Mechanical Systems and Signal Processing 25 (2011) 1011–1027

Contents lists available at ScienceDirect

Mechanical Systems and Signal Processing

journal homepage: www.elsevier.com/locate/jnlabr/ymssp

Identifying and quantifying structural nonlinearities in engineering applications from measured frequency response functions

A. Carrella *, D.J. Ewins

University of Bristol, Department Aerospace Engineering, BLADE, University Walk, Bristol BS8 1TR, UK

ARTICLE INFO

Article history:
Received 14 June 2010
Received in revised form
7 September 2010
Accepted 8 September 2010
Available online 21 September 2010

Keywords:
Nonlinear identification
Nonlinear modal testing
Nonlinear modal analysis
Experimental
Nonlinear modal analysis

ABSTRACT

Engineering structures seldom behave linearly and, as a result, linearity checks are common practice in the testing of critical structures exposed to dynamic loading to define the boundary of validity of the linear regime. However, in large scale industrial applications, there is no general methodology for dynamicists to extract nonlinear parameters from measured vibration data so that these can be then included in the associated numerical models. In this paper, a simple method based on the information contained in the frequency response function (FRF) properties of a structure is studied. This technique falls within the category of single-degree-of-freedom (SDOF) modal analysis methods. The principle upon which it is based is effectively a linearisation whereby it is assumed that at given amplitude of displacement response the system responds at the same frequency as the excitation and that stiffness and damping are constants. In so doing, by extracting this information at different amplitudes of vibration response, it is possible to estimate the amplitude-dependent 'natural' frequency and modal loss factor. Because of its mathematical simplicity and practical implementation during standard vibration testing, this method is particularly suitable for practical applications. In this paper, the method is illustrated and new analyses are carried out to validate its performance on numerical simulations before applying it to data measured on a complex aerospace test structure as well as a full-scale helicopter.

1. Introduction

In order to assess and to predict the dynamic behaviour of a structure, engineers rely ever more heavily on mathematical models of the system under examination. These mathematical models can be theoretical (e.g. a set of equations) or numerical (e.g. a finite element (FE) model). Either way, the model has to reproduce the reality of the physical structure. Therefore, notwithstanding the dramatic improvements in simulation techniques, testing is always required to validate predictions and to guide the refinement of models.

One major drawback of model updating (and modal analysis) is that in most cases neither the mathematical model nor the analysis of measured data account for nonlinearities into the system. This is mainly due to the combination of a relatively small understanding of nonlinear phenomena, together with a highly complex mathematical analysis.

In reality, it is found that most practical structures do not comply with an assumption of linearity. There are a series of 'linearity checks' available that can be performed in order to assess and define the limits of the validity of linear theory to any given application. The essential question is "what to do if the structure fails the linearity check?" There is no definite

* Corresponding author.
E-mail address: A.Carrella@bristol.ac.uk (A. Carrella).

0888-3270/$ - see front matter
doi:10.1016/j.ymssp.2010.09.011