Fluid-structure Interaction Simulation of Complex Floating Structures with a Two-phase Flow Level Set Method

Antoni Calderer and Fotis Sotiropoulos

Department of Civil, Environmental, and Geo- Engineering, St. Anthony Falls Laboratory,
University of Minnesota, 2 Third Avenue SE, Minneapolis, MN 55414, United States
e-mail: fotis@umn.edu, web page: http://cfdlab.safl.umn.edu/

ABSTRACT

We proposed a powerful computational method for simulating two-phase free surface flows interacting with three-dimensional complex rigid bodies. The method we adopted [1] combines the fluid-structure interaction (FSI) curvilinear immersed boundary (CURVIB) method of Borazjani, Ge, and Sotiropoulos [2] with the two-phase flow level set approach of Kang and Sotiropoulos [3].

A critical aspect when extending the CURVIB method to simulate FSI problems involving two-phase flows is the importance to accurately compute the force that the fluid imparts to the moving body. We developed a new technique based on projecting the fluid pressure to a fictitious body surface by using the momentum equations along the wall-normal direction.

An extensive validation by simulating various free surface-body interaction cases demonstrated the accuracy of the method and its potential to capture complex non-linear behaviours of the flow, such as, turbulence, wave breaking, or structure overtopping. All of the benchmark cases as well as the laboratory experiments that we tested led to results with excellent degree of agreement with the expected results or measurements. In particular, we showed that for this type of two-phase flow problems the proposed technique for body force computation, compared to the standard approach of [2], could significantly improve the predicted motion of the body. Some of the cases include a free decay test of a circular cylinder, a roll decay test of a rectangular barge, and a free falling wedge impinging the water free surface.

The simulations elucidate the formation of rich three-dimensional dynamics mostly formed at the air phase due to the water waves induced by the moving body. In the particular case in which the waves break, a large massive separation is observed at the cusp of the wave leading to the formation of complex coherent structures with loops, arch, and hairpin vortices.

This work is the first part of a more general computational framework currently under development capable of incorporating to the flow offshore wind and wave conditions. As a result, floating offshore structures, such as floating wind turbines, wave energy converters, or floating oil platform can be simulated using realistic site-specific environmental conditions.

REFERENCES

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