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ABSTRACT

In the development of offshore wind energy resources, the basic hydrodynamic performance analysis of FOWT plays a crucial role for evaluating its adaptability to the marine environment and operational reliability. This paper provides numerical contribution to the comparative study conducted in the ISOPE 2023 regarding the limit load of FOWT in complex environment, by using the commercial software STAR-CCM+, the first-order linear superposition method will be used to establish the focused wave model to simulate the transient wave load. After being validated using the experimental data, a further investigation on the response of FOWT under transient excitation will be carried out.

KEY WORDS: Numerical simulation; CFD; FOWT; Focused wave

INTRODUCTION

Over the past decade, wind energy has received extensive attention as one of the clean and renewable energy sources. With more flexible installation locations and access to more substantial wind resources than onshore wind turbines, floating offshore wind turbines (FOWT) have a non-negotiable position in the renewable energy industry (Spearman, et al., 2020 & Strivens, et al., 2021). According to the Offshore Wind Market Report 2022, global floating offshore wind capacity nearly tripled from 26,529MW (2021) to 50,623MW in 2021 (Musial, et al., 2022). The higher wind energy density brings greater challenges to the application of FOWT, which requires further research and analysis on the basic hydrodynamic performance of FOWT.

Simulation tools are regarded as the key to numerical simulation, and their number, demand and fidelity are increasing. In the past, most simulations have been performed using potential-flow-based solvers for the hydrodynamics and Blade-Element-Momentum theory (BEMT). These tools have also been applied to the performance analysis of floating offshore wind turbines. Several potential-flow solvers were used to simulate different loading conditions involving OC5 semi-submersible floating wind turbine by Robertson et al (2017). It could be confirmed that potential-flow-based methods do not accurately represent the oscillatory motion of the floater at natural frequencies. The reason is that the simplified methods used by these solvers are not accurate in predicting the viscosity effect (Tran, et al., 2015 & Gueydon, et al., 2016).

Sebastian and Lackner (2012) showed that BEMT is also not applicable to those complex conditions. Viscous-flow solvers based on the Reynolds-averaged Navier-Stokes (RANS) equations have the advantage of scrutinising the flow characteristics around floating objects, and viscous effects can be more accurately predicted. This was also confirmed by Tran and Kim (2016) and Liu et al. (2017). They used the RANS solver to simulate the coupled dynamic response of the whole floating wind turbine system, including a moving float and a spinning rotor at full scale, and their results agreed well with experimental and NREL FAST data.

The above studies mainly focused on the hydrodynamic loading and motion response of FOWT platform under regular or irregular wave conditions. In general, in order to approximate the wave-structure interaction under real sea conditions, irregular waves with long duration are often adopted, which consumes a lot of time and is expensive to calculate (Dysthe, et al., 2008). However, focused waves, as strongly non-linear waves, are generated by modulating a prescribed wave spectrum to produce a series of regular wave trains, in which a number of waves components add up at a specific time and space point. Therefore, focused wave is considered to be an economical and efficient method to replace irregular wave for the study of nonlinear effects of offshore structures (Davis, et al., 2008).

Ballock et al (1996) designed focused waves by focusing wave components in a highly non-linear wave group. Based on this, the phase transition caused by the nonlinearity of wave-wave interaction of focused waves was investigated. Gao et al (2016) studied the nonlinear effects caused by focused waves acting on a semi-submerged horizontal cylinder. The results were compared with a regular wave having identical wave crest and trough-to-trough period. Related to this, Lin et al. (2021) studied the wave-structure interaction of the same float in regular waves with different wave amplitudes and a fixed period, regular waves with different wave periods and a fixed wave steepness, and focused waves with different peak wave amplitudes, so as to reveal the nonlinear effects that may be caused by different waves.

In summary, very few previous studies have investigated the dynamic response of semi-submersible platforms under focused waves while