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A DIRECT IDENTIFICATION ALGORITHM FOR THE ESTIMATION OF THE STIFFNESS DISTRIBUTION OF FRAME STRUCTURES

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ABSTRACT

An identification procedure is presented for assessment of the stiffness distribution in structures with the aid of an inverse-problem algorithm. The procedure is based on an FE model of the structure with an unknown stiffness distribution and a subset of measured vibration frequencies and vibration modes. Two independent stiffness indicators - axial and flexural – are used, determined by means of the axial strain and the curvature mode shapes, respectively. The procedure permits simultaneous location of damaged elements, with accurate quantification of damage severity. Furthermore, it is applicable to a variety of structure types, including frames, beams and trusses. The effects of random measurement noise and of realistic joints are taken into consideration. The effectiveness, reliability, and range of application of the procedure are demonstrated in a numerical study.

Various identification techniques have been developed over the years[1][2]; most of them were confined to simple structures usually to simple-supported beams. For 3D frame structures much less works are reported in the literature. Li et al[3,4] developed an identification method for 3D frame element based of cross-modal strain energy (CMSE). Their procedure is based on the assumption that the mode shapes of the damaged structure is exact and was calculated analytically, which does not suit to a realistic structure. Reliable identification algorithm must take into account realistic vibration measurements, that is the effects of random measurement noises and of realistic joints must be taken into consideration.

This work extends the method proposed by the author[5,6], which is analogous to direct calculation of the dynamic stiffness, Maeck and De Roeck[7]. Since damage consists typically of local phenomena, their effect on the lower frequency in the global measured response of the structure may be insignificant. Pandey et al[8] found that the curvature mode shape is more sensitive to local damage. Yet, estimation of the curvature mode shapes from experimental data is difficult and usually involves a post-processing procedure. It was found[5] that the axial strain mode shapes are also sensitive to local damage compared to the in-plane axial displacements, and since the former are obtained directly from measurement data, their use in the identification procedure makes it more promising. On the other hand, changes in the axial strains due to damage are smaller compared to those in the curvature mode shapes, and bearing in mind the inherent measurement noises, the stiffness thus predicted is less reliable. As a solution, the author[5] recommended a direct procedure readily implemented in a general FE model, and involving independent recourse to two stiffness indicators – axial and flexural – determined by the corresponding mode shapes, respectively. Thus, the stiffness distribution is identified, the damage located, and its severity evaluated simultaneously. Another advantage of the procedure is the need for a very small number of mode shapes (in theory, even a single mode suffices).

A numerical study with the examples of a 3D frame shows that it is able to locate both localized and multiple damage and determine its severity with a high level of reliability.

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