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On elastic open waveguides and their numerical modelling with a modal approach

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The practical concern of this talk is the non-destructive evaluation (NDE) with guided waves of elongated structures (bar, cables, pipes...) partially or totally embedded into a solid matrix (cement, rock...). These structures are widely encountered in civil engineering. Numerical models are used to obtain the properties of the waves modes (velocity, leakage attenuation...), which are essential to interpret the NDE results. This talk presents three numerical models recently developed to compute the dispersion curves, the forced response and the diffracted field in such structures.

These structures can be considered as elastic open waveguides, made of a core (the guiding structure) embedded into an infinite solid medium, such that the transverse directions (orthogonal to the direction of wave propagation) are unbounded. In this talk, a Perfectly Matched Layer (PML) of finite thickness is introduced to truncate the transverse directions. The cross-section of the waveguide can then be discretized with finite-elements while the direction of wave propagation is described analytically (SAFE-PML method). It yields a linear eigenvalue problem, whose solutions are the modes. Three types of modes are obtained: trapped modes, leaky modes and PML modes. The post-processing of trapped modes and leaky modes enables to obtain the dispersion curves of the modes, of great practical interest. PML modes are non-intrinsic to the physics because they fully depend on the PML parameters. Examples of dispersion curves are shown for various waveguides geometries.

Then, the forced response and the diffraction problems are considered. An orthogonality relationship is derived to obtain the forced response with a unique modal superposition. Modal expansions can also be used to build transparent boundary conditions on the boundaries of a small finite-element volume enclosing a defect (hybrid method). It yields the reflection and transmission coefficients of leaky modes for any type of defect. Results are presented in various configurations for 2D and 3D waveguides damaged by a notch. A particular attention is given to the solution at high-frequency corresponding to a minimal

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leakage attenuation, that is to a maximal inspection range for NDE.

Throughout this talk, the contribution of the various modes to the solutions is investigated. A mathematical study is used to clarify the effect of a PML on the modal spectrum of open waveguides. Numerically, it is shown that the solutions can be approximated in a restricted region of the waveguide by modal expansions on leaky modes only. This zone is delimited by the near-field of the source and the long-term diffraction limit. It enables to reduce the PML thickness and the number of computed modes, hence reducing the numerical cost.

References

- K. L. Nguyen, Modélisation numérique de la propagation des ondes élastiques dans les guides enfouis, PhD thesis, Ecole Centrale de Nantes, 2014
- M. Gallezot, F. Treyssède, and L. Laguerre, Contribution of leaky modes in the modal analysis of unbounded problems with perfectly matched layers, *Journal of the Acoustical Society of America* 141 (2017), EL16–EL21, DOI: 10.1121/1.4973313
- M. Gallezot, F. Treyssède, and L. Laguerre, A numerical method for the scattering by defects in axisymmetrical open elastic waveguides, *Procedia Engineering* 199 (2017), pp. 1527–1532
- M. Gallezot, F. Treyssède, and L. Laguerre, A modal approach based on perfectly matched layers for the forced response of elastic open waveguides, *Journal of Computational Physics* 356 (2018), pp. 391–409, DOI: 10.1016/j.jcp.2017.12.017