Computationally efficient delamination detection in composite beams using Haar wavelets

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The paper presents an integrated vibration-based method for delaminations detection in homogeneous and composite beams. The method is based on Haar wavelets and artificial neural networks (ANNs). Firstly, scaled modal responses of the structure are expanded into Haar series by Chen–Hsiao method (CHM), and a delamination feature index is constructed. The database of 68 datasets built on Haar wavelet and frequency-based approaches was utilized by different ANNs to establish the mapping relationship between the delamination status and the delamination feature index or frequencies. The results are compared to each other. The simulations show the proposed complex method with delamination index detects the location of delaminations and identifies the delamination extent with high precision ( > 90%); the approach requires less computations and processing time than the frequency-based approach.

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1. Introduction

Fiber-reinforced multi-layer composite materials are increasingly being used in civil infrastructure, vehicles, aerospace and light industry. Damage detection in composite structures and machinery is an important issue in terms of safety and functionality. One of the commonly encountered types of damage in laminated composites is delamination. Delaminations are caused by production stresses or service-induced strains, such as impact of foreign objects, exposure to unusual level of excitation or oscillating load over an extended period of time, etc. [1,2]. The early detection and the continuous monitoring of the delamination for the growth and location are the most important issues in the automatic delamination inspection of in-service composite structures [3].

The vibration-based structural damage detection is a relatively new research topic. The approach has several classifications. According to the structural model, the vibration-based structural damage detection approach can be divided into model-based and signal-based methods [4,5]. The model-based methods reveal the damage locations and severities through the comparison of data obtained during the experiments and with the aid of mathematical model of the structure since structural damages cause changes in the dynamic characteristics. This approach was proposed and experimentally tested by several authors [6–9]; the review and classification can be found in [10]. Contrary to the model-based methods, the signal-based methods do not use the structural model and detect damage by comparing the structural responses before and after the damage. In [11], the frequency response functions and in [12] the shear horizontal waves, derived from mode conversion of the fundamental Lamb wave, were successfully used to extract the damage detection index.