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Time-domain analysis of piezoelectric impedance-based structural health monitoring using multilevel wavelet decomposition

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ABSTRACT

A new approach to analyze the response from a piezoelectric wafer in an impedance-based structural health monitoring (SHM) method is proposed. It is shown that the time-domain response of a piezoceramic wafer provides information on the electromechanical impedance (EMI) variation when a monitored structure is damaged. Practical analysis was carried out using wavelet transform in two different levels. This approach simplifies EMI based SHM and the results show that it is more sensitive to damage than methods based on impedance measurements in the frequency domain. The efficiency of this new approach is demonstrated through experiments using an aluminum plate. The piezoelectric wafer was excited using a chirp signal and its response was analyzed using both frequency response functions (FRF) and the proposed method. The results confirm that this new approach is more sensitive to detect damage than FRF based methods.

1. Introduction

Structural health monitoring (SHM) based on wavelet transforms is a significant subject of researches. In the literature, there are a variety of articles in which wavelets are discussed and proposed as a basic signal processing tool in both civil and mechanical SHM applications. In [1], a wavelet based method was proposed to detect damage using a set of actuators and sensors, where the signals arriving at the piezoelectric sensors were analyzed through wavelet to generate a neural network model of the structure. This method is close to Lamb wave based methods, but the authors proposed a different algorithm to detect damage. In [2] the authors proposed a new metric based on wavelet and neural network, and a fuzzy set to distinguish between healthy and damaged conditions. In this case, a lead zirconate titanate (PZT) transducer was used as a vibration sensor. There are many other efforts proposing wavelet based methods for SHM in civil structures [3–5]. Some of them are used to identify modal parameters and others are based on Lamb waves, as found in [6,7] and in [8], respectively. In mechanical engineering the wavelet has been exploited as well. In [9–12] the authors proposed wavelet based methods to detect damage in mechanical applications, but also they used PZT as a sensor to detect vibration or identify natural frequencies.

Due to the importance of SHM, the literature presents some excellent overviews on wavelets based methods. For instance, Yu and Giurgiutiu [13] presented an overview of SHM methods including an interesting wavelet based method where the basic principle is the Lamb wave technique. In [14] the authors present a literature review on damage detection of structures based on wavelet analysis. In these cited works and in other wavelet based SHM methods found in the literature, a PZT is used

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