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Finite Element Model Updating with Experimental Natural Frequency and Zero Frequency

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This paper presents an application of the finite element (FE) model updating method with the use of natural frequency and zero frequency. A sensitivity analysis is employed to update the FE model, in which the zero frequencies are target parameters to supplement the number of design variables of vibration characteristics. An iterative FE model updating scheme based on the sensitivities of the natural frequency and the zero frequency with respect to the structural parameters is provided. The natural frequencies and the zero frequencies are identified from either the analytical frequency response functions or the experimental frequency response functions. Two case studies, a numerical FE model of cantilever beam and a real cantilever beam, are considered to verify the accuracy of the proposed method. In the present method, the flexural stiffness values of beam elements are updated with target parameters consisting of the natural frequencies and the zero frequencies. These 2 case studies confirm that the proposed method can be effectively applied for the FE model updating.

INTRODUCTION

Recently, many investigations on the health monitoring of offshore structures were carried out to retain their structural performance and to detect damage in offshore structures. Xu et al. (2010) studied damage detection of an offshore platform using a mode decomposition technique. Wang et al. (2010) and Park et al. (2011) used modal properties to assess damage of offshore jacket structures. The main health monitoring method is a hybrid analysis method which consists of experimental modal analysis (EMA) and the finite element method (FEM). EMA estimates the mode characteristics of a structure by removing the error contained in the transfer functions, or in the measured response data. Techniques have been developed to identify reliably the vibration properties of structures. A structure's dynamic characteristics are obtained by vibration tests, and then an FE model is modified on the basis of the experimental parameters through an iterative scheme.

Many FE model updating methods have been applied to minimize the differences in structural properties, such as stiffness, mass and/or damping parameters, between the test structure (e.g., the existing structure) and the FE model. Various methods including early FE model updating and methods developed in the 1990s were reviewed by Friswell and Mottershead (1995). Lu and Tu (2004) developed a 2-level neural network approach of an FE model updating with the vibration data. Lin and Zhu (2006) studied an FE model updating method for structures utilizing experimental frequency response function (FRF) data. Both Teughels et al. (2003) and Bakir et al. (2008) carried out FE model updating using a global optimization technique with the coupled local minimizers. Arora et al. (2009) studied a model updating technique which uses complex FRF.

The FE model updating with experimental data is a useful tool for evaluating structural integrity. However, one of its drawbacks in general is lack of information. In other words, information available for natural frequencies, mode shapes or number of degrees of freedom is limited. For highly indeterminate structures, the number of unknown parameters, such as the stiffness properties of a structural system, is larger than the number of measured parameters. Because of insufficient data, the inverse problem of FE model updating might be a structurally underdetermined system which causes the ill-conditioning of updating equations. Thus undesirable errors are generated between the FE model and the real structure. The local maximum error can be produced when solving ill-conditioned equations, even though the several target parameters, such as natural frequencies of the FE model, exactly match to the measured ones.

These limitations motivated the introduction of other quantities in the FRF to be utilized in the problem of FE model updating. One such addition is a zero frequency or anti-resonant frequency. Mottershead (1998) demonstrated that the sensitivities of the zero frequencies could be expressed as a linear combination of the sensitivities of the natural frequencies and the mode shapes. Wahl et al. (1999) conducted research on calculating the sensitivity matrix of a zero frequency and discussed the usefulness of future applications in the fields of system identification and location of structural faults. The main advantage of the use of zero frequency is that the zero frequencies are located along the frequency axis in FRF and can be measured easily with acceptable accuracy like the natural frequencies. The zero frequencies can reduce the influence of measurement errors that cause the ill-conditioning of the FE model updating problem. Further, the correlation between

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