

Innovative Fusion for Pipeline Corrosion Detection: Fiber Optic Sensing, Physics-Based Modeling, and Deep Learning

Pengdi Zhang¹, Enrico Sarcinelli¹, Abhishek Venketeswaran², Ruishu F. Wright², Khurram Naeem¹, Nageswara Lalam², Paul Ohodnicki¹

¹Department of Mechanical Engineering and Materials Science, University of Pittsburgh

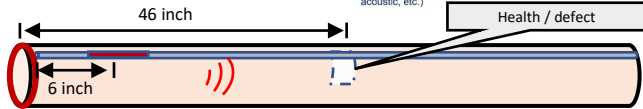
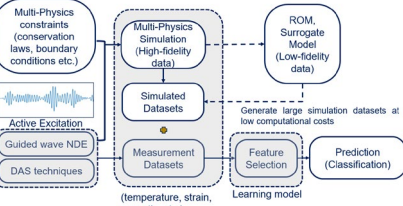
²National Energy Technology Laboratory, 626 Cochran Mill Road, Pittsburgh, PA, USA 15236

Motivation:

Current status: Invisibility of underground pipelines prior to Failure and the requirement for long-range monitoring of the underground pipelines.

Improvement: Combine guided wave ultrasonics and distributed fiber optics for structural health monitoring (SHM) and nondestructive evaluation (NDE) of pipeline conditions.

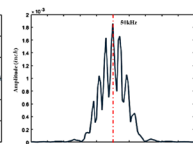
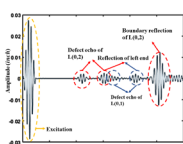
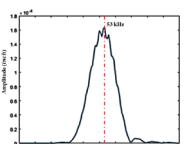
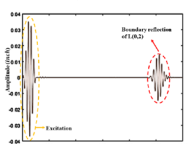
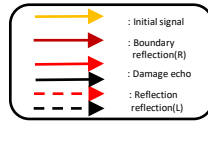
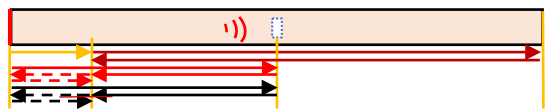
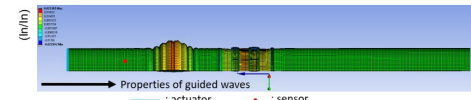
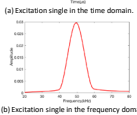
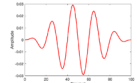
Project Outline:



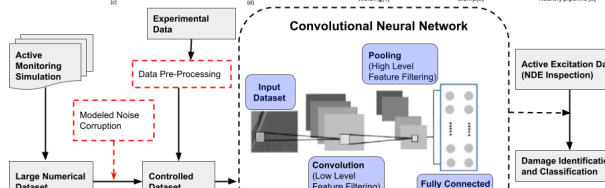
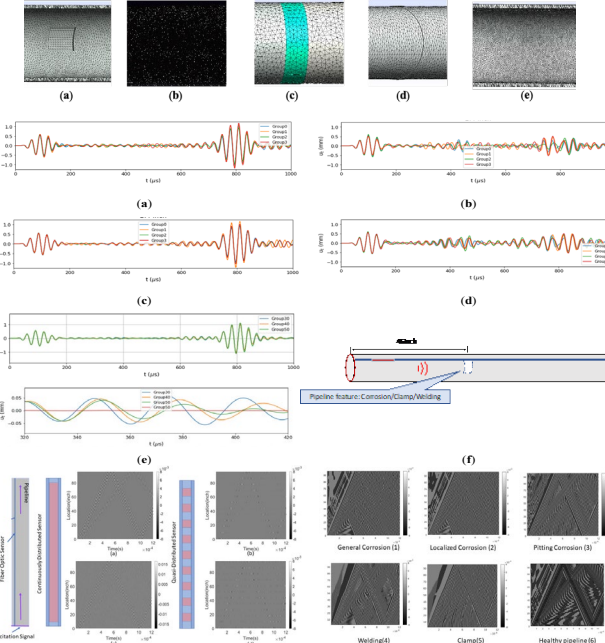
- Software: ANSYS, transient structural module;
- Method: Dynamic implicit analysis;
- Target: Guided wave propagation and simulated optical fiber sensing.

Excitation :

- Position: Left side of pipeline (yellow label)
- Signal: 50 kHz 5 cycle sinusoidal signal modulated with a Hanning window
- Loading method: Based on global coordinate system, load excitation in Z direction;



Categorization of pipeline corrosion:



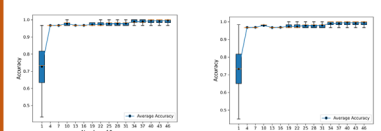
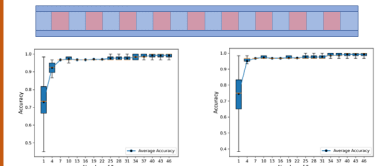
Purely High-Fidelity Simulation Data: Training Without Noise:

Real Label \ Predicted Label	Healthy	Localized	General	Clamp	No defect
Healthy	0.92%	0.00%	0.00%	0.00%	0.00%
Localized	0.00%	100.00%	0.00%	0.00%	0.00%
General	0.00%	0.00%	100.00%	0.00%	0.00%
Clamp	0.00%	0.00%	0.00%	100.00%	0.00%
No defect	0.00%	0.00%	0.00%	0.00%	100.00%

Hybrid Experimental-Simulated Data: Training with Added Experimental Noise:

Real Label \ Predicted Label	Healthy	Localized	General	Clamp	No defect
Healthy	12.2%	0.00%	0.00%	0.00%	0.00%
Localized	0.00%	97.1%	0.00%	0.00%	0.00%
General	0.00%	0.00%	97.1%	0.00%	0.00%
Clamp	0.00%	0.00%	0.00%	100.00%	0.00%
No defect	0.00%	0.00%	0.00%	0.00%	100.00%

Quasi-Distributed Sensor



The prediction accuracy changes with different sensor numbers under different signal-to-noise ratio

Publications: [1] Zhang, P., Venketeswaran, A., Wright, R. F., Lalam, N., Sarcinelli, E., and Ohodnicki, P. R., 2023, "Quasi-Distributed Fiber Sensor-Based Approach for Pipeline Health Monitoring: Generating and Analyzing Physics-Based Simulation Datasets for Classification," *Sensors*, **23**(12), p. 5410.

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