Damage Detection through Wavelet Transform and Inverse Analysis

<u>Anna Knitter-Piatkowska</u>†, Tomasz Garbowski†, Andrzej Garstecki†

†Institute of Structural Engineering, Poznan University of Technology
Piotrowo 5, 60-687 Poznan, Poland
anna.knitter-piatkowska@put.poznan.pl

ABSTRACT

Methods of damage identification (detection) are expected to provide information whether damage exists or not. This work is concerned with methods to identify damage based on measurement of structural response to the actual actions or actions specially planned and applied to the existing defected structure. Various methods of inspection (e.g. X rays, vibration, acoustic emission, etc.) are used for damage detection. In general they allow to identify the position of damage and possibly also its form and magnitude.

If the response of the existing structure is compared to the response of its computer model which contain parameters characterizing the expected defects then we denote this method as approach (1) for brevity. Different kind of responses can be monitored, namely displacements, velocities or accelerations, to construct the discrepancy function. Through the minimization of the differences between measurable quantities: (a) computed by the numerical model, and, (b) recorded on the existing damaged structure, the information on the defects can be assessed. Recently alternative approaches (2) have been developed, in which the time-consuming optimization procedures can be avoided. In these approaches data processing techniques are applied only to the response signal of the existing defective structure. This group of techniques includes special methods of artificial intelligence, e.g. Artificial Neural Networks (ANN); methods of signal processing, e.g. Fast Fourier Transform (FFT); or Wavelet Transform (WT), in continuous form (CWT) or discrete (DWT) [1].

In this work the methods (1) and (2) and their combinations are discussed. The attention is focused on DWT which allows to detect and localize the damage, mainly because wavelets demonstrate strong disturbance in a place where the damage is localized (see Fig. 1). Estimation of the magnitude of the damage can be done by making use of e.g. Lipschitz exponent. However, data processing of the structural response signal using CWT or DWT has appeared to be rather ineffective in identification of the type or shape of a defect. Therefore, herein the usefulness of an alternative method of more precise damage identification is studied. The proposed method is a combination of DWT (method 2) and inverse analysis (method 1).

The inverse analysis provides an important tool if one would like to characterize a bigger number of damage parameters in the locally deteriorated elements of the structures. Such technique uses, besides the wavelet representations of the experimental measurements, also their numerical counterparts obtained from the computer test simulation. In this work authors use a parametrized FE model which mimic the real structure subjected to dynamic mechanical excitation. All control parameters gathered in the vector **x** are embedded in the numerical model; by changing them one can minimize the discrepancy between the wavelet representation of both 'real' and numerically computed measurable quantities. Here the 'real' experiment

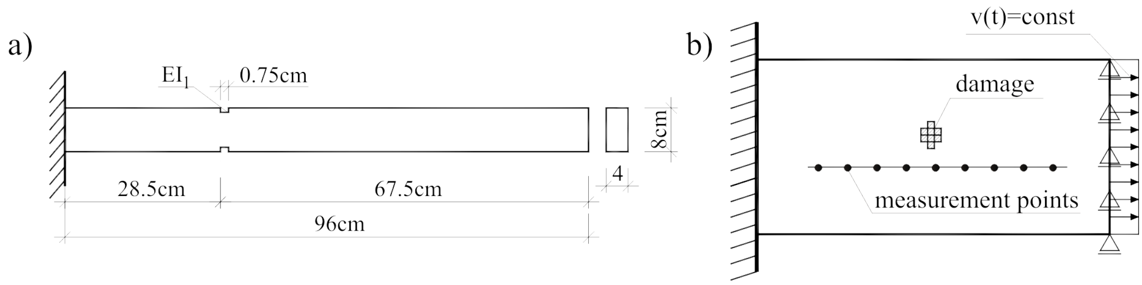

Figure 1: Damge detection by DWT; a) A plate with an inclusion of 10% softer material; b) Wavelet transform Deubechies 4 indicating damage. Velocity $v(t) = v_0 H(t - t_0)$ imposed at the boundary with $v_0 = const$, and H the Heaviside function.

is substituted with a numerical one called here pseudo-experiment in which all parameters (e.g damage localization, type or shape of damage, number of monitored points, etc.) are known. By different initialization of the vector **x** in the numerical model (which is different from the pseudo-experimental one), and by comparing the converged values of the sought parameters to those parameters used for pseudo-experimental data generation, one can check the robustness of the proposed method.

First for the discrepancy function minimization (within least-square framework) the deterministic, iterative Trust Region Algorithm (TRA) is used, in the later stage the global minimization technique such as Genetic Algorithms (GA) are employed. However, the minimization techniques, in general, require a big number of computations to be utilized, therefore in order to reduce the cost of an identification procedure the meta-model of the system is constructed [2]. Such model substitute a numerical one with its mathematical approximation build herein by Radial Basis Functions (RBF) and alternatively by feed-forward ANNs; both use preliminary truncated data by Proper Orthogonal Decomposition (POD) techniques.

The contribution of this work is a novel approach to Structural Health Monitoring (SHM) based on damage detection through wavelet transformation, numerical FE modeling and mathematical programming. The inverse analysis employed here uses two distinct minimization algorithms, in order to select the most suitable technique of DWT application to SHM. This preliminary work serves as a check of the usefulness of the proposed technique, and will be validated, in future, by a real experiment on structural elements.

References

[1] A. Knitter-Piatkowska, Z. Pozorski, A. Garstecki, Application of discrete wavelet transformation in damage detection. Part I: Static and dynamic experiments. *Computer Assisted Mechanics and Engineering Sciences* 13:21-38, 2006.

[2] T. Garbowski, G. Maier, G. Novati, On calibration of orthotropic elastic-plastic constitutive models for paper foils by biaxial tests and inverse analyses. *Structural and Multidisiplinary Optimization* (available on line, in print) 2011.