Measurement 50 (2014) 78–85

Contents lists available at ScienceDirect

Measurement

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

Experimental modal analysis performed by high-speed digital image correlation system

F. Trebuňa *, M. Hagara

Technical University of Kosice, Department of Applied Mechanics and Mechatronics Faculty of Mechanical Engineering, 04200 Kosice, Slovakia

ARTICLE INFO

Article history:
Received 11 July 2013
Received in revised form 5 December 2013
Accepted 23 December 2013
Available online 6 January 2014

Keywords:
Digital image correlation
Experimental modal analysis
Modan 3D

ABSTRACT

In this paper a modification of a high-speed correlation system for the purposes of mechanical structures modal parameters estimation is described. Together with hardware modification an original version of a program Modan 3D was created, which is a complex tool for execution of an experimental and operational modal analysis. In the contribution the authors present just some information about a part of the program used for the experimental modal analysis. They describe algorithm required for a calculation of a normal mode indicator function (NMIF), a complex mode indicator function (CMIF), damping ratios as well and visualization of the mode shapes. A functionality of the program was tested during the analysis of two thin steel samples. A reliability of the reached results was verified by means of a system specialized for vibration analysis.

1. Introduction

There are many various methods serving for the estimation of modal parameters [1]. For the investigation of such objects, whose stiffness parameters could be markedly influenced after an application of the mechanical transducers of acceleration, the modern optical noncontact principles are developed. Into the group of noncontact methods also a digital image correlation method can be included, basic principle of which lies in a comparison of digital snapshots of investigated objects during the process of its loading. The results of investigation are in a form of displacement fields, respectively deformation fields and strain fields as well [2–5]. In the instance of using Dantec Dynamics high-speed correlation systems, by which the sample frequencies of cameras reach in the order of several thousand samples per second, the manufacturer talks about the possibility of using them in vibration analysis. For a reason, that a control and evaluating software of these systems Istra4D does not directly allow the modal parameters estimation, we have decided to modify a high-speed correlation system for the purposes of experimental and operational modal analysis and develop a program called Modan 3D enabling to acquire natural frequencies, mode shapes and damping ratios for both types of analyses. This program is developed especially for the high-speed correlation system Q-450 Dantec Dynamics.

2. Experimental modal analysis performed by digital image correlation method

The basic of the program Modan 3D consists in an acquisition of the frequency response functions in every virtual grid corner point (labeled as mask point) of the investigated object and their subsequent processing leading to the modal parameters estimation. A broadband object excitation is performed by a modal hammer only in one location – it concerns the method with one input and a multiple output (SIMO).

2.1. The acquisition of input data from a modal hammer

The data acquisition from the modal hammer has been enabled by two special additional apparatuses – CCLD amplifier and AD/DA converter. A block scheme of

* Corresponding author. Tel.: +421 55 6022462; fax: +421 55 6334738.
E-mail address: frantisek.trebuna@tuke.sk (F. Trebuňa).

0263-2241/$ - see front matter © 2014 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.measurement.2013.12.038

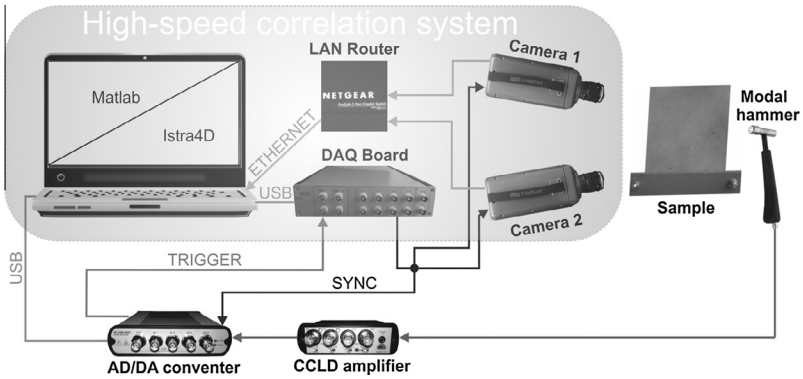

Fig. 1. Block scheme of connection between high-speed correlation system and additional devices for execution of experimental modal analysis.

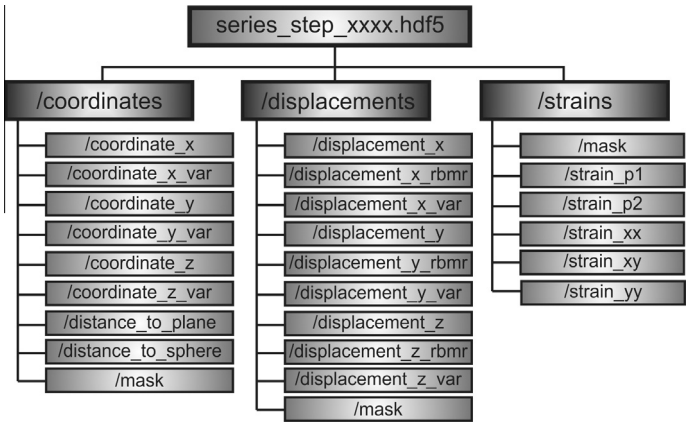

Fig. 2. HDF5 file exported by the program Istra4D.

connection between high-speed correlation system and additional devices, which together serve for realization of experimental modal analysis, is depicted on the Fig. 1.

For such a created system a special script in Matlab has been written, by which it is possible to record an input signal and activate trigger for ensuring the recording of cameras image.

2.2. The algorithm of the program Modan 3D for performing of experimental modal analysis

The algorithm for experimental modal analysis consists of three main parts. While the first one is fully automated, in the second and the third one, respectively, the user intervention is necessary. The outputs of the first part are two modes estimation functions, where in ideal instances the peaks should determine the object natural frequencies. In the second part the user chooses the frequencies that are subjected to analyses by MAC criterion. The last step is the graphical visualization of the mode shapes with corresponding damping ratios for the chosen frequencies.

The exported data from the program Istra4D in a form of HDF5 (HDF – Hierarchical Data Format) files are the basic elements for a work with the program Modan 3D. As indicates the format name, it concerns hierarchically structured file. Uppermost are the groups containing subsets, datasets, attributes, or the connections and some information about the data type as well, which describe their character and way of interpretation.

Istra4D generates the HDF5 file with a structure depicted in Fig. 2. It contains three main groups (coordinates, displacements and strains), whereby each of them consists of several datasets with the amounts of the quantities measured in mask points. The number of these points is dependent on a size of virtual grid specified in the correlation parameters setup. The points with the value 1 represent the correlated locations. If the value is 0, it concerns either unfilled places or the parts of investigated objects, which from some reason could not be correlated. The total size of mask is then expressed as a product of maximal quantum of mesh rows and columns $m \times n$.

The file mentioned above can be simply processed in the program Matlab. This is a main reason, why also Modan 3D is created in this program.

In the first step of algorithm the program reads all the measurements data and creates the relevant data matrices needed for next mathematical processing. The mentioned data are: