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A new wavelet-based method for determination of mode shapes: Experimental Results

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Abstract

In this article a new method is proposed to determine the mode shapes of linear dynamic systems from the results of wavelet analysis. A previously proposed method based on a modified Morlet wavelet function with an adjusting parameter is used to identify the natural frequencies and damping ratios of system. The mode shapes are obtained from the time signal of responses and the extracted natural frequencies from wavelet transform of response signals. The method is applied to a steel real beam excited by an impact force. It is shown that the extracted mode shapes are not scaled. Therefore, the mass change method is used for scaling of the mode shapes.

Keywords: Mode shapes, Wavelet transform, Natural frequency, Free responses.

1. INTRODUCTION

Estimation of the modal parameters in terms of natural frequencies, damping coefficients and mode shapes from experimental data is a fundamental problem in structural dynamics. The modal parameter identification methods may be categorized in to Single Degree Of Freedom (SDOF) methods and Multi Degrees Of Freedom (MDOF) methods. Pick peaking method, circle fit method and line fit method are the classical methods for modal parameter identification [1]. The recent method of three point finite difference method [2] gives more accurate results compared to the traditional methods. Least square complex exponential method [3], poly-reference time domain method [4], Ibrahim time domain method [5], automated parameter identification and order reduction for discrete time series [6] are among the MDOF methods for modal parameter determination [7]. The basis of most of these methods is Fourier analysis which transforms the time data to the frequency data. However, Fourier analysis cannot determine the modal parameters accurately in the noisy environments. Some methods consist of pre-filtering of the input signals can improve the results. Moreover, close modes may hardly be identified using the techniques based on the Fourier analysis. Recently, wavelet analysis has attracted researchers in applied physics and engineering as well as the other branches of science due to its powerful capability in analyzing a signal [8]. In contrast to the Fourier transform which has a uniform resolution in frequency domain, the wavelet transform has the property of double resolution in both the time and frequency domain. By using this property, the wavelet transform can be adjusted to analyze the non-stationary signals. Also, the strongly coupled modes can be identified by tuning the wavelets. Moreover, the inherent ability of wavelet transform in filtering out the noise contaminating a signal is an important advantage for identifying the modal parameters. In previous years, some researches have been conducted for identification of modal parameter using wavelet transform [9-13]. The input signals to these wavelet techniques are mostly the ambient time records without the knowledge of input force and consequently these methods are comparable to output-only techniques in modal testing.

Three methods for estimating the damping ratios based on the Continuous Wavelet Transform (CWT) were proposed in [14]. A procedure of identification of natural frequencies and damping ratios of the system from its free decays using wavelet transform was proposed in [15]. A modified Morlet wavelet function with adjusting parameter was proposed in [16] to improve the accuracy of identification. A modal parameter identification procedure using continuous wavelet transform including the mode shape identification has been proposed in [17]. An identification method for natural frequencies and damping ratios based on a modulated Gaussian wavelet transform from impulse response function is