ABSTRACT

This study presents machine learning based framework for guided wave based detection of structural damages using minimal experimental data and sparse sensing. Guided waves have high damage sensitivity can propagate over long range. This makes them ideal for structural health monitoring applications. However, extracting damage information from guided wave propagation data - particularly for multiple damage scenarios and geometrically complex structures – remains a challenging inverse problem. Such problems are generally solved using machine learning. However, such an approach requires a huge training dataset. Generating this dataset through experiments or high fidelity numerical model is neither practically feasible nor computationally efficient. To address this challenge, this work develops damage features extracted from low-cost, low-fidelity computational simulations for machine learning, which yield satisfactory performance when validated against experimental data. The first study involves detection of multiple damages in a one dimensional wave propagation path in stiffened aluminium plate. Artificial neural network (ANN) trained solely using intrinsic mode based features extracted from simple 1D finite element simulation (FE) data at one sensing point has been shown to predict damages efficiently from the features extracted from 3D FE simulation and experimental data. Second study involves detection of multiple disbonds in a scarf joint with a top patch. This problem has been solved in two steps using probabilistic neural network and artificial neural network. Damage features have been extracted from nonlinear and mode conversion features from plain strain simulation data. The efficiency and robustness of the trained models have been demonstrated through 3D FE and experimental data. Next, a machine learning assisted baseline free scheme for damage localization in composite plates has been proposed. These studies demonstrate that with proper feature selection simpler simulation guided machine learning can facilitate robust guided wave based damage detection, even under limited experimental data and sparse sensing. This helps reduce experimental and computational burden, thus advancing practical implementation of machine learning assisted SHM.

Keywords: Guided waves, Structural Health Monitoring (SHM), artificial neural network (ANN), Probabilistic Neural Networks PNN, correlation coefficient (CC), lead zirconate titanate (PZT), Regression (R), Non-destructive evaluation (NDE)