Numerical Wave Tank for the Investigation of Floating Wind Turbines Hydrodynamics

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Abstract

Floating offshore wind turbines (FOWT) are a promising solution for harvesting wind energy in deep water. Currently, some industries and laboratories work on FOWT design with aero-hydro-servo-elastic solvers. IFPEN together with SBM Offshore develops a tension leg platform (TLP) for floating wind turbine. To design this concept, the software DeepLinesWindTM is used to simulate the coupled behavior of the turbine subject to wind with the floater motion due to waves. Hydrodynamic loads computed in such tools are based on potential flow theory or Morison empirical formula and benefit from a strong validation background in O&G industry. Model tests showed the applicability of such theories to FOWT but the accuracy might be improved in various ways to optimize the design.
Empirical coefficients for Morison formula could be reassessed in specific sea condition representative for FOWT. Also, a strong combination of both theories is currently used to determine hydrodynamic loads and the exact validity range of such an approach could be determined. Higher order wave loads are also a major topic in FOWT study. For the moment, very few experimental results exist in a basin or in open sea water and the design of FOWT relies on theoretical and numerical calculus. All these reasons highlight how Computation Fluid Dynamics (CFD) can help to understand and improve hydrodynamic load prediction for FOWT.

For this purpose, a numerical wave tank is implemented in OpenFOAM (Greenshields, 2019), an open source CFD code. As a first step, one aims at simulating the flow field on a constrained floating platform submitted to waves. In CFD, momentum and transport equations are resolved in a given volume, reproducing basin or open sea conditions, to determine velocity, pressure and phase fraction fields. Hydrodynamic loads can be computed as the sum of the integration of pressure and shear stress over the structure.

The first step was to propagate waves in a controlled way. Two solvers were used in OpenFOAM: waveFoam (Jacobsen, 2017) and olaFlow (Higuera, 2015). Regular waves characterized by their amplitude, depth and period are modelled. Both solvers were tested and compared to evaluate their capability to generate and propagate waves along a numerical tank in deep-water condition. Second order and deep water waves seem to be better absorbed with the passive absorption solver (waveFoam) than with the active one (olaFlow), the last method being initially developed for shallow waters. Also, both solvers result in an amplitude

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attenuation along the tank, increasing with wave order. The VOF method (MULES) used in these simulations may influence the wave elevation decrease (Roenby, 2017). isoAdvector geometric VOF method will be tested and compared to MULES.
The second step towards the simulation of a FOWT, deals with a constrained cylinder in second order and deep-water waves. CFD simulation results are checked against towing tank tests at MARINTEK, Trondheim (Stansberg, 1997) as in OC5 project (Robertson, 2015). Hydrodynamic loads obtained with olaFlow and waveFoam simulations without turbulence model are similar to basin results. However, wave run-up calculations differ and seem less stabilized with active absorption than passive one. A study of boundary condition (Neumann, Dirichlet) led to similar results and highlights the negligible aspect of viscous loads due to turbulent flow conditions imposed on the cylinder (RE=10E4). The activation of k-omega SST turbulent model is responsible for a very important and known decrease of amplitude in the tank (Larsen and Fuhrman 2018). New turbulence models such as stabRAS (Larsen, 2018) and a buoyancy modified model (Devolder, 2017) will be tested.

Keywords: computational fluid dynamics, wave, wave generation, wave absorption, hydrodynamics, floating offshore wind turbine, OpenFOAM, waveFoam, olaFlow, turbulence, fluid, structure interaction