Applications of CFD-Based Numerical Wave Basin for Offshore Floating Platforms

Hyunchul Jang, Lawrence S. H. Lai, Hakun Jang
Technip Energies
Houston, Texas, USA

ABSTRACT

This paper presents a CFD-based numerical wave basin tool developed by Technip Energies, which is called MrNWB. It has been validated with a collection of benchmark studies for different offshore floating platforms and two of the validation studies for a semisubmersible and a ship-type FPSO are presented in this paper. MrNWB can serve as a complementary tool to physical wave basin tests for offshore platform design. A key benefit is the ability to provide high-fidelity information at all required locations and times during the design and operations of the offshore platforms. The numerical wave basin is applied to floating offshore wind turbine (FOWT) simulation with a novel coupling methodology between MrNWB and OpenFAST which is an open-source wind turbine simulation tool developed by NREL. The newly developed numerical wave basin tool has been successfully validated for the DeepCWind semisubmersible model tests in a test condition with irregular waves and steady wind.

KEY WORDS: Computational Fluid Dynamics (CFD), Numerical Wave Basin, Offshore Floating Platforms, Floating Offshore Wind Turbine, Non-linear Irregular Wave, Greenwater.

INTRODUCTION

In current industry practice, global performance analysis for offshore floaters is typically carried out by potential-theory-based mid-fidelity tools, which require empirical parameters to model viscous and other non-linear effects. Because of inherent approximations in solutions of the mid-fidelity tools, model testing in physical wave basins is routinely used to verify the numerical results and provide calibrations for the empirical parameters. However, physical model test of an offshore floater is commonly performed only once through the whole engineering design phase due to the limited availability and associated cost of wave basin facilities.

With the advances in high-performance parallel computing hardware and software, Computational Fluid Dynamics (CFD) is expanding to offshore engineering applications. Several recent benchmark studies have demonstrated that CFD is capable of capturing both nonlinear and viscous effects in marine hydrodynamics and predicts wave- and current-induced offshore platform motions accurately. Technip Energies (T.E.N) has been developing a CFD-based numerical wave basin named Mooring/riser Numerical Wave Basin (MrNWB), which is a fully coupled analysis tool incorporating a CFD solver, potential-based wave models, and a line-dynamics model for mooring/riser system. The numerical wave basin has been validated against physical model test results for various offshore floating platforms such as semisubmersible (Wu et al, 2016), tension-leg platform (TLP) (Wu et al., 2014), Spar, and ship-type FPSO (Baquet et al., 2019). The CFD simulation results have been systematically validated from system identifications to 3-hour irregular wave simulations. It has been shown with response spectra and statistics that the CFD simulations predict well the platform’s global performance for all frequency ranges, including high- and low-frequency responses where the nonlinear hydrodynamic loadings and mooring system affect the responses the most. The CFD-based numerical wave basin can serve as a complementary tool to physical wave basin tests for offshore platform design. A key benefit of this tool is the ability to provide high-fidelity information at all required locations and times during the design and operations of the offshore platforms.

Recently, MrNWB has been applied to floating offshore wind turbine (FOWT). The first benchmark validation has been performed in the OC6 CFD JIP initiated by National Renewable Energy Lab (NREL). The objectives of the JIP were to validate 3-hour irregular wave tests using three different CFD-based numerical wave basin tools including MrNWB (Wang et al., 2022). All CFD-based numerical wave basin tools showed good agreement with the model test data; however only hydrodynamic motion responses of the platform were considered without consideration of a wind turbine. Further development of FOWT simulation with consideration of the dynamics of a wind turbine has been achieved by the authors in Jang et al. (2023). In the newly developed numerical wave basin, aero-servo-elastic behaviors of the wind turbine blades and tower are simulated by OpenFAST, NREL’s wind turbine analysis tool, and the hydrodynamic loads on the platform and mooring system are simulated by MrNWB. This novel coupled-analysis tool is called the Wind Turbine Numerical Wave Basin (WTNWB). WTNWB has been successfully validated for the DeepCWind semisubmersible model tests in a test condition with irregular waves and steady wind. It solves several drawbacks of