Hydrodynamic response of a floating offshore wind turbine using an artificial compressibility finite volume method

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ABSTRACT
This work presents the hydrodynamic response of a Floating Offshore Wind Turbine (FOWT) using numerical methods and it is a part of the 1st FOWT Comparative Study. The methodology is based on an artificial compressibility finite volume solver coupled with a mooring line dynamic solver. The corresponding equations are solved concurrently within the same computational framework. All physical aspects are addressed, such as wave excitation, hydrodynamic response of the floater and mooring lines assembly. Numerical results suggest good comparison with the experimental data.

KEY WORDS: CFD; Mooring lines; Artificial Compressibility; VOF; Floater dynamics

INTRODUCTION
Floating offshore wind turbines (FOWT) have emerged as a promising solution for deploying wind turbines (WT) in deep water. Modelling of FOWT systems pose several challenges since we need to consider the complex hydrodynamic interactions between the turbine, the mooring system and the surrounding water. Apart from the complex operating environment of FOWTs, there is always the need for reduction of the Levelized Cost of Electricity (LCOE) of FOWTs. The reduction of the LCOE can be benefited from the application of hydrodynamic solvers, by taking into account as much physical aspects as possible (wave excitation, wind turbine dynamics, mooring line dynamics, etc). To this end, high fidelity numerical tools are expected to become a necessity when designing floater support structures.

This work is part of the 1st Floating Offshore Turbine (FOWT) Comparative Study (Ransley, et al., 2022). An experimental campaign has been carried out in the COAST Laboratory Ocean Basin at the University of Plymouth. The floater selected for the measurements is a 1:70 scale model of the IEA 15MW reference wind turbine (IEA-15-240-RWT) (Gaertner, et al. 2020) and UMaine VoltturnUS-S semi-submersible platform (Allen, et al. 2020). The experimental campaign includes static equilibrium load cases, free decay tests (in heave, surge and pitch) and the hydrodynamic response for two focused wave train cases. The main scope of the 1st FOWT Comparative Study is to evaluate the accuracy and efficiency of various numerical approaches for modelling wave interaction with a FOWT support structure.

The paper outline is as follows. Initially, a short description of the numerical methodology is presented. Afterwards, the equilibrium point of the floater is found and numerical results are compared with measurements. Finally, decay and incident wave test cases are presented and contrasted against experimental data, where good overall agreement is found.

HYDRODYNAMICS
In the following sections the numerical tools employed are briefly described. Starting from the hydrodynamics, we employ the in-house finite volume CFD solver, MaPFlow developed at NTUA (Ntouras and Papadakis, 2020). In this work we consider incompressible two-phase flow. To model two-phase flows the Volume of Fluid (VOF) method (Hirt and Nichols, 1980) is utilized, while the incompressibility constraint is imposed using the Artificial Compressibility (AC) method (Chorin, 1967). The AC method couples velocity and pressure by adding in the continuity equation an artificial pseudo–time derivative for pressure. In each real timestep, internal iterations are made and at the end of the step, the pseudo–time derivative approaches zero thus the original set of equations becomes hyperbolic in pseudo–time and the arsenal of hyperbolic solvers can be exploited.

In the following a brief description of the numerical method is provided.