A two-dimensional numerical study of radiation of piston mode fluid resonance in a narrow gap

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ABSTRACT
Radiation damping may play an important role in the prediction of gap resonance amplitude by potential flow models. In this paper, the radiation of the gap resonance between twin fixed floating boxes is numerically studied by using a linear potential flow model in frequency domain. An impermeable lid is forced to heave at the free surface in the gap. The characteristics of its added mass and radiation damping, and radiation wave amplitude in the far field are calculated under various geometric conditions. Moreover, the ratio of radiation damping to the viscous damping due to wall friction is quantified. We find that the ratio of the viscous damping force due to wall friction to radiation damping is approximately 34%–43%, and that due to flow separation to radiation damping is about 140%–320%. The results well explain the prediction performance of potential flow models with/without the viscous damping due to wall friction and/or flow separation.

KEY WORDS: Gap resonance; radiation damping; wave radiation; piston mode

INTRODUCTION
When two large vessels, for example, a LNG carrier and an FLNG, are in side by side arrangement, a long and narrow gap will be formed between the ships. Incident waves with certain frequencies can excite the vertical resonant motions of water columns in the gap. The phenomenon is often referred to as ‘gap resonance’. Similar resonance phenomenon may also occur in the moonpool of a drilling ship or platform. The large-amplitude gap resonance will affect the ship-to-ship transfer operations, and it is therefore of practical interest.

The gap resonance problem has attracted many attentions over the past decades. Both experiments (e.g., Saitoh et al., 2003; Faltinsen et al., 2007; Tan et al., 2014; Zhao et al., 2017; Chua et al., 2019) and calculations (e.g., Molin, 2001; Zhu et al., 2005; Lu et al., 2011; Feng et al., 2017; Gao et al., 2020) have been conducted to understand the physical characteristics of gap resonance and develop the corresponding simulation tools. Within the framework of potential flow theory, semi-analytical and numerical models have been proposed and used to estimate the resonant water response in a narrow gap or rectangular moonpool. The comparisons of the estimation results with experimental data indicate that (Faltinsen et al., 2007; Lu et al., 2011), inviscid potential flow models are able to predict resonant frequencies reasonably, but they generally over-estimate the resonant amplitudes of water columns due to the omission of viscous effects. To overcome this problem, modified potential flow models have been proposed which take into account the viscous damping in the fluid response by modifying the boundary conditions at the free surface in the gap or over structure surfaces (e.g., Chen, 2004; Molin et al., 2009; Liu and Li, 2014; Liu and Falzarano, 2019), where linear or/and quadratic damping were included in these modified models to predict the resonant amplitudes reasonably while maintaining the computational efficiency (Faltinsen and Timokha, 2015; Tan et al., 2019).

With the development of computing technique, CFD (Computational Fluid Dynamics) solvers are widely used as simulation tools for wave-structure interaction problems nowadays. The CFD models based on Navier-Stokes equations are able to accurately simulate the resonant wave response in a narrow gap or moonpool since the viscous effects are included in the simulations. Lu et al. (2010, 2011) studied the gap resonance between two or three fixed floating boxes in waves through two-dimensional CFD simulations. Kristiansen and Faltinsen (2010) investigated the fluid resonance between a floating body moored closely to a vertical wall based on a nonlinear numerical wavetank. In addition to two-dimensional studies (e.g., Kristiansen et al., 2012; Moradi et al., 2015; Tan et al., 2017; Jiang et al., 2019), only a few three-dimensional CFD simulations have also been conducted so far (e.g., Feng et al., 2017; Wang et al., 2019). Generally, it is still challenging to conduct CFD modeling of gap resonance for practical purpose since it is rather time-consuming and requires extensive computational resources.

Although the over-prediction of inviscid potential flow models in resonant amplitude is usually significant, we would like to point out that in some cases of Faltinsen et al. (2007) and Lu et al. (2020), the over-estimations by potential models were found to be almost negligible. In fact, when the distance between the two floating