Influence of the wavelet order on proper damage location in plate structures

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Abstract

The rectangular thin plates were analysed in this paper. First, the static response in plate structure subjected to the uniform load was derived by applying the finite element method. Next, the analysis of the obtained signal was carried out with the use of Discrete Wavelet Transform (DWT), provided that damage exists in the considered plate structure. It was assumed, that in the middle of the structure a certain area of the plate is thinner. The aim of this work was to choose the appropriate wavelet order to reveal the localization of defect. The results of selected numerical example proved the efficiency of proposed approach.

Keywords: defect detection, structural identification, Discrete Wavelet Transform, Finite Element Method

1. Introduction

In civil engineering the control of the structure condition is one of the most important issues. This problem is complex and difficult, particularly in the case of heterogeneous materials, for example concrete, when any of failure is difficult to detect. In this case, non-destructive methods are useful because they enable to examine the internal defect based on the element external observation.

Among the various methods for identifying defects in structures [2, 1] Wavelet Transform (WT) should be mentioned [7,6]. Moreover, the area of defects can be effectively detected using the discrete form of signal analysis method, i.e. Discrete Wavelet Transform [4,3]. The paper presents the idea of detecting defects in thin plates when the signal is in the form of a static response caused by a uniformly distributed load. The results of selected numerical example are presented.

2. Problem formulation

The main purpose of the proposed approach is to find a way of selecting the correct order of wavelet in DWT method to detect the internal damage. The rectangular thin plates simply supported on four columns in every corner were analysed. The static response in plate subjected to the uniform load was obtained applying the software (Autodesk Robot Structural Analysis) which is based on the finite element method (FEM). The difference between the deflection of undamaged plate and the defective structure was almost undetectable.

Next, the analysis of a structural response was carried out with the use of Discrete Wavelet Transformation (DWT). Discrete signal decomposition, according to the Mallat pyramid algorithm, takes the following form [5]:

$$f_J = S_J + D_J + \ldots + D_n + \ldots + D_1, \qquad n = J - j, \tag{1}$$

where discrete parameter J is the level of multiresolution analysis (MRA), S_J – smooth signal representation and D_1 the most detailed representation of the transformed signal. To fulfill the requirements of DWT the function f_J must be approximated by $N = 2^J$ discrete values.

In the current analysis Daubechies family of wavelets, with the order between 2 and 20 (even numbers only), was used.

3. Numerical test

Exemplary numerical calculations have been performed for the rectangular concrete slab resting on four columns (Fig. 1). The model of structure is a rectangular thin plate supported by point hinges located close to the corners. The plate is made of concrete C25/30 for which the Young's modulus is $E = 30.5$ GPa and the Poisson's ratio $\nu = 0.2$. The dimensions shown in Fig. 1 are adopted as follows: $L = 2.0$ m, $b = 0.1$ m and $h = 0.15$ m. In the middle of the plate span some defect was introduced, i.e. for a certain area ($d = 0.2$ m, $e = 0.06$ m and $f = 0.16$ m) the plate is thinner $h_1 = 0.1$ m.

Along the line located parallel to the longer edge ($g = 0.3$ m) 64 nodes were established. Next, in these nodes deflections caused by the structure self-weight were determined. The obtained signal, the static response of structure was decomposed by using the family of asymmetrical Daubechies wavelets with sharp edges. The efficiency of the method was tested for various order of the wavelet.

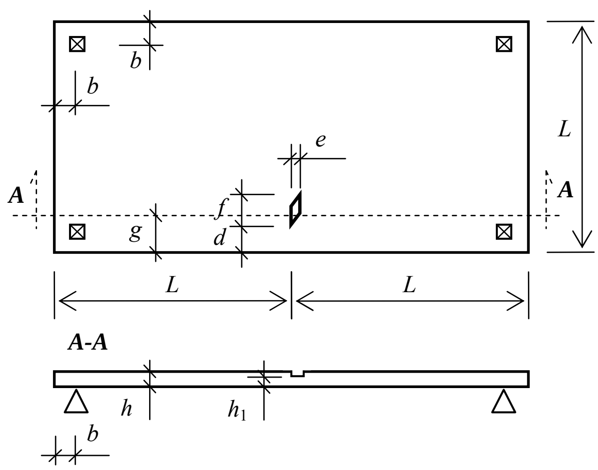

Figure 1: The concrete plate structure supported on four columns

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The results of the analysis are presented in Figs. 2 to Fig. 5 for number of measurements $N = 64$.

