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A QUASI-SIMULTANEOUS COUPLING APPROACH FOR FLUID-SOLID INTERACTION IN OFFSHORE APPLICATIONS

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In hydrodynamic applications with moving or deforming structures, a major factor affecting the simulation efficiency is the ratio of the added mass of the fluid to the structural mass [1, 2]. In the traditional partitioned formulation, where the fluid loads are imposed on the structure and the structural motions imposed on the fluid, higher added mass ratios lead to large amplification factors in the fluid-structure iterations, which cannot be controlled by reducing the time step. Usually, this effect is tackled by applying subiterations with severe under-relaxation within each time step, making these coupling methods computationally expensive.

The mentioned problems could be bypassed by solving the two subdomains in a monolithic way. Usually, this is complicated since the simulation methods for the subdomains have to be integrated down to the inner algorithmic loops. This requires access to both subdomain codes, which can be quite cumbersome and even impossible in case of black-box codes. Here, we will follow a quasi-simultaneous method which approaches as close as possible a fully-simultaneous, monolithic approach.

The quasi-simultaneous approach was originally developed to add viscous effects to inviscid airfoil simulations [3]. It makes use of an "interaction law". In this maiden application, the interaction law describes approximately how the inviscid flow reacts to changes in the boundary layer. Algorithmically, this interaction law can be regarded (and implemented) as a boundary condition to the viscous-flow equations.

In the applications discussed in this paper, the interaction law will be an approximate model for the structural equations built from the solid-body modes and the main elastic modes of the structure. The fluid solver is the symmetry preserving finite-volume VOF method ComFLOW [4, 5]. A finite-element method is used to solve the elastic structure response based on a Euler-Bernoulli beam. Kinematic and dynamic relations couple the fluid dynamics to the structural dynamics.

It will be explained how the ratio of added fluid mass to structural mass plays an essential role. It may require the use of severe under-relaxation of the traditional coupling methods. The quasi-simultaneous method is shown to be much more effective. The numerical stability with and without interaction law is verified with a schematic test case of a tank with a flexible bottom. Validation is shown by an oscillating CALM buoy, a falling life boat, and a dambreak behind a rubber gate, for each of which experimental data is available.

REFERENCES

[1] P. Causin, J.F. Gerbeau and F. Nobile, Added-mass effect in the design of partitioned algorithms for fluid-structure problems. *Comp. Meth. Appl. Mech. Eng.*, Vol. **194**(42), pp. 4506-4527, 2005.

[2] C. Forster, W.A. Wall and E. Ramm, Artificial added mass instabilities in sequential staggered coupling of nonlinear structures and incompressible viscous flows. *Comp. Meth. Appl. Mech. Eng.*, Vol. **196,** pp. 1278-1293, 2006.

[3] A.E.P. Veldman, New, quasi-simultaneous method to calculate interacting boundary layers. *AIAA J., Vol.* **19,** pp. 79-85, 1981.

[4] K.M.T. Kleefsman, G. Fekken, A.E.P. Veldman, B. Iwanowski and B. Buchner, A Volume-of-Fluid based simulation method for wave impact problems. *J. Comput. Phys.,* Vol. **206,** pp. 363-393, 2005.

[5] R.W.C.P. Verstappen and A.E.P. Veldman, Symmetry-preserving discretization of turbulent flow. *J. Comput. Phys., Vol.* ***1*87,** pp. 343-368, 2003.