Mechanical Systems and Signal Processing 25 (2011) 2191–2202

Contents lists available at ScienceDirect

Mechanical Systems and Signal Processing

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

Comparison of FRF measurements and mode shapes determined using optically image based, laser, and accelerometer measurements

Christopher Warren, Christopher Niezrecki*, Peter Avitabile, Pawan Pingle

Department of Mechanical Engineering, University of Massachusetts Lowell, One University Ave., Lowell, MA 01854, USA

ARTICLE INFO

Article history:
Received 9 September 2010
Received in revised form
15 January 2011
Accepted 27 January 2011
Available online 4 February 2011

Keywords:
Digital image correlation
Point tracking
Full-field measurement
Vibration measurement
Mode shape correlation
Modal testing

ABSTRACT

Today, accelerometers and laser Doppler vibrometers are widely accepted as valid measurement tools for structural dynamic measurements. However, limitations of these transducers prevent the accurate measurement of some phenomena. For example, accelerometers typically measure motion at a limited number of discrete points and can mass load a structure. Scanning laser vibrometers have a very wide frequency range and can measure many points without mass-loading, but are sensitive to large displacements and can have lengthy acquisition times due to sequential measurements. Image-based stereo-photogrammetry techniques provide additional measurement capabilities that compliment the current array of measurement systems by providing an alternative that favors high-displacement and low-frequency vibrations typically difficult to measure with accelerometers and laser vibrometers. Within this paper, digital image correlation, three-dimensional (3D) point-tracking, 3D laser vibrometry, and accelerometer measurements are all used to measure the dynamics of a structure to compare each of the techniques. Each approach has its benefits and drawbacks, so comparative measurements are made using these approaches to show some of the strengths and weaknesses of each technique. Additionally, the displacements determined using 3D point-tracking are used to calculate frequency response functions, from which mode shapes are extracted. The image-based frequency response functions (FRFs) are compared to those obtained by collocated accelerometers. Extracted mode shapes are then compared to those of a previously validated finite element model (FEM) of the test structure and are shown to have excellent agreement between the FEM and the conventional measurement approaches when compared using the Modal Assurance Criterion (MAC) and Pseudo-Orthogonality Check (POC).

1. Introduction and motivation

Modal testing can be performed using a variety of different experimental techniques. Accelerometer, laser vibrometer, and stereo-photogrammetry measurement systems all have advantages and drawbacks, so each must be implemented where they will be most effectively employed. Accelerometers are by far the most traditional and widely used sensors employed in modal testing. Their ease of use allows for quick, broadband measurements to be made, however the effects of mass-loading (especially at higher frequency ranges or for lightweight structures) can corrupt a measurement and a large channel count can be challenging due to cost and bookkeeping. Laser Doppler vibrometers provide a non-contacting,

* Corresponding author.
E-mail address: Christopher_Niezrecki@uml.edu (C. Niezrecki).

0888-3270/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.ymssp.2011.01.018