Damage Detection of Offshore Platform Model Using Empirical Mode Decomposition and Wigner-Ville Distribution

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ABSTRACT

The use of the combined method of empirical mode decomposition (EMD) and Wigner-Ville distribution (WVD) is presented for the vibration-based damage detection of offshore platform model. Empirical mode decomposition is a time-series analysis approach that extracts a custom set of basis functions to describe the vibration response of a system. Combined with the WVD technique, the EMD method provides some unique information about the nature of the vibration response. Firstly, EMD technique is used to decompose the response signal of structural vibration into several mono-component signals named intrinsic mode functions (IMFs). Some selected intrinsic mode functions is analyzed via WVD method to detect the occurrence and severity of damage. Experimental study with a three-dimensional offshore structural model containing a simulated damage subjected to excitation was performed to demonstrate the efficiency and validity of the proposed method. The results show that the combined method of EMD and WVD can be used to indicate the presence of structural damages in an efficient manner. This work is the first stage of a project whose objective is to develop a reliable low-cost technique for structural health monitoring using the vibration response of offshore platform.

KEY WORDS: Empirical Mode Decomposition; Wigner-Ville Distribution; Structural Health Monitoring; Structural Damage Detection

INTRODUCTION

Offshore structures are frequently subjected to damages caused by aging, environmental, fatigue and other factors during their service life due to. Many damages can significantly affect the structural properties including stiffness, natural frequencies, etc., which are extremely important to the performance and safety of offshore structures. Therefore, the ability of damage detection is becoming increasingly significant for structural health monitoring of offshore structures. As one of structural health monitoring techniques, vibration-based damage identification has been employed broadly over the last decade.

Extensive researches have been reported in recent years about structural damage detection of offshore structures using advanced time-frequency signal processing procedures. A signal measured from the sensors located on a structure can not be analyzed directly to determine the structural condition unless the damage intensity is considerable high. It is necessary to process the original signal to extract useful features about the structural parameters and damage. In order to reveal the sufficient and accurate feature, the signal is often transformed to different domains including time, frequency and time-frequency, etc. Fourier analysis or Short time fourier transform, wavelet analysis and Hilbert-Huang analysis are the popular methods among the all signal processing-based structural damage identification techniques. Because of its ability to identify the significant information about the modal parameters e.g. natural frequency, mode shapes, etc., Fourier transform-based structural damage identification methods can be found frequently in many reports (Chiang, 2001). As an extension of the traditional Fourier analysis, wavelet analysis provides a multi-resolution and time-frequency analysis for non-stationary data and therefore can be effectively applied for structural health monitoring (Staszewski, 1998; Hansang Kim, 2004). Helong Li(2007) investigated the combination method of EMD and wavelet analysis and its application in structural health monitoring. Recent applications of discrete wavelet transform for structural health monitoring can be found in Hera and Hou (2003). The EMD method combined with Hilbert Transform is also known as ‘Hilbert-Huang Transform’ (HHT) developed by Huang et al(1998) . Because of its effectiveness in analyzing a nonlinear, non-stationary signal, the HHT was recognized as one of the most important discoveries in the field of applied mathematics. Application of HHT used as damage detection and system identification approach can be found in Yang et al (2004) and Darryll Pines(2006).

As one part of the Cohen class of distribution, the Wigner-Ville distribution (WVD) method is a basic and promising time-frequency method for structural monitoring[P.D. Spanos, 2007]. Therefore, the WVD method has been considered as an effective analysis tool for non-stationary or time-varying signals during recent years. It has been widely used in the areas of structural modal parameter identification, machinery condition monitoring, etc. The difficulty with this method lies in the severe cross terms indicated by the existence of negative power for some frequency ranges. In addition, the application of WVD for discrete time signals suffers from the aliasing problem, which may