STRUCTURAL DAMAGE DETECTION THROUGH WAVELET DECOMPOSITION AND SOFT COMPUTING

***A. Knitter-Piatkowska*[1], *T. Garbowski*[1] *and A. Garstecki*[1]**
[1]*Institute of Structural Engineering, Poznan, Poland*

1. Introduction

Damage identification belongs to the field of problems connected with structural health monitoring and safety assessment. Safety of the structure can be decreased by defects evolving in the structure which may take the form of cracks, voids, decohesions etc. It is expected that various methods of damage identification provide information whether damage exists or not. Among a large number of non-destructive testing one can propose for example X rays, vibration, acoustic emission, heat transfer, etc. These methods of inspection allow to identify the position of damage and possibly also its form and magnitude. In this work methods of damage identification based on measurement of structural response to the actual actions or actions specially planned and applied to the existing defective structure are proposed. Different types of structural response namely displacements, velocities or accelerations can be monitored. By the comparison of the response of the existing structure with the response of its computer model containing expected damage parameters one can construct the discrepancy function. Minimization of the differences between measurable quantities computed by the numerical model and recorded on the real defective structure allows to obtain the information on the defects. Recently alternative approaches have been developed where data processing techniques are applied to the response signal of the damaged structure only, therefore the time-consuming optimization procedures can be avoided. At present the great potential is assigned to methods of artificial intelligence e.g. Artificial Neural Networks (ANNs) or methods of signal processing e.g. Fast Fourier Transform (FFT) and Wavelet Transform (WT) in continuous (CWT) or discrete (DWT) form.

In this work the attention is focused on Wavelet Transformation in its discrete form. The most fundamental challenge is the fact that damage is typically local phenomenon and may not significantly influence the global response of structures. Signal decomposition using WT allows to detect and localize the damage because wavelets demonstrate strong disturbance in a place where the damage is localized. To assess the magnitude of the damage Lipschitz exponent for example can be used. However, data processing of the structural response signal using WT proved to be rather ineffective in identification of the type or shape of a defect. Therefore, the possibility of using a new approach of more precise damage identification based on Artificial Neural Networks is studied. Here the attention is focused on Radial Basis Function Networks (RBFNs).

2. Description of the proposed method

The proposed method uses both Discrete Wavelet Transformation and Artificial Neural Networks as a damage detection tools which, in combination, gives possibility to detect not only the localization of damage but also its shape and/or size. All geometrical features of defect together with its localization in the structure form a vector of parameters $\mathbf{x}$ to be identified. In order to verify if such identification can be done in the real experiment, it is commonly accepted to build first a computer model which mimic the examined structure and perform on it the numerical identification procedure. Usually a pseudo-experimental validation analysis consist of two steps: (1) first a reference model with a-priori chosen parameters $\mathbf{x}^*$ is computed and all necessary signals are stored; (2) later the numerous of identification procedures are performed starting from different values of $\mathbf{x}_i \neq \mathbf{x}^*$ in order to check if convergence to known solution $\mathbf{x}^*$ can be obtained. Alternative to (2) is to use, instead of iterative solver, the ANN for $\mathbf{x}^*$ prediction. ANN provides a vary fast identification tool which can be used 'in situ' on a portable computer without any time-consuming computations nor sophisticated software. However ANNs require to be trained, which is, in general, an expensive process if many training examples need to be generated, yet the training is done once-for-all in the preliminary phase (i.e. not during the identification phase). Here the training samples are computed by the Finite Element (FE) model, which for various damage parameter vectors $\mathbf{x}_i$ computes the response signals (displacement and acceleration fields). Then the signal is transformed through DWT and the wavelet coefficients are computed; all coefficients form a vector $\mathbf{c}$, and together with corresponding damage parameters gathered in $\mathbf{x}$, are used as training data for ANNs (each training sample consists of damage parameter vector $\mathbf{x}$ as ANN's output and wavelet transformation coefficient vector $\mathbf{c}$ as an input).

In the first step of validation the different types of damage (e.g. inclusions, voids, stiffness or cross-section reduction, etc.) are employed in the numerical model in order to check which defect type perturbs the most the measurable signals and therefore the sensitivity of the signal with respect to damage parameters. The recorded signals are the deformations and accelerations of various points in the structure (here beams and plates are investigated). In beams defect is modeled as a step-wise reduction of cross-section on a small area and/or stiffness reduction whereas in plate structures defects have the form of voids or inclusions (also reduction of cross-section and stiffness is checked).

In the later stage the attention is focus on proper training techniques of ANNs and reduction of input data (wavelet transformation coefficients vector $\mathbf{c}$) through principal component analysis. The minimum number of ANN training samples (i.e. the number of damage scenarios) necessary in appropriate construction of model approximation is also studied here in order to reduce the number of experiments to be performed.

3. References

[1] S. Timoshenko and S. Woinowsky-Krieger (1991). *Theory of Plates and Shells*, 2nd ed. McGraw Hill, New York, 122-131.

[2] Z. Waszczyszyn and L. Ziemiaski (2001). Neural networks in mechanics of structures and materials - new results and prospects of applications, *Computers and Structures*, **79**, 2261-2276.

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