ABSTRACT

This paper presents a fully nonlinear numerical investigation on the resonant waves in the gap between two floating barges by using the Quasi Arbitrary Lagrangian-Eulerian finite element method (QALE-FEM) based on the fully nonlinear potential theory. In the investigations, two identical floating barges undergo forced oscillation in heave. The wave elevations and the force acting on barges are recorded. The nonlinearity involved, the effects of the width of the gap and the draft of the barge on the significance of the nonlinearity are discussed in details.

KEY WORDS: QALE-FEM; Resonance; Two floating barges; Nonlinearity

INTRODUCTION

Resonance is one of the important features in nature, which dominates some mechanical systems in periodic motion and occurs under a condition that the motion frequency is equal to the natural frequency. Typical examples include the sloshing in a tank (Faltingsen, 1978; Wu et al 1998; Zhou, 2010), the motion of the liquid in the gap between two structures in close proximity (Wang and Wu, 2008; Sun et al, 2010; Wang et al 2011; Yan et al, 2009, 2011). The latter represents one of concerns in offshore engineering operations, e.g. during the offloading of liquefied natural/petroleum gas (LNG/LPG) from a floating production storage and offloading system (FPSO) to a LNG carrier.

Both experimental (Kashiwagi et al., 2005; Hong et al., 2005) and numerical investigations (e.g. Ma and Yan, 2009; Yan et al. 2009, 2011) have been carried out to study the motion of fluid confined by two structures in close proximity, the forces/moments acting on and the responses of the structures. A strong resonant phenomenon in the gap has been confirmed. Wang & Wu (2008) and Wang et al ( 2011) used both second-order theory and fully nonlinear potential theory to study 2D resonant waves in the gap between two floating structures. Similar work has also been preliminarily studied by the authors of this paper. For example, Yan et al (2009, 2011a) simulated two floating bodies in forced motions. The radiation coefficients have been estimated based on the time-domain results. Both 2D and 3D results have been produced and discussed. Yan et al. (2011b, 2012) investigated the responses of two floating structures in close proximity to oblique waves. A more detailed literature review about the numerical simulations addressing this problem has been given in our previous publications and will not be repeated here.

However, it is worthy of noting that the nonlinearity involved is significant and may dramatically weaken the dimensionless amplitude of the envelope, as revealed by Wang, et al (2011) who compared 2nd-order time-domain results with corresponding fully nonlinear results and concluded that the 2nd-order theory may overestimate the wave amplitude in the gap and so the wave loads on the structures. Yan et al. (2009, 2011ab, 2012) also suggested that even 3rd-order approximation may be insufficiently accurate for estimating the wave loads on structures under or close to resonant condition based on limited comparisons between fully nonlinear results and 3rd-order approximation. These call for fully nonlinear investigation for the studies on the resonant wave motion in gap between multiple structures.

Previous fully nonlinear studies have mainly been carried out under two-dimensional (2D) assumption, e.g. Maiti & Sen (2001), Koo & Kim (2007) and Wang et al. (2011). This is acceptable for the cases with long structures. This paper will continue working on 2D problems, aiming to extend the understanding of the physics and provide useful references for further 3D studies. The numerical investigation will be done by using the QALE-FEM method, which has been applied to studying multiple structures in waves covering the responses of two structures to steep waves, forces and radiation coefficients of two heaving structures in close proximity and the wave motions in the gap of two structures, as indicated above. We will continue the study in this direction but will focus on the resonant wave motion in the gap between two floating structures in forced motion for a long period of simulations, which has not been done before. The significance of the nonlinearity, the effects of the draft of the structures and the width of the gap, will be detailed discussed. It should be noted that 3D studies by the authors of this paper (Yan et al., 2011a), who compared 2D and 3D results of hydrodynamic forces on two closely located structures due to forced heaving motion, have suggested that 2D analysis may lead to very different results from 3D analysis. The