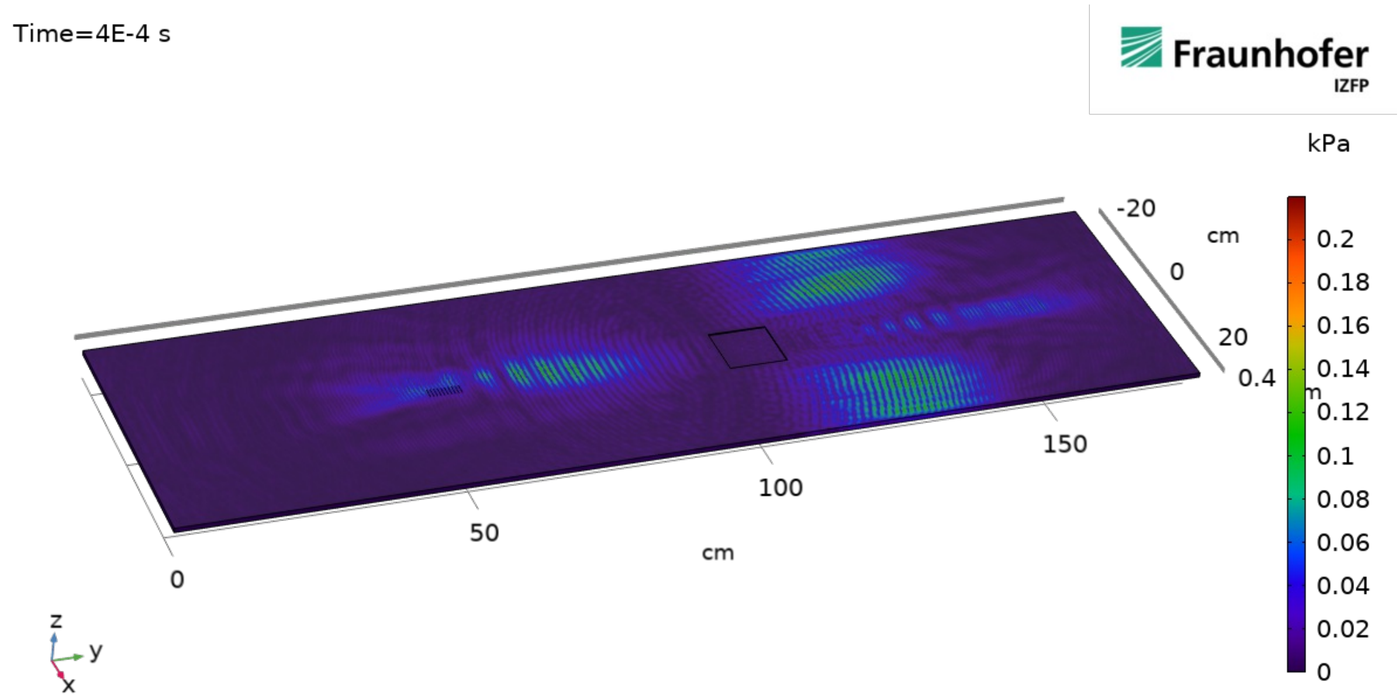

Figure 1