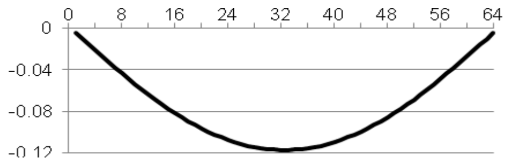

Figure 2: The deflections caused by the plate self-weight

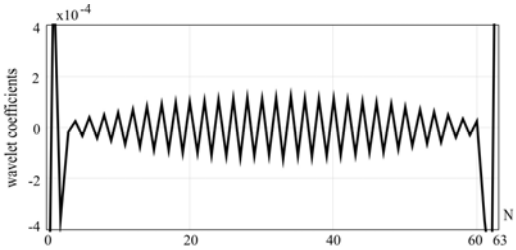

Figure 3: DWT; Daubechies 4 wavelet, detail 1; signal: deflection of the plate structure

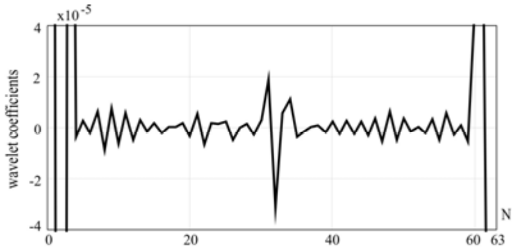

Figure 4: DWT; Daubechies 6 wavelet, detail 1; signal: deflection of the plate structure

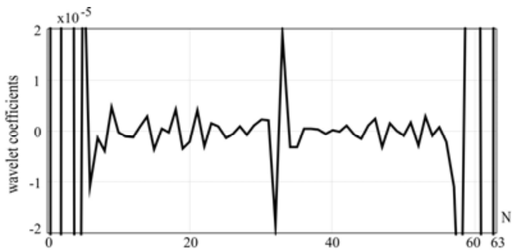

Figure 5: DWT; Daubechies 8 wavelet, detail 1; signal: deflection of the plate structure

An evident disturbance of the transformed signal is expected as the indicator of the damage presence in the examined structure. It is visible in Fig. 2 that the global static response of the structure, deflections in this case, did not give the answer whether and where is the defective element. An attempt to analyze the difference between the deflections of undamaged and the defective structure was also ineffective. Moreover, the DWT of the signal with the Daubechies 4 wavelet (Fig. 3) did not indicated the damage location, despite the fact that in previous similar analysis that range of the wavelet was sufficient. Hence, it has become necessary to increase the order of wavelet, which in fact meant more wavelet coefficients of the low pass filter used in wavelets transform algorithms. Damage was undoubtedly localized by the high peaks of the transformed signal (Fig. 4, 5) both by Daubechies 6 and Daubechies 8 wavelet. Detail 1, as the most detailed representation of the transformed signal, was taken into consideration. However, the increasing of the wavelet order results in bigger boundary disturbances in the transformation window.

4. Conclusions

The main purpose of the proposed approach is to find a way of selecting the correct range for wavelets in DWT method in order to detect the internal damage. The rectangular thin plates simply supported on four columns in every corner were analysed. The static response in plate subjected to the uniformly distributed self-load was obtained applying the software (Autodesk Robot Structural Analysis) which is based on the finite element method (FEM).

The implementation of DWT, Daubechies asymmetrical family of wavelets, to identification of signal discontinuity in the plate structures is presented in the paper. The presented numerical examples proved the efficiency of the proposed method in proper damage location provided, that adequate order of the wavelet function is applied. However, the proposed approach is qualitative, allows location of damage, but does not enable to assess its severity. The analyzed line of deflection passes through the damaged area. The influence of the distance between the damaged element and the measured deflection line on effective damage localization will be investigated in the future. Although considered plate is 2*D* structure, applied one-dimensional Discrete Wavelet Transform leads to efficient results in defect detection, even for the relatively small number of measurement points ($N = 64$).

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