ABSTRACT

This paper uses the quasi arbitrary Lagrangian-Eulerian finite element method (QALE-FEM), based on the fully nonlinear potential theory (FNPT), to numerically investigate the nonlinear hydrodynamic interaction between two floating structures. The QALE-FEM has been proved to be more computationally efficient than all other numerical methods at the same accuracy level. The radiation problem is mainly considered. Several cases with different configurations are numerically simulated. For some cases, the predicted results are compared with those from other methods available in literatures. The nonlinearity and the effects of the gap between two structures are investigated.

KEY WORDS: Fully nonlinear interaction; floating structures in close proximity; potential flow; QALE-FEM method; radiation

INTRODUCTION

With the increasing demand by the gas/oil industry in ocean, more and more floating structures, such as floating production storage and offloading (FPSO) systems, floating storage and regasification units (FSRU), liquefied natural/petroleum gas (LNG/LPG) carriers, have been built and utilised. Those structures may be moored to one another with relative small distance during the operation, e.g. when a LNG/LPG carrier is being loaded from a FPSO. Under these conditions, the hydrodynamic interaction between two structures may be of great concern since it can influence the motion of the structures and thus may affect their safety.

Many experimental and numerical studies on hydrodynamic feature of a single floating body have been made. A great deal of knowledge have been accumulated and utilised to guide the design of floating structures. For detailed review, readers may be referred to Ma and Yan (2008). However, laboratorial observations (Kashiwagi, Endo and Yamaguchi, 2005; Hong et al., 2005) and numerical investigations (e.g. Yan and Ma, 2008) have confirmed that the hydrodynamic behavior of a floating body accompanied by others with relatively small distance may be significantly different to those of a single body, due to the complex strong interaction between bodies. This fact calls for detailed studies on the interaction between two floating bodies in close proximity. Both experimental and numerical studies can be used to address this issue. The later is preferred over the former in terms of both the research expense and the capability of providing continuous spatio-temporal distribution of physical quantities. Therefore, the numerical method will be chosen and only the related reviews on numerical investigations will be given in this paper.

To numerically simulate this problem, one may carry out a study with a single floating body near a side wall. Such cases are equivalent to those with two floating body under symmetrical condition. By using this strategy, Hsu and Hu (1996) investigated a 2D oscillating rectangular structure on a free surface with side wall, Zheng et al. (2004) studied the radiation and diffraction of water waves by a 2D rectangular structure with a side wall, Teng, Ning and Zhang (2004) simulated a uniform cylinder in front of a vertical wall. By applying a symmetrical boundary at the side wall, the size of the computational domain in such a case is half of that used by the corresponding direct numerical simulation of two structures. Therefore, less computational resource and CPU time are required. However, the symmetrical condition is rarely seen in reality. This limits the application of this strategy.

Due to the limitation of the above strategy, direct simulations involving two or more floating bodies are more commonly performed. The numerical studies on hydrodynamic features of multiple floating bodies with small gap in between, such as radiation problem, diffraction problem and their response to waves, have been carried out for decades. Both 2D and 3D investigations have been carried. For 2D studies, simple-shaped floating bodies, such as barge-type bodies, are usually chosen (e.g. Wu and Price, 1987; Sannasiraj, Sundaravadivelu and Sundar, 2000; Maiti and Sen, 2001; Li et al., 2005; Gesraha, 2006; Koo and Kim, 2007). In their investigations, different incident waves, e.g. directional waves (Sannasiraj, Sundaravadivelu and Sundar, 2000) and oblique waves (Gesraha, 2006), are considered. Although those 2D investigations resulted in some useful conclusions, such as the different characteristic of the hydrodynamic parameters near resonance area of frequency, the occurrence of sloshing waves in the gap between two barges (Wu and Price, 1987), they only represent the bodies with very large or infinite length, such as breakwaters. For real floating structures, e.g. FPSO, LNG/LPG carriers, a 3D simulation may be necessary.