Defect detection in plates using dynamic response signals and Discrete Wavelet Transform

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Abstract

The paper presents the defect detection in plates considering the influence of dynamic characteristics, especially with regard to the vibration modes. The aim if this work is to detect the localization of defect provided that damage exists in the considered plate structure. The Kirchhoff plate bending is described and solved by the Boundary Element Method (BEM). Plates have rectangular shape and different boundary conditions. The analysis of a structural response is carried out with the use of signal processing tool namely Discrete Wavelet Transformation (DWT). Defects in plates are introduced as slots near the plate boundary.

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

1. Introduction

Defect detection in engineering structures is significant for monitoring of a structural behaviour. There are different non-destructive techniques which enables the identification of defective part of a structure. This problem is extensively investigated by scientists and some approaches based on e.g. optimization of loads [1], information of natural frequencies [2], heat transfer [3], inverse analysis [4], soft computing methods such as evolutionary algorithms [5] or artificial neural networks (ANN) [6] are applied. The area of defects can be effectively detected while using another type of the signal analysis method called wavelet transformation (WT) [7]. This method can be applied also in its discrete form [8, 9]. Combining Discrete Wavelet Transform with, earlier mentioned, ANN or inverse analysis one can precisely identify damage details [10]. The paper presents the issue of defect detection in thin plates excited by external static or dynamic loads. Numerical examples are presented.

2. Problem formulation

The aim of the presented work is to detect the localization of defects provided that they exist in the considered plate structure. Numerical investigation is conducted basing on signal analysis of structural dynamic response. The plate bending is described and solved by the Boundary Element Method (BEM). The boundary and boundary-domain integral equations are derived in singular and non-singular approach [11]. The rectangular plates simple-supported on boundary are taken into account. The static fundamental solution and the Bèzine approach [12] is used to establish the vector of inertial forces. The analysis of a structural response is carried out with the use of Discrete Wavelet Transformation (DWT). The multiresolution signal analysis while using Mallat pyramid algorithm [13] is applied. Defects are introduced by the additional edges forming a crack in relation to the basic plate domain. The experiments are simulated numerically.

3. Selected numerical example

A rectangular plate, simply-supported on two opposite edges is considered (Fig. 1). Two first eigenmodes are examined. Measured variables are amplitudes of deflections along selected line 1−1. Decomposition of the obtained signal is carried out using DWT with Daubechies 4 and Coiflet 6 wavelets. The plate shown in Fig. 1 is taken into consideration. The plate properties are: E = 205 GPa, ν = 0.3; plate thickness h = 0.05 m; dimensions of the plate: l_1 = 2.0 m and l_2 = 1.0 m respectively; the dimensions of the slot: e = 0.005 m, f = 0.4 m. All plate edges are divided into 30 boundary elements of the constant type. The deflection line is determined by parameter g = 0.25 m. Results of the analysis are presented in Figs. 2−5 for N = 64 measurement points.

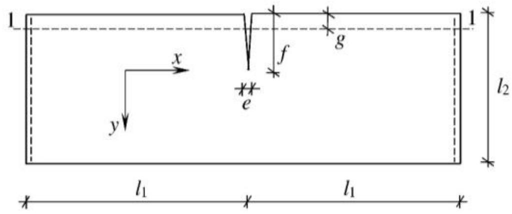

Figure 1: The plate simply-supported along two opposite edges

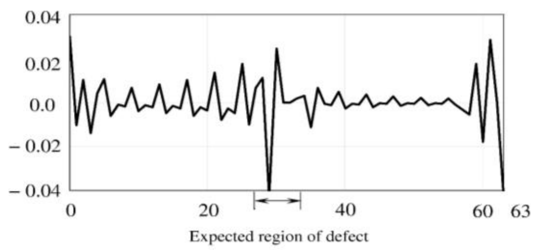

Figure 2: DWT; Daubechies 4 wavelet; signal: amplitudes of deflection along line 1−1 in accordance to the first mode

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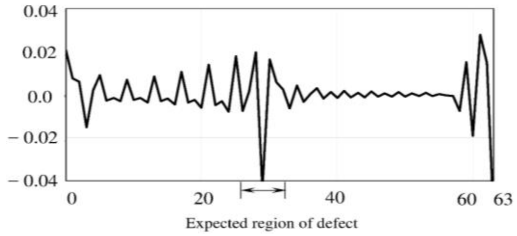

Figure 3: DWT; Coiflet 6 wavelet; signal: amplitudes of deflection along line 1−1 in accordance to the first mode

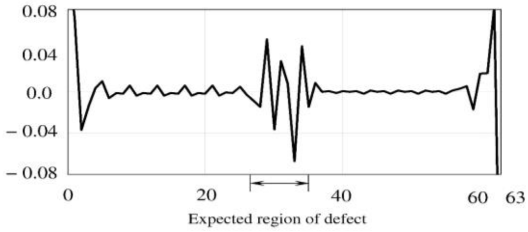

Figure 4: DWT; Daubechies 4 wavelet; signal: amplitude of deflection along line 1−1 in accordance to the second mode

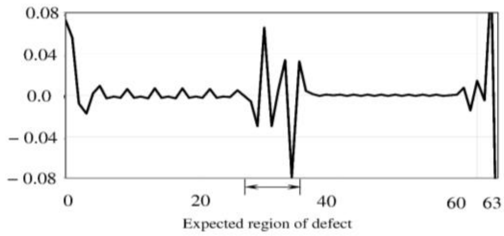

Figure 5: DWT; Coiflet 6 wavelet; signal: amplitudes of deflection along line 1−1 in accordance to the second mode

The detail 1 of the decomposed response signal is analysed. Noteworthy is the fact that while using asymmetrical Daubechies wavelet (Figs. 2 and 4) as well as nearly symmetric Coiflet wavelet (Figs. 3 and 5) for signal transformation the damage location is clearly depicted by the evident disturbances and high picks for both modes.

4. Concluding remarks

The implementation of discrete dyadic wavelet transformation to identification of signal discontinuity in the free vibration analysis of plates is presented in the paper. The thin plate bending is described by the boundary and domain integral equations and solved using the BEM approach. Although the considered issue is two-dimensional from the point of view of deformation description, applied one-dimensional Discrete Wavelet Transform (DWT) leads to efficient results in defect detection. It discovers small disturbances in response signal of defected structure and does not require the reference to a signal from undamaged structure. Considered examples quite correctly identify the presence and position of defects. The analysis is carried out without any signal noise reduction. Effectiveness of the proposed method is indicated by previously presented numerical investigation, where the defects are properly localized, even for the relatively small number of measurements (N = 64).

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