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CURVATURE RATE APPROACH TO THE ESTIMATION OF THE STIFFNESS DISTRIBUTION IN STRUCTURES

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A procedure for identifying the bending stiffness distribution in structures is presented. The algorithm is based on the correlation between a parameter called curvature increased factor (CIF) and the bending stiffness of the structure. Since damage induces redistribution of the internal forces and moments along the strucure, it must be considered in order to correlate accurately between the curvature and the bending stiffness. Therefore, the study offers an iterative procedure, which eliminates the effect of the moment redistribution from the CIF and eventually correlates accurately between CIF and the bending stiffness.

Vibration-based non-destructive damage identification assessment has been attracting growing interest over the past two decades. The basic idea of the non-destructive global dynamic methods is that the modal parameters (natural frequencies, mode shapes, and modal damping) are functions of the physical properties of the structure (mass, stiffness, and boundary conditions), so that changes in the latter make for changes in the former, i.e. in the modal properties.

Damage typically consists of local phenomena and its effect on the lower displacement mode shape in the global measured response of the structure may be insignificant. Curvature rate and strain mode shapes, on the other hand, are more sensitive to local damage (Pandey et al., [1]) and so they were used extensively to locate damage primarily in continuous 1-D structures. In order to apply this concept to general structures, the accurate estimation of the strain or curvature mode shape should be considered, as well as the effect of the redistribution of internal forces and moments on the curvature distribution.

Different kinds of damage, such as cracks and corrosion, usually reduce local stiffness and so affect the structural behavior. In the present study such damage is simulated by a defective area on the structure with a reduced bending stiffness. The study proposes using the curvature increased factor (CIF) as a sensitive and effective indicator for the bending stiffness distribution of the structures. Specifically, the CIF is derived from the change of the curvature of a specific section and is divided by the curvature of the same section in undamaged state. The undamaged (intact) state can be considered analytically, and only modal information from the damaged state is needed. In statically determinate structures, the CIF is related directly to the bending stiffness of a specific section. However, for statically indeterminate structures Ref. [2], the curvature value may also change due to redistribution of bending moments. This effect must be eliminated in order to accurately correlate the CIF and the bending stiffness in plates. Since the internal moment redistribution is not known in the identification procedure and is dependent on the stiffness distribution, an iterative procedure is proposed.

Acceptable estimation of curvature rates from experimental data is difficult and involves a post-processing procedure. The limited number and location of the measured modal displacement should be taken into consideration, along with possible noises and measurement inaccuracies. Therefore, this study offers to evaluate the curvature rate from a given set of modal displacements by a new post-processing procedure – an optimal smoothing techniuqe. The proposed techniuqe assumes that the dynamic response of the structure is acquired by placing sensors in equally distributed spacing for 1D structure or equally distributed grid for 2D structures. It involves a so-called weighted residual penalty-based technique, and with the aid of linear shape functions, enables to evaluate the modal rotations and the modal curvatures at any desired location along the structures.

The study will demonstrate the procedure's effectiveness, reliability, and range of applicability using numerical simulations.

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