Crack Detection and Characterization in Polyethylene Pipes: Machine Learning Supported Ultrasonic Guided Wave Approach

PHMSA Pipeline and Hazardous Materials Safety Administration

Said El-Hawwat, Jay Shah, Dr. Hao Wang
Department of Civil and Environmental Engineering , Rutgers, The State University of New Jersey

RUTGERS THE STATE UNIVERSITY OF NEW JERSEY

Main Objective

This project was awarded to Rutgers University in order to develop nondestructive testing (NDE) methodology for condition assessment of polyethylene (PE) pipe defects through experimental tests, numerical simulation, and machine learning.

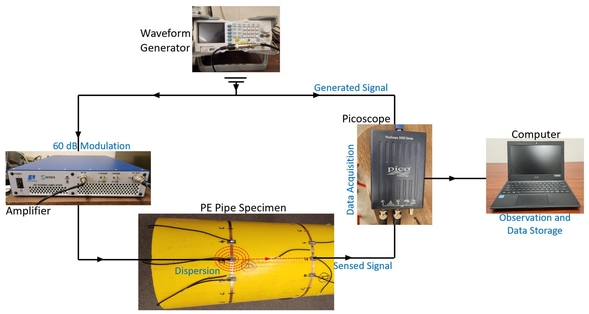


Figure 1. Experimental Setup

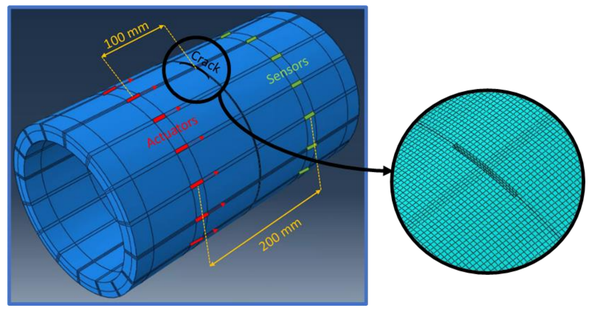


Figure 2. Finite Element Model

Project Approach/Scope

Ultrasonic guided wave testing is performed on PE pipe specimens with a controllable crack defects. The frequency of the inspecting signal was optimized through wave dispersion and attenuation analysis. Numerical simulations are conducted to simulate wave propagation and create synthetic database for training of machine learning models. The accuracy of classification algorithm for crack depth and length is evaluated through experimental results.

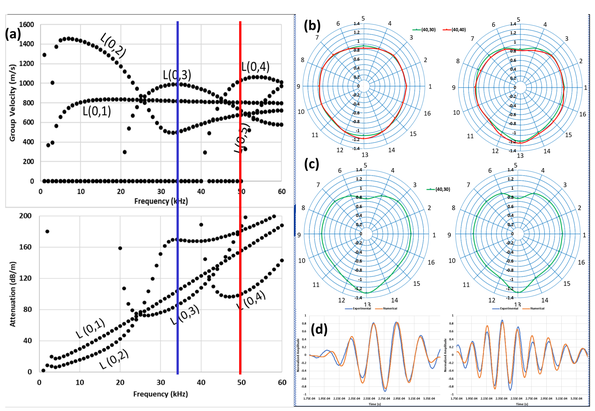


Figure 3. (a) Group Velocity and Attenuation Dispersion Curves, (b) Numerical and (c) Physical Damage Detection, (d) Cross Correlation

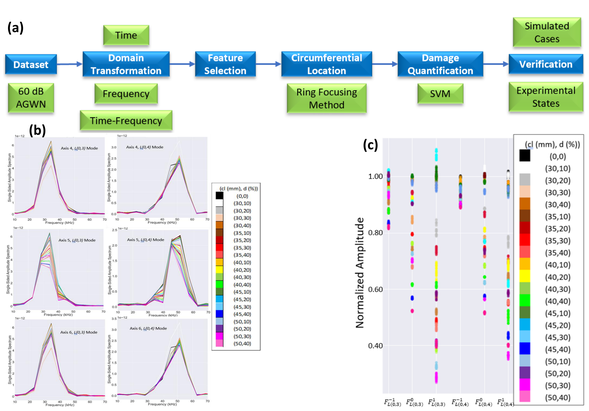


Figure 4. (a) Analysis Procedure, (b) Frequency Domains in Synthetic Database, (c) Normalized Frequency Domain Features

Expected Results or Results to Date

Three separate ML models were executed using SVM (Support Vector Machines) over the normalized frequency domain features. These include 6D SVM, 2D SVM over the normalized energies at each mode, and 2D SVM over the normalized peaks at each mode. Classification was deemed accurate for all three. Model verification was conducted using numerically generated validation cases and experimental results.

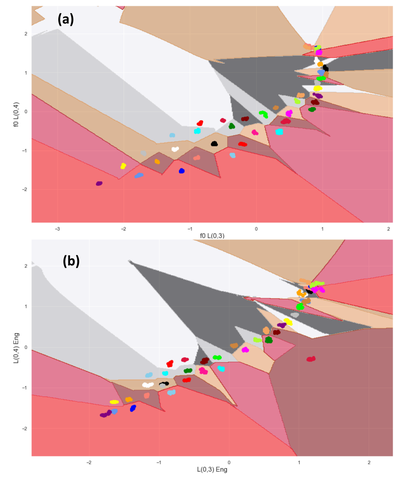
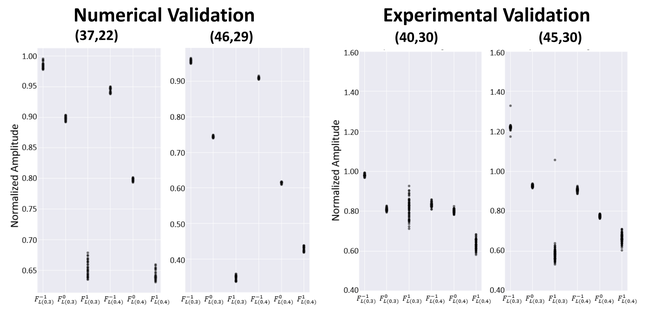


Figure 5. SVM Hyperplanes and Observations (a) Normalized Frequency Peaks (b) Normalized Frequency Energy



Validation State	Classified Damaged State 6D SVM	Classified Damaged State Central Frequency Bins	Classified Damaged State Sum of Frequency Bins
(37,22)	(35,25)	(40,20)	(40,20)
(46,29)	(45,30)	(45,30)	(45,30)
(34,40)	(35,40)	(35,40)	(35,40)
(42,25)	(40,20)	(40,20)	(40,20)
(32,11)	(30,5)	(50,5)	(45,10)

Validation State	Classified Damaged State 6D-SVM	Classified Damaged State Central Frequency Features	Classified Damaged State Frequency Sum Features
(40,10)	(0,0)	(35,10)	(0,0)
(40,30)	(50,25)	(50,20)	(30,30)
(45,10)	(0,0)	(45,5)	(35,5)
(45,20)	(45,30)	(45,20)	(45,10)
(45,30)	(50,35)	(45,20)	(45,20)

Figure 6. Experimental and Numerical Validation of Models

Acknowledgments

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