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Boundary Element Method for Fluid-Structure coupling: application to aerospace structures

J.-S. Schotté[1] and R. Le Mestre[1,2]

[1] ONERA, Châtillon, France, schotte@onera.fr and www.onera.fr
[2] ENSTA, Palaiseau, France, robin.le-mestre@ensta-paris.fr and www.ensta-paris.fr

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We are interested here in the vibrations of a structure in contact with one or more internal or external fluids. To study the dynamics of such systems, the coupled fluid-structure equations are linearized around an equilibrium position, and, by assuming that the velocity perturbation field is irrotational, the loads exerted by the fluids on the moving structure can be decomposed in terms respectively proportional to the structure displacement, velocity and acceleration, giving what are generally called the fluid added stiffness, damping and mass terms. If the fluid has its own dynamics, characterized by eigenmodes (acoustic modes in case of a compressible fluid, sloshing modes in case of an heavy fluid with a free surface, etc.), they will be coupled with the structure dynamics too [1].

The determination of all these fluid mass, stiffness, damping and coupling operators can be done numerically by a Finite Element Method (FEM) in case of an internal fluid, but the external fluid case is better dealt with a Boundary Element Method (BEM). This one is based on an integral representation of the fluid response due to the structure wall motions. A collocation method allows to discretize the associated integral equation and to numerically construct the matrices associated to the different operators. These matrices being full and non-symmetric, using suitable computation and storage technics, such as Hierarchical Matrices (H-matrix), can be necessary to deal with problems of industrial size [2].

Two examples of this approach will be presented: the first one relates to the modelling of propellant sloshing inside space launcher tanks in vibrations. The main interest of a BEM approach to deal with an internal fluid case like this one is to avoid a volume mesh generation of the liquid domain for each considered filling level. This is particularly interesting when the tank internal geometry is complex because of internal propellant management devices (pipes, etc.). The presence of anti-slosh baffles can also be modelled with some adaptations of the BEM. The second example relates to the modelling of couplings between a deformable airship and its surrounding external and internal fluids. We will particularly focus on the fluid added mass effects which are of prime importance for such light structures. Numerical and experimental validations will be presented to try to determine the validity domain of the proposed model [3].

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