Comparative Study of Hydrodynamic Responses of Floating Offshore Wind Turbine Platform Under Focused Wave Using Experiment and OpenFOAM

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ABSTRACT

The present study investigates the effect of focused wave on floating offshore wind turbine platform based on open source toolbox OpenFOAM. The focused waves are generated based on the Pierson-Moskowitz spectrum in the waves2Foam toolbox; the multiphase solver waveFoam developed based on interFoam in OpenFOAM and kOmegaSST turbulent model are used to solve viscous, incompressible, multiphase flows, where PIMPLE algorithm is adopted to deal with the velocity-pressure coupling; the dynamic mesh technique is utilized to realize the 6-DOF (six degrees of freedom) motion of semi-submersible platform; moreover, the waves2Foam mooring module, viz., a static catenary model, is embedded into OpenFOAM to implement the analysis of mooring line connected with the floating platform. A comparative study of CFD simulation and model test is conducted, including focused wave test, static equilibrium test, free decay test, platform dynamic response and mooring line tension and the comparisons show good consistency. The test cases considered in this study are those proposed in the 1st FOWT Comparative Study.

KEY WORDS: Floating offshore wind turbine, focused wave, hydrodynamic, mooring line.

INTRODUCTION

As an important composition of renewable energy, wind energy has been the subject of widespread interest and attention due to the continued development of wind power. To further tap into wind energy resources in the ocean, wind farm construction is gradually expanding from offshore to deep sea locations, driven by advancements in wind power technology. Floating offshore wind turbine (FOWT) platform is a common form of wind power foundation in deep sea environment due to their ability to adapt to complex marine conditions. However, FOWTs are more susceptible to experiencing extreme wave conditions in deep sea areas, which can potentially cause platform destruction and mooring line breakage. The study of the hydrodynamic characteristics of FOWT platforms under extreme sea wave conditions is of great significance for platform design and application.

The most common used methodology to study the hydrodynamic characteristics of floating bodies are model tests and numerical simulations. Model tests are the authoritative method for studying the hydrodynamic characteristics of FOWT (Coulling et al., 2013; Shin et al., 2013), in which corresponding similarity criteria such as the Reynolds similarity criterion and Froude similarity criterion are adopted to establish a scaled model. Several studies (Banks and Abdussamie, 2017) set up a test model of a semisubmersible platform to study its motion response under different steepness of focused waves and found that the magnitudes of heave and pitch motions increases as wave steepness increases. Non-linear hydrodynamic effects of irregular waves have been shown to have an important influence on the low-frequency platform dynamic in the surge and pitch motion of the OC4 platform, as observed in the experiment by Azcona et al. (2019).

In recent years, computational fluid dynamics (CFD), a simulation method known for its high cost and excellent accuracy in accounting for viscous effects, has been extensively used to investigate the hydrodynamic characteristics of FOWT due to advancements in computing power (Bruinsma et al., 2018; Dunbar et al., 2015; Li and Bachynski, 2021). CFD can also serve as a supplement to model experiments due to its ability to provide detailed information about the flow field. Zhou et al., (2019) developed a numerical model using CFD to study the hydrodynamic characteristics of FOWT and found the nonlinearity of the hydrodynamic loading and motion responses increase with wave steepness. Furthermore, a significant difference was observed in the motion response between a focused wave and an irregular wave of the FOWT, with the nonlinear effect being well-captured for various wave steepness (Zhou et al., 2021).

In this paper, we establish a numerical model of the UMaine VolturnUS semi-submersible platform (Christopher et al.) using OpenFOAM (Jasak, 1992) to compare with the model test results of “1st FOWT Comparative Study” (Ransley et al., 2022). The focused wave elevation, static equilibrium test, free decay test, motion response, and mooring line tension of the focused wave case are compared with the results of the model test.