ABSTRACT

Floating structures have distinct advantages in adapting to the sea environment of different water depths and are widely used in ocean engineering. One of these structures is the floating oil/gas platform, often used for oil/gas exploitation offshore or deep sea. As a kind of disastrous wave, the freak waves are projected to happen more frequently and more intensively with global climate change, posing a considerable threat to the safe operation of marine floating structures. In this context, this study examines the freak wave impacts on a tension-leg moored floating platform numerically by using the SPH (Smoothed Particle Hydrodynamics) open-source code DualSPHysics. The wave kinematics (i.e., wave profiles and wave run-up) and dynamics (i.e., wave impact pressures and forces), as well as the structural responses (i.e., platform motions and tension forces of mooring cables), are investigated by invoking the experimental data.

KEY WORDS: Particle method; Wave slamming; Extreme wave; Floating structure

INTRODUCTION

With global climate change, extreme waves are becoming more frequent in the ocean. Freak waves, also known as rogue or monster waves, are a specific category of extreme waves. They are those with wave heights two times larger than those expected from the Rayleigh distribution for wave heights (Dysthe et al. 2008). Their occurrences have been widely confirmed and studied (Akhmediev et al. 2009, Didenkulova and Anderson 2010). The Draupner wave corresponds to the first measured freak wave in the ocean, which has a peak elevation of 18.5 m above the still water level (Cavaleri et al. 2016).

Freak waves contain huge energy and pose great threats to the safe operation of marine structures such as fixed marine structures (Deng et al. 2016, Qin et al. 2017) and floating structures (Li et al. 2020, Qu et al. 2020). During Hurricanes Katrina in 2005, the recorded wave height reached 16.9 m, and the extreme waves caused 1,392 fatalities and between $97.4 billion to $145.5 billion in damage (Bitner-Gregersen and Gramstad 2015). Therefore, it is essential to fully understand the physics behind freak wave impacts on ocean structures.

Many experimental studies have been conducted to examine the complex process of freak wave interaction with floating structures. For example, Luo et al. (2020) investigated the freak wave impinging on a tension-leg moored floating platform through wave flume experiments and examined the freak wave-induced impact pressures, platform motions and tether forces. In a follow-up study, Luo et al. (2022) studied the effects of air gap on freak wave actions. Singh et al. (2020) studied the dynamic response of a floating moored oscillating water column device under focused waves. Zeng et al. (2023) performed experimental investigations on the dynamic response of an in-place floating offshore wind turbine (FOWT) under freak wave actions.

With the rapid development of numerical algorithms and computer hardware, CFD (Computational Fluid Dynamics) modelling has been an essential tool in analyzing wave structure interaction problems. Among the various numerical models, the Lagrangian particle methods have been rapidly developed and widely used due to their intrinsic advantages in handling large deformation, moving interface, etc. (Luo et al. 2021, Khayyer et al. 2022, Zhang et al. 2022). Typical particle methods include SPH and the Moving Particle Semi-implicit (MPS) method. Rudman and Cleary (2016) applied SPH to model the rogue wave impact on a semi-submersible platform focusing on the effects of the mooring system on platform motions and mooring tensions. Tan et al. (2023) investigated the accuracy of SPH in simulating the hydrodynamics of floating offshore wind turbines (FOWTs). Zhang et al. (2022) used the coupled MPS and Finite Element Method (FEM) method to study the hydroelastic response of floating platforms/ships crashing into waves.

In the last two decades, the SPH theories and open source codes have been getting significant developments, e.g., GPUSPH (Hérault et al. 2010, Shi et al. 2017), DualSPHysics (Crespo et al. 2015), SPHInXsys (Zhang et al. 2021), SPHERA (Salis et al. 2022) and SPHydro (Lyu et al. 2023). The present study employs the SPH open-source code.