A new immersed boundary method for the simulation of fluid-structure interactions in OpenFOAM

CONSTANT Eddy [a,*], FAVIER Julien [a], MELIGA Philippe [a], SERRE Éric [a], MELDI Marcello [b]

[a]Aix Marseille Université, CNRS, Centrale Marseille, M2P2 UMR 7340, 1345, Marseille, France.
[b]Institut P', CNRS – Université de Poitiers – ENSMA, 11 Bd Marie et Pierre Curie, 86962 Futuroscope Chasseneuil Cedex, France

ABSTRACT

The flow past a bluff body creates an unstable wake in the form of a Kármán street, characterized by the shedding of vortices at a well-defined frequency. In return, these vortices exert periodic in-line and cross-flow forces on the bluff body. If the shedding frequency is close to the natural frequency of the body, such oscillations excite large structural vibrations known as vortex-induced vibrations (VIVs). The control of VIV amplitudes is of practical interest for many engineering amplications, for instance low vibration amplitudes help improve the stealth of military aircrafts and to prevent fatigue damage on the risers used in offshore petroleum production. Conversely, large vibration amplitudes of a cylinder in water streams are valuable in the perspective of renewable energy production [2], for instance, electrical energy can be produced if the oscillation of the cylinder periodically displaces a magnet inside a coil.

As a first step towards the control of such vibration amplitudes, the immersed boundary method proposed by [1] has been implemented as a new library within the open source CFD solver *OpenFOAM* for incompressible bluff body fluid flows. The method encompasses the presence of fixed and moving solid obstacles in a computational mesh, without conforming to their boundaries. Standard Cartesian meshes are employed(uniform or stretched), which allows to use efficient and accurate flow solvers. The immersed obstacles are defined using a body force added on the conservation equations, and evaluated on Lagrangian markers that can move over the Eulerian mesh to capture the motion or the deformation of the body.

Work has been validated at Reynolds numbers in the range Re=30-3900 with laminar and turbulent flow with RANS and DES models. We focus on the development of IB conditions for turbulence modeling and the initial validation of an IB RANS/LES solver (SA - SA DDES - SA IDDES) with and without wall function which allow us to use a coarser grid. A Mass Spring Damper System has been implemented and is in good agreement with reference data reported in the literature [3] for the simulation of VIVs. A finite element solver has been implemented to extend the algorithm to the simulation of deformable bodies.

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