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CFD Simulation of Wave Energy Converters in Focused Wave Groups Using Overset Mesh

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This paper presents the numerical modelling of two point absorber wave energy converters (WECs) with and without a moonpool under focused wave conditions. The numerical model applies the overset mesh technique in order for the mesh to conform with the large-amplitude WEC motion induced by the focused wave groups. The incident wave group is first examined by a mesh convergence test and by comparing with the experimental data. The simulations are then carried out with the presence of the WEC. In total, three wave conditions are considered, each with the same wave period but with different wave heights. Nonlinear effects on the WEC motion are clearly exhibited when the wave steepness increases. The accuracy of the numerical results is carefully assessed against experimental data. Furthermore, the effects of the moonpool on the dynamics of the WEC are also discussed, where the WEC motion is compared for the case with and without a moonpool under the same wave conditions.

INTRODUCTION

In recent years, the possibility of harnessing energy from ocean wave resources has gained great interest, where different design concepts of wave energy converters (WECs) have been proposed, such as oscillating water columns, bottom-hinged pitching devices, floating pitching devices, overtopping devices, and point absorbers. Point absorbers are one of the simplest WECs. Their characteristic length is generally smaller than the typical wavelength at the peak wave frequency. Meanwhile, they are typically subjected to large-amplitude motions close to resonance. In such a condition, a highly nonlinear wave-structure interaction is expected, where local wave breaking and overtopping may occur. Moreover, the damping coefficient of the WEC can be composed of not only the radiation wave damping but also the power take-off (PTO) damping, as well as the viscous damping. The viscous damping force itself can be important in many cases, which are due to vortex shedding and shear stress force; see, for example, Gu et al. (2018), Palm et al. (2018), Wei et al. (2015), and Giorgi and Ringwood (2017). Such characteristics make the wave-structure interaction process highly complex and distinct from the traditional large-volume offshore structures.

Regarding the prediction of the point absorber WEC in waves, various methods can be applied (Penalba et al., 2017). For preliminary studies and concept development in the early stage, low accuracy may be accepted, and high-speed computation is important. Linear or second-order models in the frequency domain are widely used, where different design concepts in a variety of wave conditions can be computed in a short time; see, for example, Davidson et al. (2015). However, such methods typically neglect the viscous effects. Furthermore, the linear or second-order free surface conditions cannot predict overtopping or local wave breaking. On the other hand, computational fluid dynamics (CFD) models based on Navier–Stokes solvers have been used widely in coastal and offshore engineering to simulate highly nonlinear free surface flow (Xue and Lin, 2011; Lin et al., 2016, 2017; Ma et al., 2016). Examples of fully nonlinear CFD simulations on the point absorbers have been presented in Yu and Li (2013), Palm et al. (2016), Hu et al. (2011), Qian et al. (2005), Ransley et al. (2017), and Luo et al. (2014).

In the present work, two geometries of a point absorber WEC with and without a moonpool in focused wave groups are considered. The existence of a moonpool allows internal fluid flow within the moonpool (Fredriksen et al., 2014), which can affect the global motion of the WEC. A two-phase flow solver in the open-source toolbox OpenFOAM is applied, and its new overset meshing functionality is utilized for the mesh to better describe the large-amplitude motion of the WEC. The main focus of the present paper is the assessment of the CFD model for this particular flow problem as part of the contributions to the CCP-WSI Blind Test Series 3 (Ransley et al., 2020), where, similar to its Series 1 test (Ransley et al., 2019), the capability and accuracy of different flow models are examined by a direct comparison of the numerical results with the experimental data in the time domain.

EXPERIMENTS

The experiments were performed in the COAST Laboratory Ocean Basin at Plymouth University, United Kingdom (Ransley et al., 2020). The basin is 35 m long and 15.5 m wide. The depth of the basin was set to 3 m in this set of experiments. Two types of wave energy converters were considered in the experiments—namely, the simple hemispherical-bottomed cylinder and a cylinder with a moonpool, as shown in Fig. 1. Their mass properties are given in Table 1. The WECs were moored vertically by a linear spring, which connects to the basin bottom. The spring stiffness was 67 N/m, and the pretension forces on the mooring lines were 32.07 N and 31.55 N for the two cases.

The wave parameters for the incident wave groups are given in Table 2. All the wave groups were crest-focused with the same peak frequency but increasing wave steepness. Each wave was created using linear superposition of 244 wave fronts with frequencies evenly spaced between 0.10 Hz and 2 Hz. For all cases, 13 wave gauges were placed in the wave basin, as illustrated in

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KEY WORDS: Wave energy converter, overset mesh, floating body, focused wave group.