Nonlinear identification of structures using ambient vibration data

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1. Introduction

Structural systems are often referred to as being linear or nonlinear. However, all real structures are inherently nonlinear. Nonlinear behavior is observed even in rather simple structures like plates and beams, as a result of buckling or large deformation related effects. The nonlinear behavior of a structure may be also possible due to a local (friction, joint and link flexibility, backlash and clearance, nonlinear contact) or a global (geometric nonlinearities, nonlinear material behavior) nonlinearities. However, in most of the cases they are usually approximated by a linear model for the purpose of dynamic analysis and design, solely due to computational ease and convenience. For linear models, modal based methods are most widely used in structural system identification, model updating, structural control and health monitoring.

However, the presence of nonlinearity in a structural system changes its behavior, thus making the use of the linear model improper and in the majority of cases even impossible. The basic principles that apply for a linear system, which form the basis for modal analysis are not valid anymore for nonlinear systems. The superposition and the homogeneity as well as the Maxwell reciprocity principles do not apply for a nonlinear system. A nonlinear mechanical system shows a tendency to redistribute the energy of the input spectrum. This results in modulation, super and sub-harmonics and broadband spectra in some areas. The generation of harmonics depends on the excitation. The frequency response functions are also excitation dependent, which makes impossible their further application for modal analysis. Modal models are unsuitable to predict the behavior of nonlinear systems. Accordingly, new tools for detection, quantification and modeling of nonlinearities in dynamical systems are necessary. Several methods have recently been developed for detecting the presence of nonlinearity in a system [1–6]. Some procedures rely on characteristic features for nonlinear systems, like the distortion of the FRF and Hilbert transform of FRF plots. During recent years, considerable research work has been reported on modeling nonlinear behavior of dynamic systems, suggesting a variety of approaches. The use of Volterra series [7] to describe the nonlinear systems is one of the most widely accepted one.

Several methods exist in the literature for detecting the presence of non-linearity. These methods can be broadly classified as frequency domain and time domain analysis based techniques [1]. The frequency domain based nonlinear detection methods include homogeneity test and Hilbert transform of frequency response functions, coherence function, Hilbert marginal spectrum, wavelet packet transform component correlation coefficient, bispectral analysis, wavelet packet energy spectrum, etc. Similarly, the time domain nonlinear indicators include instantaneous frequency, holder exponent, auto and cross correlations of time history response, etc. More details on these detection methods can be found in Kerschen et al. [1], Worden and Tomlinson [3] and Hickey and Worden [8].

Civil structures will inevitably suffer a certain level of deterioration during its service life owing to corrosion and/or fatigue.