Abstract

Guided wave based structural health monitoring (SHM) using piezoelectric transducers is considered one of the most suitable candidate for the development of the active and online monitoring technology. With the advancement in the field of artificial intelligence (AI), data-driven solutions are now considered the major requirement for intelligent and autonomous SHM systems. The research work carried out aims to discuss the challenges associated with interpreting Lamb waves responses from a plate-like structure motivating the formulation of data-driven machine learning (ML) and deep learning (DL) algorithms to analyze such complex Lamb responses. The present study is carried out in four phases, in the first phase, early ML models like ANN are adopted and the ability of handling anomalies such as overlapping echos present in the recorded Lamb wave signals from a 1.6 mm thin Al-5052 plate, is investigated. It is concluded that the performance of ANNs is strongly linked with the robustness of feature extraction and signal processing schemes adopted. In the second phase, an one-dimensional convolutional neural network (1D-CNN) is selected to improve the overall robustness, and reduce the dependency on feature extraction and signal processing algorithms. Both sequential and multi-headed 1D-CNN architectures are studied. To train the different 1D-CNN models, a diverse database is constructed consisting numerically and experimentally generated responses. The proposed multi-headed 1D-CNN classifiers generalizes well on the unseen samples and has achieved generalization over the problem. In the next phase, selected multi-headed versions of the 1D-CNN model are tested on publicly available *Open Guided Waves OGW* benchmark data of carbon fibre-reinforced polymer (CFRP) plate. Finally, in the last phase, the concept of transfer learning introduced to overcome the shortcomings of DL models such as the data-dependent performances. In transfer learning framework (TLF), a variant of the stacked 1D-CNN Autoencoder model will selectively outsource its pre-trained layers to a separate 1D-CNN model, which is a supervised learning model aimed to perform tasks, such as classification. In order to train both the source model and the target model, two separate databases are constructed using the same *OGW* diagnostic data repository. A total of three different TLF variants have been developed, trained and tested. In summary, the thesis presents ML-based data-driven techniques towards automated and in-service SHM of thin-walled aircraft structure.

Keywords: Structural health monitoring, CFRP composites, piezoelectric transducers, Lamb waves, ANN, signal processing, 1D-CNN, autoencoder, transfer learning.