Application of Machine Learning-Base K-Means Clustering for Feature Recognition of Fibre Bragg Grating Acoustic Signal from Different Delamination Sizes

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Abstract*— Continuous monitoring of composite structures is crucial to preserve their integrity over their entire service life, particularly when it comes to detecting subtle interior degradation like delamination. Extensive research has been dedicated to examining the utilisation of conventional electrical sensors for the purpose of collecting acoustic waves to quantify delamination. However, electrical sensors are well known to have several drawbacks. In this work, fibre Bragg grating (FBG) sensor is used to assess delamination, as the alternative to conventional electrical based sensors. In this study, composite plates were fabricated with varying sizes of delamination. The composite specimen has been equipped with a sensor network consisting of two multiplexed FBGs to acquire acoustic signals from an impact at the centre of the specimens. The use of a classification model derived from the analysis of sound signals from the FBGs has demonstrated significant success in identifying and characterising the result from different delamination sizes. The root-mean-square and peak value of the signals were extracted, and classification models were developed using these data sets. The results reveal that the overall percentage of accuracy is 91.7% for various delamination sizes. The findings offer compelling proof that employing an FBG sensor network for detecting delamination could be a practical choice for monitoring the health of plate-like composite structures.

Keywords— composite, fibre Bragg grating, delamination.

I. INTRODUCTION

Composite materials offer advantages such as excellent mechanical properties, high thermal resistance, good fire behavior, high impact resistance, great abrasion resistance, exceptional electrical insulation, and stiffness [1]. On the other hand, composite structures are typically vulnerable to internal deterioration, such as delamination, even when they are in operation for extended periods of time [2-4]. Delamination can lead to a reduction in stiffness, which frequently culminates in a catastrophic collapse. Hence, it is essential to employ suitable structural health monitoring (SHM) techniques to evaluate the expansion of delamination and mitigate the deterioration in structural integrity in composite structures.

The identification of delamination through the propagation of acoustic waves is well stated in scholarly literature. Piezoelectric transducers (PZT) and acoustic emission (AE) sensors have gained widespread recognition as benchmark sensors utilized to capture acoustic waves. The study conducted by Wang et al. [5] examined the application of piezoelectric composite material as both structural components and sensing elements for the analysis of guided wave propagation and interaction with damage. Meanwhile, the use of multiple PZTs for monitoring the delamination of composite double cantilever beams was described by Zhao et al. [6]. The signals were subjected to post-processing techniques including the Hilbert transform, Fourier transform, and wavelet transforms. According to the results of that research, variations in the length of the delamination have a substantial influence on the timing of arrival as well as the higher frequency modes. Hervin et al. [7], have employed PZT to investigate the phenomenon of Lamb wave mode scattering on a composite structure with delamination. Based on the findings, it was determined that there was a significant association between the amplitude of the waves and the depth of the separation. Aggelis et al. [8] affixed a total of eight AE sensors onto a hybrid cement material that was reinforced with a composite hollow beam. The aim of this setup was to observe and monitor the development of matrix fracture and delamination in the material. However, the existence of delamination was linked to lowered frequency values, as evidenced by the findings of the study, which revealed that the incidence of matrix cracking was associated with raised frequency values. Li et al. [9] employed two AE sensors to examine the impact of delamination length in a composite cantilever beam on the rising angle and strain energy release rate of the waveforms. The outcome of the study suggests that both established criteria are effective in identifying instances of delamination.

Regardless of previous studies, it is important to emphasize that PZT and AE sensor are electrical based sensors. Electrical sensors are frequently accompanied by a range of drawbacks, including significant signal attenuation, susceptibility to electromagnetic interference (EMI), and unsuitability for operation in challenging environmental conditions [10, 11]. The mentioned constraints can be efficiently resolved through the utilization of fiber optic sensors. Fiber Bragg grating (FBG) sensors have been extensively studied and widely published in the field of fiber optic sensors because of their

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