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Boundary Element Method for Fluid-Structure coupling: application to airship aeroelastic stability

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This work studies the dynamic behavior of a light, flexible free structure (more specifically an airship) interacting with the surrounding fluids: an internal lifting gas at rest and an external flow. These fluids result in a complex problem that can't be tackled using RANS simulations given the large size of airships [1], hence the need for a reduced model. The behavior of the system is characterized around a quasi-steady equilibrium state for given translation and rotation velocities of the airship, taking into account the prestresses of the flexible membrane by the internal gas pressure. The dynamical equation is then obtained by linearizing the potential, irrotational flow and structure equations around the steady-state equilibrium. The linearized loads exerted by the fluids on the structure result in added mass, damping and stiffness terms, proportional with the displacements, velocity and acceleration of the membrane respectively [2].

Because the external fluid domain is infinite, its resolution by means of the Boundary Element Method (BEM) is particularly suited [1]: the latter method enables to obtain a solution based on a surface mesh of the membrane (instead of meshing the whole fluid domain) with the help of an integral representation. The fluid operators of the external problem can be adapted to describe the internal gas behavior as well. The BEM operators being full, a Hierarchical Matrix acceleration method has been implemented to reduce both storage and computational costs in order to deal with problems involving many degrees of freedom [3].

This work focuses more particularly on the airship aeroelastic stability analysis by switching the dynamic equation in the frequency domain. Solving the eigenvalues of the whole fluid-structure system is difficult since the added mass, damping and stiffness operators of the fluid are full. Thus, the problem is solved here on a reduced basis composed of *in vacuo* pre-stressed structural modes. The linear and quadratic dependency of the added damping and stiffness operators enables to perform stability analysis on a range of velocities of the flow. We observe that the flexibility of the airship results in a risk of flutter once a critical velocity is reached, which is in good agreement with other studies from the literature [1].

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