Radiated noise from fluid loaded stiffened shells subject to a turbulent boundary layer

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Cylindrical shells are often intended as simplified models to represent the physics of underwater vehicles. When a vehicle is moving underwater, the flow is likely to create a turbulent boundary layer (TBL) over the shell surface, as illustrated in Figure 1. The TBL induces vibrations on the shell, which results in the radiation of noise. Numerical simulations are nowadays widely used to predict the vibroacoustics of structures and re-design them to mitigate the flow-induced noise. However, most of the methods available in literature tackle the case of flat plates and only few results are available for cylindrical shells. In this paper, we give an overview of a method for calculating both the response of a fluid loaded cylindrical shell and the outward emitted noise, with different degrees of complexity. The method relies on the reciprocity principle and setting the response of the fluid-loaded structure in the wavenumber domain.

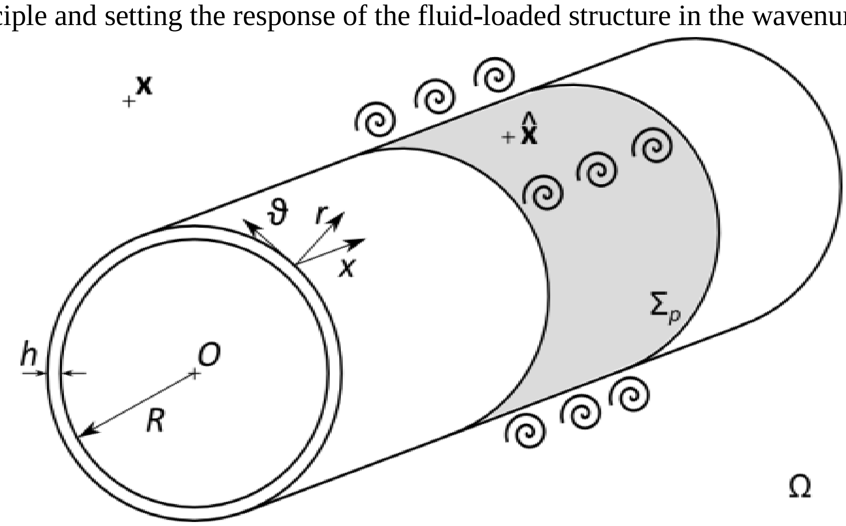

Figure 1: Cylindrical shell excited by a turbulent boundary layer on Σ_p

On the one hand, the TBL is a partially space-correlated random pressure field that can be characterized by means of the wall pressure cross-spectral density (CSD). As in typical practical applications the radius of the cylindrical shell is large in comparison with the TBL thickness, classical models for planar TBLs (see e.g., [1]) can be used with minor adaptations. On the other hand, one can define the sensitivity function at a shell's point as its vibroacoustic response when excited by a cylindrical acoustic plane wave. This allows one to compute the auto-spectral density (ASD) of the radiated noise by integrating the product of the TBL wall pressure CSD with the sensitivity functions, over the wavenumber domain [2]. Besides, Lyamshev's reciprocity principle shows that such sensitivity functions are totally equivalent to the radial velocity response of the shell when excited by an acoustic unit monopole, in the wavenumber domain (*i.e.* using a Fourier transform along the axial coordinates and a Fourier series along the circumferential coordinates, see [3, 4]). Resorting to the reciprocity principle has the advantage of considerably reducing the number of load cases which shall be considered to obtain the sensitivity functions.

In this work, the above technique is applied to predict the acoustic pressure radiated by different submerged cylindrical shells under TBL excitation. For infinite shells, an analytical formulation is described to calculate the sensitivity functions. That also includes the case of an infinite shell with regularly spaced stiffeners. For finite shells with arbitrary internal structures, a dedicated sub-structuring approach is employed. This sub-structuring approach, known as the condensed transfer functions (CTF) method, permits coupling the analytical model of a submerged cylindrical shell with a finite element model (FEM) of its internal structures [5]. The CTF method allows for a significant geometric versatility at a very reasonable computational cost, which makes it very appealing for industrial applications up to several kHz.

The considered test cases involve different phenomena and underlying physics. Aspects such as the role of propagative Bloch-Floquet waves in noise radiation by periodically stiffened structures, or the influence of the mechanical coupling between the shell and non-axisymmetric inner structures are addressed in detail. An explanation is also given for the very different behavior for the radiated acoustic pressure in the near and far fields.

References

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