Modelling the Hydrodynamic Response of a Floating Offshore Wind Turbine Using OpenFOAM and a Quasi-static Mooring Model

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ABSTRACT

This work represents a contribution to the 1st FOWT Comparative Study. The Reynolds-averaged Navier-Stokes solver, interFoam, is used to simulate the hydrodynamic response of a 1:70 scale model floating offshore wind turbine in load cases including static equilibrium, decay tests in heave, surge and pitch as well as two focused wave events. Mesh deformation is used to accommodate the body motion and the catenary moorings are modelled using a quasi-static method. Wave generation and absorption is achieved via relaxation zones. The numerical solutions are compared with the available physical measurements and are shown to agree well for heave motion but significant differences are present for the other degrees of freedom and the mooring line loads.

KEY WORDS: IEA-15-240-RWT; VolturnUS-S; CFD; OpenFOAM; Quasi-static catenary mooring model; Comparative study.

INTRODUCTION

This paper details one contribution to the 1st FOWT Comparative Study (Ransley et al. 2022), on the hydrodynamic response of a floating offshore wind turbine (FOWT), using the open-source computational fluid dynamics (CFD) software, OpenFOAM.

In the field of offshore engineering, numerical modelling has become an integral part of the research, design and innovation (RD&I). However, accurate modelling of the associated fluid-structure interaction problems is challenging and can be computationally expensive (prohibiting its routine use by industry). As a result, a wide range of numerical tools exists, in which developers apply various levels of approximation to the governing equations in order to, effectively, balance the required physical accuracy of the model with its computational efficiency. However, when it comes to numerically predicting the response of moored floating platforms, under complex environmental loads, considerable uncertainty remains and it is not yet clear which numerical method, and what level of approximation, is most appropriate. As a result, a lack of confidence in the reliability of numerical solutions, limits the value numerical modelling can add to industry practices. This has, arguably, led to over-engineering of platform concepts, to mitigate risk, and higher overall costs (which is particularly problematic for offshore renewable energy applications, like floating offshore wind, where the margins, associated with the cost of energy, are very tight).

To try to ascertain which tool is most appropriate for a given application, comparative studies, in which a range of numerical methods are used to solve the same set of ‘load cases’, are common in the field of offshore engineering and wave-structure interaction (WSI). In most cases, a set of physical data (typically from scale model experiments) is also compared with the numerical solutions, i.e. ‘validation’. However, code-to-code comparisons are also common, in which no physical data, for the specific load cases, is available, i.e. ‘verification’. For example, the International Energy Agency (IEA) has been conducting a number of comparative studies for model ‘verification and validation’ purposes for both offshore wind systems (Wang et al. 2021; Wang et al. 2022) and wave energy converters (WECs) (Wendt et al. 2019; Kramer et al. 2021; Bingham et al. 2021), and; the CCP-WSI (Collaborative Computational Project on Wave Structure Interaction) have performed a number of ‘blind’ tests in which participants simulate the wave-structure interaction problem without prior access to the physical data (Ransley et al. 2019; Ransley et al. 2020; Ransley et al. 2021b). The blind nature of the CCP-WSI studies differs from conventional comparative studies, in which physical data tends to be available to the participants at the time of the computation, and open discussion between the participants is encouraged.

The 1st FOWT Comparative Study (Ransley et al. 2022) follows the conventional ‘open’ format and consists of a number of load cases considering the hydrostatic and hydrodynamic response of a 1:70 scale model of the International Energy Agency’s (IEA) 15MW reference wind turbine (IEA-15-240-RWT) (Gaertner et al. 2020) and UMaine VolturnUS-S semi-submersible platform (Allen et al. 2020). The load cases consist of static equilibrium cases (with and without the mooring system included), free decay cases (focusing on the primary degrees of freedom (DoF): heave, surge and pitch), and two focused wave cases (one ‘operational’ and one ‘extreme’). The Study only considers the hydrodynamic response of the floating offshore wind system, i.e. no aerodynamic loading is considered. The full description of the load cases, physical model and experimental set-up is available, to the participants,