Engineering Structures 33 (2011) 1348–1356

Contents lists available at ScienceDirect

Engineering Structures

journal homepage: www.elsevier.com/locate/engstruct

EMD-based random decrement technique for modal parameter identification of an existing railway bridge

X.H. He [a,*], X.G. Hua [b], Z.Q. Chen [b], F.L. Huang [a]

[a] School of Civil Engineering and Architecture, Central South University, Changsha 410075, Hunan, China

[b] Wind Engineering Research Center, College of Civil Engineering, Hunan University, Changsha 410082, Hunan, China

ARTICLE INFO

Article history:
Received 6 July 2010
Received in revised form
9 January 2011
Accepted 12 January 2011
Available online 8 February 2011

Keywords:
Parameter identification
Random decrement (RD) technique
Empirical mode decomposition (EMD)
Nonstationary
Steel bridges
Health monitoring

ABSTRACT

Vibrational measurement data are often nonstationary and modal parameter identification based on these data is of practical value for structural health monitoring and condition assessment. The empirical mode decomposition (EMD) is a most recent tool for analysis of nonstationary signals. An EMD-based random decrement (RD) technique is presented to identify modal parameters from monitoring vibrational data. The nonstationary measurement data are first decomposed into a series of quasi-stationary intrinsic mode functions (IMFs) by EMD. The RD technique is then applied to the selected IMFs to obtain the free-decay response. The modal frequencies and damping ratios are finally identified from the free-decay response by minimizing the error between the measured free-decay responses and the predicted responses from a parametric model. The present method is applied to extract the modal parameters of the Nanjing Yangtze River Bridge from the measured responses. The identification result is compared to those from finite element analysis as well as from the experimental result identified with the peak-picking (PP) method. In addition, the modal frequencies of the bridge loaded with heavy trains are also identified and compared to the 'empty' bridge. The EMD-based random decrement (RD) technique provides an effective and promising tool for modal parameter identification for large bridges and other structures.

1. Introduction

In order to improve the management and maintenance level of highway bridges, structural health monitoring (SHM) systems have been widely adopted over the past decades to monitor and evaluate structural health and operational condition of large scale bridge structures [1,2]. Successful implementation and operation of structural health monitoring systems on bridges have been widely reported in different countries (e.g. [3–7]). Vibration measurements are one of the necessary ingredients in a structural health monitoring system. The main objective of vibration measurements is to extract the dynamic properties of a bridge such as modal frequencies, mode shapes, and damping ratios and the obtained modal parameters may be further used for finite element model improvement, damage detection and condition assessment. Therefore, a reliable data analysis or signal processing method is of vital importance but remains a challenging problem for researchers and engineering practitioners.

The main task in modal parameter identification is to determine modal parameters from dynamic measurement data. The traditional methods of parameter identification need both input and output measurement data by establishing system models in the frequency domain or time domain; these models include frequency response functions, time-series recursive equations, and state equations. Modal parameter identification has been carried out popularly in aerospace and mechanical engineering based on the both input and output measurements [8].

The input is often ambient such as drop weights, shakers even shoot rockets. On the one hand, if the excitation force is too small, the needed signals will be shaded by noises or not be excited; on the other hand, if the excitation force is too big, the structure will be damaged or destroyed. However, it is very difficult for a large bridge to be artificially excited. In civil engineering, the ambient vibration testing has an advantage of being inexpensive and not interrupting the normal operation since no excitation equipment and traffic interruption are needed, and also has potentials for implementing real-time condition assessment. Recognizing that the ambient excitation induced by wind and traffic loadings are not easy to quantify, parameter identification based on the ambient vibration testing has been posed as an output-only identification problem [9]. In a general way, the vibration measurement in structural health monitoring is output-only dynamic testing. The modal parameter identification technique based on output-only vibration measurements has been successfully applied in many long-span bridges, for example, the Tsing Ma suspension bridge [10], the

* Corresponding author. Tel.: +86 731 82655012.
E-mail address: xuhuihe@mail.csu.edu.cn (X.H. He).

0141-0296/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.engstruct.2011.01.012