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AN IMPROVED WAVE / FINITE ELEMENT FORMULATION FOR STUDYING HIGH-ORDER WAVE PROPAGATION IN LARGE-SCALED WAVEGUIDES.

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The problem considered in this paper concerns the broadband analysis of wave propagation in large-scaled or thick laminated composite waveguides. Guided waves in such structures are increasingly encountered in automotive and aerospace industries or in the field of structural health monitoring. As wave propagation is studied in structurally advanced waveguides, there is an increasing need for numerical methods to be compatible with finite element modeling. The wave finite element method, combining periodic structure theory (PST) introduced by Mead [1] with a finite element method (FEM), is an effective numerical tool for such purposes. However, broadband analysis of composite waveguides suffers sizable computational costs, due to the requirements for a high spatial discretization.

Hence, we propose a method, based on a cross-sectional transfer matrix projection on a reduced set of shape functions associated with propagating waves, to compute dispersion curves for highly discretized waveguides. The reduced basis is build using propagating, positive-going wave solutions of a reduced number of generalized eigenvalue problems [2]:

$$\mathbf{S}\boldsymbol{\Phi} = \lambda\boldsymbol{\Phi} \tag{1}$$

where $\mathbf{S}$ is the cross-sectional transfer matrix, λ the propagation constant and $\boldsymbol{\Phi}$ is the state vector containing nodal forces and displacements of the waveguide cross-section. This reduced formulation allows high-order wave analysis such as complex cross-sectional (Fig. 1b) deformations or wave localization for thick laminated composite beams.

The method is validated on the multilayered elastic beam illustrated Fig. 1a. Limitations of the classical wave finite element method (WFE) are highlighted and the results (Fig. 2) are compared to the proposed formulation for high-order propagating waves. Furthermore, this model order reduction strategy enables numerical analysis for structuraly advanced waveguides on a broadband frequency range [3].

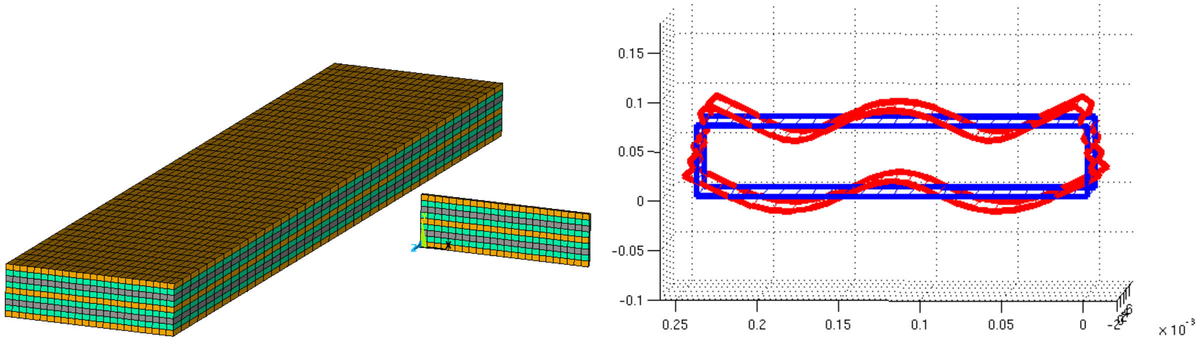

Figure 1: (a) : Cross-sectional discretisation of a thick laminated composite beam. (b) Deformed shape associated with a second-order propagating wave (red), undeformed shape (blue).

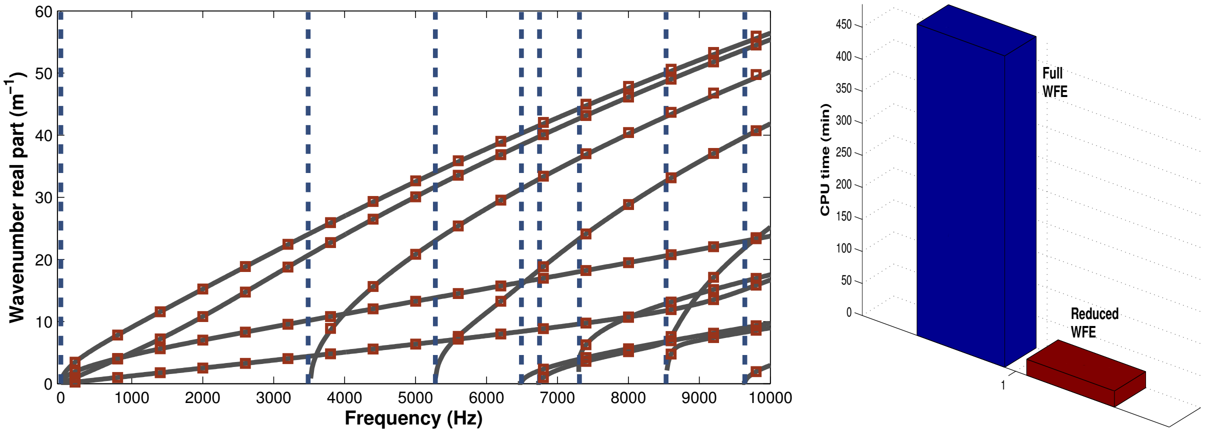

Figure 2: (a) Comparison between full (red □) and reduced (black —) wavenumbers for the laminated waveguide. (b) CPU time comparison between the classical WFE method (blue) and the proposed reduced formulation (red).

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