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Development of a substructuring approach to model the vibroacoustic behavior of submerged stiffened cylindrical shells coupled to non-axisymmetric internal frames

Many works can be found in the literature concerning the vibroacoustic modelling of submerged stiffened cylindrical shells, because of high interest in the industrial domain, in particular for aeronautical or naval applications. However, only a few of them take into account non-axisymmetric internal frames, as for instance engine foundations or floor partitions, that can play a role on the vibroacoustic behavior of the system. On one hand, analytical models to include plates or resonators into stiffened cylindrical shells are available but are limited because of their low versatility, and are thus not always representative of the industrial need. On the other hand, discretization methods, such as the Finite Element Method (FEM), are very well adapted to take into account the geometrical complexity but are limited to low frequencies regarding the size of the system and the current computational capacities, and can be not suitable for preliminary design purpose. That is why a substructuring approach called the Condensed Transfer Function (CTF) approach is proposed in the first part of this thesis. The aim is to take advantage of both analytical models and element-based models, in order to be able to deal with the geometrical complexity, and to calculate at higher frequencies than with element-based methods only. The substructuring method is developed in the general case of thin mechanical structures coupled along curves. A set of orthonormal functions called condensation functions, which depend on the curvilinear abscissa along the coupling line, is considered. This set is then used as a basis for approximating and decomposing the displacements and the applied forces at the line junctions. Thanks to the definition and calculation of condensed transfer functions for each uncoupled subsystem and by using the superposition principle for passive linear systems, the behavior of the coupled subsystems can be obtained. The method is first developed and validated for plates and convergence criteria are defined in relation with the size of the basis of condensation functions. The CTF method is then applied to the case of a submerged stiffened cylindrical shell with non-axisymmetric internal frames. The system is partitioned in 3 types of subsystems: the submerged shell, the axisymmetric frames (stiffeners, bulkheads) and the non-axisymmetric frames. The submerged shell is described by a semi-analytical method based on the Flügge equations in the spectral domain. The axisymmetric frames are described by axisymmetric Finite Element models and the non-axisymmetric frames by Finite Element models.

In the second part of the thesis, the CTF method is applied to different test cases in order to study the influence of non-axisymmetric internal frames on the vibro-acoustic behavior of a cylindrical shell under different types of excitation particularly relevant for naval applications. First, in the case of a point force, it can be shown that additional circumferential orders play a role in the response of the system coupled with non-axisymmetric internal frames, and the radiation efficiency tends thus to increase. This trend is verified experimentally in air on a model. Then, the influence of internal

structures when the system is submerged in water and impinged by an acoustic plane wave is examined. In addition to Bragg and Bloch-Floquet scattering due to interferences created by the rib periodicity, the numerical model highlights scattering phenomena due to waves propagating in the internal structures. Finally, the wavenumber-point (k,M) reciprocity technique is used complementary to the CTF method to estimate the response of a complex shell under random excitations (i.e. diffuse sound field, turbulent boundary layer). Results of a test case consisting of a submerged stiffened cylindrical shell excited by a diffuse sound field and a turbulent boundary layer shows that the non-axisymmetric internal frames have a strong influence on the power spectral densities of the shell acceleration and a smaller one on the power spectral density of the pressure in the fluid domain.