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Investigation on Motion Responses of a Flexible Floating Anti-collision System with Connected Horizontal Buoys

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The flexible floating anti-collision system (FFAS) is an effective solution to lowering the risk of collisions between uncontrolled vessels and marine structures. Besides the threat of vessel collision, the hydrodynamic response as a result of harsh waves is also a key concern for FFAS design. In the present study, three-dimensional experiments are conducted to investigate the wave-induced motion response of a modular FFAS consisting of five connected horizontal buoys along the longitudinal direction. Extensive measurements are carried out synchronously to quantify the motion responses of both the central and adjacent buoys under a beam regular wave. The effect of wave height and wave period on the hydrodynamic response of the FFAS has been analyzed. The results reveal that both the central and adjacent buoys are inspired significant sway and roll under a beam wave at $T = 8\sim9$ s, which can be attributed to the possible resonance of the FFAS system. It leads to remarkable variations of motion between the two buoys in surge and yaw directions, particularly under large wave heights.

INTRODUCTION

To lower the risk of collisions between navigation vessels and offshore structures (e.g., cross-sea bridges, wharfs, production platforms, offshore wind turbines), various solutions have been proposed and investigated (Minorsky, 1959; Petersen and Pedersen, 1981; Storheim and Amdahl, 2014). Among these solutions, the flexible floating anti-collision system (FFAS) has been proven as an effective way to prevent the possible vessel collisions (Oda and Nagai, 1976). There are many advantages to a typical FFAS—for example, it is easy to install, expand, relocate, and remove, and it is cost effective for deep water and poor foundations (Chen et al., 2013; Z Sun et al., 2017, 2018). The survival of the FFAS as a separate offshore structure under harsh wave conditions is the key concern for engineering application. Thus, it is necessary to investigate the hydrodynamic responses of the FFAS to meet the sustainable design requirements.

In the past couple decades, the hydrodynamic responses of modular floating system have drawn much attention from many researchers. On the basis of potential theory, Che et al. (1992) carried out two-dimensional hydrodynamic analysis on a flexible modular floating structure by neglecting the hydrodynamic interactions among the modules. As demonstrated by Fang and Kim (1986), however, interactions among the modules have a significant impact on the motions of the system. Martinelli et al. (2008) conducted three-dimensional (3D) experiments to investigate the performance of a floating breakwater with three floating units. It was revealed that the complex layout significantly increased the relative motion of the floating units and enlarged the connecting force. Tajali and Shafieefar (2011) examined the response amplitude operator and connector forces of a modular system under various wave periods and incident angles. Their results showed that the hydrodynamic responses of the system were subject to pontoon dimension, connector stiffness, and wave conditions. Also, the loads on the connectors and mooring lines subjected to various design parameters have been addressed by Riggs et al. (2000), Peña et al. (2011), and Loukogeorgaki et al. (2014). In addition, there are also a few studies on the hydroelastic responses of the modular system under various wave conditions. Under regular waves, Loukogeorgaki et al. (2017) conducted extensive experiments to obtain the hydroelastic responses of a pontoon-type modular floating breakwater, and they discuss its correlation to the loads on connectors. J Sun et al. (2018) conducted a model test to measure the displacements of the modules, bending moments, and mooring forces of a pontoon-type floating bridge under regular waves. The results reveal that the nonlinear effects of wave loading have a significant effect on the bending moment and should be considered in the design of floating bridges.

In this study, we proposed an FFAS consisting of five connected horizontal buoys anchored on the seabed. 3D experiments have been conducted to investigate the hydrodynamic responses of this pontoon-type modular system. The motion responses of the central and adjacent buoys have been measured synchronously under beam regular waves. The effects of wave height and wave period on the motion responses of the modular system have been addressed in detail. The motion variation between the buoys has also been highlighted under wave conditions with a large wave height and long period.

The rest of this paper is presented as follows. In the next section, the experimental setup and test procedures are described. Then, the motion characteristics are presented and discussed. Finally, conclusions are drawn in the last section.

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