# Autonomous Monitoring of Breathing Debonds in Composite Structures Using Non-Linear Ultrasonic Signals

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## ABSTRACT

Stiffened composites are often used for lightweight construction in aeronautic, aerospace, marine, infrastructure and automobile engineering sectors, owing to their fire resistance, acoustic damping and high stiffness-to-weight-ratio. Various stiffeners are bonded to the base plate in these structures. At these stiffener-baseplate bond interphase, breathing-type debonds can occur owing to cyclic loading, impact, ageing and improper handling. During operations, these debond regions can grow further and lead to a sudden failure if not detected beforehand. Therefore, identifying and classifying these hidden damages is essential. This paper aims to develop a robust structural health monitoring strategy for the independent assessment of such breathing-type debonds between baseplate and stiffener based on a deep learning architecture that uses nonlinear ultrasonic signals to automatically assess breathing-like debonds in lightweight stiffened composite structures. Towards this, nonlinear finite element simulations of ultrasonic guided wave response of composite structures and laboratory-based experiments have been undertaken on multiple composite panels with and without baseplate-stiffener debonds using a fixed network of piezoelectric transducers (actuators and sensors). Guided wave signals in the time domain are collected from the network of sensors onboard the composite structures. These signals in the frequency domain represent nonlinear signatures as the existence of higher harmonics. These higher harmonic signals are separated from the registered guided waves or the raw signals and converted to images of time-frequency scalograms using continuous wavelet transforms. A deep learning architecture is designed that uses the convolutional neural network to automatically extract the discrete image features for the characterisation of composite structures under healthy and variable breathing-debond conditions. The proposed deep learning-aided health monitoring strategy demonstrates a promising autonomous inspection potential with high accuracy for such complex structures subjected to multi-level breathing-debond regions.