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Damage Detection in Offshore Jacket Structures from Limited Modal Information

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ABSTRACT

An algorithm to locate and size damage in jacket-type offshore structures for which only post-damage modal parameters are available for few modes of vibration is presented. A theory of damage localization and severity estimation (which yields information on the location and severity of damage directly from changes in mode shapes) is formulated. Next, a method to identify baseline modal parameters (i.e., frequencies, damping, and mode shapes of the undamaged state) of the structures is formulated. Finally, the feasibility of the damage detection algorithm is demonstrated by using a numerical example of an offshore jacket platform with limited modal information.

INTRODUCTION

The majority of offshore oil-production platforms are jacket-type, welded, steel tubular, space frames (Dawson, 1983). In these structures periodic inspections are mandatory, because critical damage can result from hostile environmental loads such as fatigue or ship collision. Divers currently perform such inspections using visual inspection techniques (Winkworth and Fisher, 1992). However, many adverse conditions (e.g., poor visibility, concealment of damage by marine growth, prohibitive cost, unacceptable hazard in deep water, nonavailability of properly trained divers, and dependence of inspection on weather condition) can limit, both technically and economically, the effectiveness of the inspection.

During the past decade, a significant amount of research has been conducted in the area of nondestructive damage detection (NDD) via changes in modal responses of structures. Many researchers have attempted to relate changes in eigenfrequencies of structural members to changes in those members' properties such as cracks, notches or other geometrical changes (Gudmunson, 1982; Chondros and Dimarogonas, 1980). Also, much attention has been focused on the possibility of using the vibrational characteristics of structures as an indication of structural damage (Cawley and Adams, 1979; O'Brien, 1980). More recently, studies focusing on the vibrational approach to NDD appear to be accelerating. Attempts have been made to monitor structural integrity of bridges (Biswas et al., 1990; Fletch and Kernichler, 1990) and to investigate the feasibility of damage detection in large space structures using changes in modal parameters (Stubbs and Osegueda, 1990; Chen and Garba, 1988).

In offshore applications, research efforts have been made to detect changes in structural integrity by monitoring changes in frequencies (Kenley and Dodds, 1980; Crohas and Lepert, 1982; Nataraja, 1983). However, the feasibility of using frequency changes to detect damage in existing offshore structures is limited for at least two reasons. Firstly, significant damage may cause very small changes in vibration frequencies, particularly for larger platforms, and these changes may go undetected due to measurement or processing errors (Rubin and Coppolino, 1983). Secondly, variations in deck mass or marine growth cause measurement uncertainty in frequency changes that further hamper the effectiveness of using frequency changes, for damage detection (Shahrivar and Bouwkamp, 1986). In an effort to overcome these difficulties, research efforts have focused on monitoring changes in mode shapes of offshore platforms (Rubin and Coppolino, 1983; Shahrivar and Bouwkamp, 1986). They concluded that (1) the mode shapes were much more sensitive to damage than were eigenfrequencies; and (2) the effects of increase in deck mass, marine growth, or change in the position of deck center of mass could be differentiated from the effect of damage by measuring normalized components of modal displacement for the mode shapes. However, subsequent studies to predict the presence and locations of damage in offshore platforms focused on monitoring changes in mode shapes when damage was introduced into a member (or members) of the offshore platforms (Idichandy and Ganapathy, 1990). Here, we note that in their research programs, Rubin and Coppolino (1983), Shahrivar and Bouwkamp (1986), and Idichandy and Ganapathy (1990) only reported experimental results. They did not perform the inverse problem of damage localization and severity estimation in the structures.

In addition to these research efforts, many other NDD-related problems associated with jacket-type structures remain to be solved. Outstanding needs still remain to locate and estimate the severity of damage in offshore platforms: (1) with many members; (2) for which only few mode shapes are available; (3) for which baseline (i.e., the undamaged state) modal responses are not available (e.g., the majority of existing jacket platforms); and (4) in a dynamic environment of modeling, measurement, and processing uncertainties.

The objective of this paper is to present a promising methodology to locate and estimate the severity of damage in jacket-type platforms with the following three characteristics: (1) few (i.e., less than or equal to three) modes are available; (2) not all degrees of freedom (i.e., translational and rotational) at a given location are measured by sensors; and (3) no modal parameters of the undamaged (i.e., the baseline) structure are available. To achieve the objective, the investigation is performed in three parts. We first present a theory of damage localization and severity estimation that yields information on locations and magnitudes of damage

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