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Feasibility study of structural damage detection using NARMAX modelling and Nonlinear Output Frequency Response Function based analysis

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ABSTRACT

Nonlinear Output Frequency Response Functions (NOFRFs) are a series of one-dimensional functions of frequency recently proposed by the authors to facilitate the analysis of nonlinear systems in the frequency domain. The present study is concerned with a feasibility study of the application of the well-known Nonlinear Auto-Regressive Moving Average with eXogenous Inputs (NARMAX) modelling method and the NOFRFs-based analyses to the detection of damage in engineering structures. The new technique includes three steps. First, a NARX model is established by applying the NARMAX modelling method to input and output data collected from a test on an inspected structure. Then, the NOFRFs and an associated index for the inspected structure are determined from the established NARX model. Finally, structural damage detection is conducted by comparing the values of the NOFRF index of the inspected structure with the values of the index for a damage-free structure. An experimental application to the detection of damage in aluminium plates demonstrates the potential and effectiveness of the new damage detection technique.

1. Introduction

Damage such as fatigue cracks are a potential source of catastrophic structural failure [1]. To avoid the failures caused by damage, many researchers have performed extensive investigations to develop various non-destructive examination (NDE) techniques such as, e.g., ultrasound [2], eddy current [3], optical and thermal [4] methods, the guided acoustic wave (including the Lamb waves) approach [5], and vibration-based techniques [6–15]. The ultrasound and eddy current methods are normally used to conduct a point-to-point inspection of structures. This allows local measurement and precise location of damage positions. But, an inspection of a whole structure using these methods could be extremely time-consuming. The applications of optical and thermal techniques are often limited to surface or near surface defect detection in structures with relatively simple geometries. The guided wave techniques have the potential to inspect a large area for simple structures such as pipes and rails. For more complex structures, Lamb wave signals could be very intricate and complicated and hence hard to interpret; this produces a great obstacle to the industrial application of Lamb wave techniques.

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