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Identification Analysis of Structural Damage on Unit-Linked Offshore Floating Models

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ABSTRACT

This paper is concerned with the identification analysis of structural damage detection on the unit-linked floating structure model based on the fluid-coupled free vibration equation and filtering theory. The problem of structural damage detection is formulated as an inverse problem. The formulated inverse problem is analyzed under the consideration of stochastic properties on the responses of the system. In this study, two kinds of filtering algorithm, namely, the extended Kalman filter and the new filtering algorithm based on the projection filter, are employed as the analytical methods of inverse problem. The location and grade of connector with the assumed damage for the unit-linked floating model are identified by using the natural coupled frequencies as observation data.

INTRODUCTION

Recently, Very Large Floating Structures (VLFS), which imagined the construction of a floating airport and an artificial floating city, have drawn considerable attention in ocean engineering fields. The Technical Research Association of Mega-Float was organized to realize the construction of VLFS in Japan. The practical experimental studies have been already carried out off the coast of Yokosuka. The various results have been presented with regard to the structural design (Kikutake et al., 1997a; Okada et al., 1997b). Based on the experiments of Mega-Float, it is considered that a large floating structure will be composed of multiple units, each a conventional-sized floater from the viewpoint of fabrication. Such unit-linked floating structures will be subjected to sea waves and wind loading continuously. It is well known that the dynamic behavior of VLFS is composed of elastic deformations and rigid body motions under dynamic loading. The unit-linked floating structure thus will accumulate damages, especially at the locations of the connector and anchor system during their service life. In order to assure structural safety, it is necessary to monitor the state of the structural system at regular intervals. The experimental modal analysis is one of the effective procedures as a periodic monitoring system, because the changes in modal properties, such as natural frequencies, mode shapes and damping ratios, characterize the evolution of damage state of unit-linked floating structures (Endo et al., 1996).

The problems with structural damage detection are formulated as inverse problems in computational mechanics and structural engineering (Tanaka et al., 1992). In general, such inverse problems must be analyzed under the consideration of stochastic properties of the mathematical model because the observations of the system are usually measured in the presence of noise. The extended Kalman filtering algorithm has been well known as the solution method for considering stochastic properties (Catlin et al., 1989). As seen in papers that analyzed various kinds of inverse problems using the extended Kalman filtering algorithm, any number of iterative calculations must be performed to estimate the optional state vector and the corresponding error covariance matrix in the stochastic dynamic system (Murakami et al., 1988). On the other hand, Tosaka and Utani (1995) proposed a new filtering algorithm based on the projection filter for a stochastic dynamic system which corresponds to the Kalman filtering algorithm based on the Wiener filter.

The aim of this paper is to show the identification analysis to detect the structural damage on the unit-linked floating structure based on the fluid-coupled free vibration equation, in combination with the filtering algorithm. Two kinds of filtering algorithm, namely the extended Kalman filter and new filtering algorithm based on the projection filter which is temporarily called T-U filter, are employed in the identification analysis. In this study, the coupled natural frequencies and connector stiffness on the unit-linked floating model are adopted as the observation data and unknown parameter that should be identified respectively.

FLUID-COUPLED FREE VIBRATION AS MATHEMATICAL MODEL

Let us consider a 2-dimensional formulation of fluid-coupled

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KEY WORDS: Damage detection, inverse analysis, Kalman filter, new filtering algorithm, unit-linked floating model, coupled natural frequency.