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Proper orthogonal decomposition based algorithm for detecting damage location and severity in composite beams

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ABSTRACT

A damage detection algorithm based on the proper orthogonal decomposition technique that can be used for structural health monitoring is presented in this study. The proper orthogonal modes are employed as dynamical invariants to filter out the influence of operational/environmental variation in the dynamic response of the structure. Finite element models of a healthy and damaged carbon/epoxy composite beam are used to generate vibration data. Varying levels of stiffness reduction for the elements in the damaged zone of the structure are used to simulate impact damage. Three damage locations (center of beam, fixed end, and free end) with three damage cases for each location are investigated. Different random force inputs are used to introduce variations in the loading conditions of the beam. The results show that the developed algorithm is capable of detecting both location and severity of damage even under changing loading conditions, with a high level of confidence.

1. Introduction

High performance composite materials have seen increasing usage, especially in the aerospace industry, over the last 30 years. The use of composites has many benefits for aerospace structures including weight savings, smoother aerodynamic shape, and a reduction in part count. Other benefits include improved fatigue performance and higher resistance to corrosion; however, the damage mechanisms of composites are very different from those of metals. Loading, impact, or manufacturing defects can initiate delaminations and crack lengths can reach a critical size before they can be detected visually. An on-board structural health monitoring (SHM) system is therefore proposed for composite structures, which can inspect the structure rapidly and provide the operator with up-to-date information about its health. Such a system would allow designers to relax the conservative designs and take full advantage of the benefits of composite materials. A SHM system would also allow operators to abandon schedule based maintenance and adopt a much more efficient condition-based maintenance.

The basic premise of a SHM system is that damage alters stiffness, mass, or damping of a structure and in turn causes a change in its dynamic response. The complete health state of a structure can be determined based on presence, location, type, and severity of damage (diagnostics) and estimation of remaining useful life (prognostics). An extensive review of SHM methods was presented by Doebling et al. [1] and Sohn et al. [2]. Montalvao et al. [3] have reviewed vibration based SHM methods with emphasis on composite materials. The proceedings of the structural health monitoring conferences [4,5] contain hundreds of papers dealing with advancements in SHM. Most of the vibration based methods use modal

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