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Experimental structural damage localization in beam structure using spatial continuous wavelet transform and mode shape curvature methods

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Abstract. An experimental dynamic vibration test using a non-contact scanning laser vibrometer is performed in order to extract the deflection shapes of two aluminium beams containing a notch cut out with a mill and two carbon/epoxy composite beams containing an impact damage of different severities. All of the beams are subjected to the clamped-clamped boundary conditions. These shapes are used as an input in a continuous wavelet transform technique for damage detection. In total, 78 wavelet functions with scale factors from 1 till 128 are used for the aluminium beams, whereas deflection shapes for composite beams are obtained in two dimensions, thus a two-dimensional wavelet transform is employed using 16 wavelet functions, all at scales from1 till 16. The scale, which is most suitable for damage identification, is found by calculating standardized damage index and the parameter called damage estimate reliability for the scales under investigation. Another method, based on mode shape curvature squares, is also applied to identify the damage. A baseline data of deflection shapes at a healthy state is not required for both methods to work. Damage identification results are compared for both methods. To assess the robustness of an algorithm involving both methods, different sensor densities are simulated by reducing the input deflection shapes by integer factors.

Keywords: wavelet, deflection shape, damage, beam, scale, reliability.

Highlights

- Deflection shapes of two aluminium beams containing a mill-cut damage and two carbon/epoxy composite beams with an impact damage are obtained through dynamic vibration testing using scanning laser vibrometer.
- The damage is localized by exploiting the transformation of mode shapes with two techniques, namely, continuous wavelet transform and mode shape curvature squares.
- The calculated damage index is standardized according to statistical hypothesis approach and the highest peaks in the profile of damage index reveal the location of damage.
- There is no need for baseline data of a healthy structure, since healthy mode shape curvatures are generated with Fourier series interpolation (one-dimensional structures) or polynomial least-squares fitting (two-dimensional structures) of mode shape curvature of damaged structure.

1. Introduction

Demands for structural integrity of different civil and engineering structures have grown over the years. This can be mainly attributed to the increasing complexity and size of such structures as civil buildings, skyscrapers, bridges, dams, stadiums, tunnels and industrial facilities. Also, these structures may have to operate in aggressive environments. The consequences of a structural failure are often tragic and involve serious financial investments. Structural health monitoring (SHM) is an emerging field in civil, mechanical and aerospace communities offering a potential to replace the existing structural inspections that are expensive, time-consuming and not always effective.

A wide variety of different damage identification methods is available. In source [1] a rotational field of statically loaded clamped-free and free-free aluminium beams has been measured using a speckle shear interferometric technique. From these measurements