Structural Modification by Reassigning Natural Frequencies of Offshore Jacket Platforms

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ABSTRACT

Offshore jacket platforms have been widely used in offshore oil and gas exploitation under hostile ocean environments. Structure damages, which may cause the change of natural frequencies, are unavoidable due to the severe environmental loads. If the natural frequencies of a damaged structure become close to the ambient vibration frequencies, excessive vibration of the platform would occur. In order to reduce the vibration level, a structural modification procedure of reassigning the natural frequencies of the platform is desired. In this paper, a structural modification algorithm aiming at reassigning natural frequencies of an offshore jacket platform is newly developed. The modifications are demonstrated either by installing a tuned mass damper at the deck, or by modifying the stiffness of floor members, of the platform. For verifying the developed algorithm, numerical studies based on finite element models are conducted for a simplified jacket platform. Numerical results indicate that the developed algorithm can properly assign the natural frequencies of the modified platform based on the preset frequencies.

KEY WORDS : Offshore platform; structural modification; natural frequency; structural dynamics.

INTRODUCTION

Oil and gas are the major sources of energy in our society. Twenty percent of these hydrocarbons are recovered from reservoirs beneath the seabed [Moan, 2005]. Steel jacket-type platforms, the most common kind of offshore structures, have been widely used in offshore oil and gas exploitation. These platforms are subjected to various kinds of environmental loading, such as wind, waves, current, ice and so on. During an offshore structure’s service life, structural damage caused by environmental loads would be continuously accumulated, and the damage might result in a significant change at the dynamic characteristics of the platform. Eventually, if the natural frequencies of the damaged platform fall into the frequency range of the dominant excitations, excessive vibration of the platform can follow. The excessive vibration not only endangers the structure integrity but also causes the discomfort to people working on the platforms. One solution to remedy this problem is to reassign the structure’s natural frequencies, keeping them away from those of ambient loads.

The reassignment of natural frequencies, which is under the category of structural modifications, is best proceed mathematically as an inverse problem. This inverse problem determines the changes of structural mass and stiffness according to the preset natural frequencies. There are two ways to achieve the goal: (i) modifying the mass and stiffness properties of the existing members of a structure, and (ii) adding new components (new degrees-of-freedom) to the structure [Maia and Silva, 1997]. Early works were reported by Tusei and Yee (1989,1991) where the authors proposed a method to determine required mass and stiffness changes that would relocate a natural frequency. That work was later extended by Li et al. (1994a, 1994b) and He and Li (1995) to study the relocation of an antiresonance and ways of optimizing the properties of a system. Braun and Ram (2001) formulated the modification problem as an optimized inverse eigenvalue problem.

This paper extends the cross-model cross-mode (CMCM) method [Hu, et al., 2007], which was developed originally for model updating, for reassigning the natural frequencies of a structure. The CMCM method has been so named because it involves solving a set of linear simultaneous equations, in which each equation is formulated based on the product terms from two same/different modes associated with two models, the baseline and updated models. In brief, the CMCM method forms simultaneous linear equations in a matrix form, with the unknown vector being the correction factors that are used to update the selected stiffness and/or mass sub-matrices. In contrast to the original CMCM method which uses both modal frequencies and mode shapes, the extended CMCM method in this paper is to determine the modifications using only the predetermined modal frequencies.

The numerical studies demonstrated in this paper are based on a four-story steel-frame offshore jacket platform. Two cases of reassigning the natural frequencies of the jacket platform are studied. In the first case, a spring-mass oscillator, similar to a tuned mass damper (TMD), is installed at the deck of the platform (which is initially reduced to a shear building model). In the second case, the reassignment of the natural frequencies is achieved via the modification of the stiffness of beam members at the deck of the jacket platform.