Towards the numerical modelling of floating offshore renewables

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The numerical modelling of fluid-structure interactions is important in the context of offshore renewables. This work targets floating wind turbines, where the turbine is supported by a floating pile moored to the seabed. Such devices are attractive in deep seas (typically deeper than 50 metres), where bottom-mounted foundations are too expensive. The numerical modelling of floating wind turbines is very challenging because of the dynamic interaction between the air-water and fluid-solid interfaces, and the presence of both rigid (i.e. the wind turbine) and deformable (i.e. the moorings) solids.

Our objective is to couple two unstructured finite-element models, in view of computing the mutual interactions between fluids and floating solids. In this work, the fluid-dynamics model `Fluidity-ICOM' [1] solves the Navier-Stokes equations on a fluid mesh covering the whole computational domain (containing both fluids and solids), whereas a super-imposed solid mesh represents the solid structures, whose dynamics is solved by the solid-dynamics model `Y3D' [2]. The solid mesh is mapped onto the fluid mesh at every time step through a volume-fraction field, and dynamic re-meshing can be used to refine the fluid-structure interfaces. This dual-mesh approach offers the flexibility of using different discretisation schemes for the solid and fluid's equations. Also, the method does not yield ill-posed problems in the resolution of the Navier-Stokes equations, when multiple solids become arbitrarily close to one another. In the presence of multiple fluids, an advection method is further used for a piecewise-constant representation of the fluids volume-fraction over each element.

The effect of the solid on the fluid dynamics, and vice-versa, is modelled through a volumetric penalty force added to the momentum balances of the fluids and solids. In order to satisfy the action-reaction principle at the discrete level, a supermesh is constructed from the intersections between fluid- and solid- meshes [3]. This ensures that Newton's third law is satisfied at the discrete level, and enables: (i) arbitrarily-high orders of representation of the discrete fields, and (ii) different representations of the discrete fields on each mesh.

First, results will be shown for the flow past a fixed actuator-disc immersed in a uniform flow and representing a wind turbine. The numerical results obtained for different mesh resolutions and thrust coefficients will be compared with a semi-analytical solution [4]. It will be highlighted how adapting the mesh dynamically to the curvatures of velocity and pressure predicts well the velocity deficit induced by the disc in its far wake (figure 1). Second, results will be shown for a cylindrical pile floating at the interface between air and water. This work provides a first-step towards the fully-coupled simulation of offshore wind turbines supported by a floating spar.

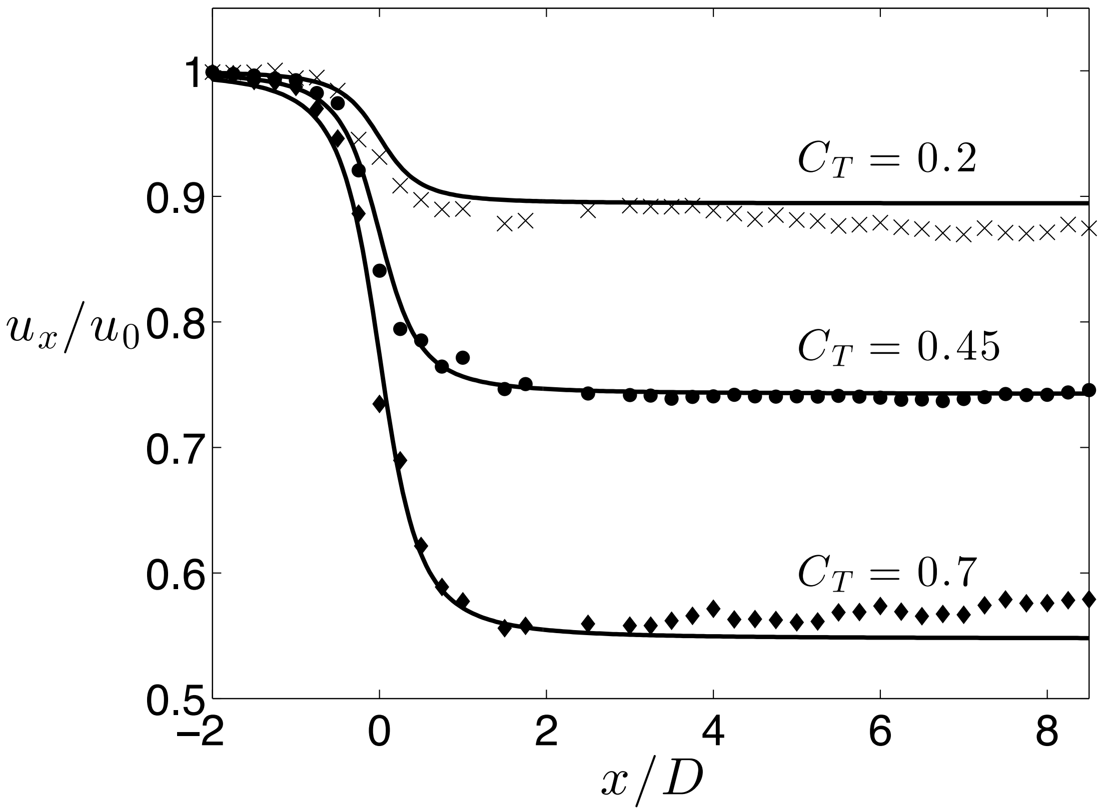

Figure 1: Streamwise evolution of the streamwise velocity (non-dimensionalised by the far-upstream velocity) for an actuator-disc of diameter D at three values of thrust coefficient. The lines represent the semi-analytical solution [4], while the symbols show the numerical results.

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