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REFINED KINEMATICS FOR DYNAMIC ANALYSIS OF THIN-WALLED COMPOSITE BEAMS

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ABSTRACT

Especially with the advent of composites, the accurate response evaluation of slender thin-walled structures subjected to a variety of dynamic loadings is nowadays an even more challenging issue in many fields such as aeronautical, mechanical, civil, and biomechanical engineering.

Dynamic response analyses of thin-walled composite structures are presented in this paper. Beam-like structures are modeled via refined finite elements in the framework of the 1D Carrera Unified Formulation (CUF). CUF 1D models have recently been developed for isotropic [1] and composite structures [2]. CUF models exploit arbitrary order expansions of the generalized variables above the cross-section of the structure. In this paper, Taylor-like polynomial expansions are adopted and the order N of the expansion is a free-parameter of the formulation. In other words, any-order models can be obtained with no need of ad hoc formulations by exploiting a systematic procedure to build finite element matrices in a form which is independent of the accuracy of the model. 1D CUF models allow to detect highly accurate shell-like static deformations and modal shapes of thin-walled structures with a significant reduction of computational costs.

The first extension of hierarchical finite elements based on the CUF for free vibrations analysis of beams with arbitrary section geometries was faced in [3]. These models were employed to carry out a more accurate free vibration analysis of conventional and joined wings [4]. Higher-order terms permitted bending/torsion modes to be coupled and were able capture any other vibration modes that require in-plane and warping deformation of the beam sections to be detected.

In this paper, the extension of 1D CUF models to the dynamic response of composite structures is presented. The Newmark time integration method [5] widely used in structural dynamics is here employed. A number of thin-walled slender configurations (by varying span-

to-length ratio, cross-section geometry, and material lay-up) under different loadings such as harmonic, impulsive, and traveling ones are analyzed. Comparisons with results from reference cases in literature and shell finite elements analyses have carried out in order to assess the formulation. The influence of non-classical cross-section deformation not detectable through classical and low-order beam theories on the time-dependent response of composite structures is investigated. The implementation of 1D CUF models in a time integration Newmark's scheme reveals the capabilities of such refined models in accurately describing the dynamic behavior of composite wings.

Table 1 shows a typical result from the present formulation. A set of harmonic loadings are applied on a clamped-clamped beam with a thin-walled annullar cross-section. As *N* increases, the third and fifth columns present the percentage error computed with respect to the Nastran shell solution, taken as a reference, for the transverse displacements of two sample points. The proposed 1D model makes it possible to describe local deformations typical of a shell-like behavior with a sizeable reduction in computational cost in terms of DOFs.

Theory	u_{xD}	Error u_{xD}	u_{zA}	Error u_{zA}	DOFs
EBBM	0.	–	0.	–	93
$N = 1$	-2.0937	-91.08 %	-1.4362	-85.47 %	271
$N = 4$	-5.9690	-74.56 %	-6.8900	-30.29 %	1395
$N = 7$	-15.7213	-32.99 %	-9.3591	-5.31 %	3348
$N = 10$	-19.7523	-15.81 %	-9.7314	-1.54 %	6138
$N = 14$	-21.1939	-9.67 %	-9.8418	-0.43 %	11160
NASTRAN	-23.4628	–	-9.8840	–	250000

Table 1: Displacements of loading points A and D for different FE models

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