Coupling analysis between vessel motion and internal nonlinear sloshing for FLNG applications

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HIGHLIGHTS

- A numerical code is developed to investigate the coupling in liquid loading vessel.
- Model tests are conducted to validate the code and provide perceptual results.
- Coupling mechanism and characteristics in different motion modes are presented.
- Sloshing nonlinearity and its effects on coupling results are discussed.
- Sensitivities of coupling effects to fill levels and wave directions are analyzed.

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ABSTRACT

The coupling interaction between vessel motions and internal tank sloshing is of vital importance for Floating Liquefied Natural Gas (FLNG) system design and operation due to the exposure to diverse sea states at any filling level. A numerical code based on potential flow is developed in this study to investigate the coupling interaction between 6 degrees of freedom (DOF) vessel motions and internal nonlinear sloshing. The impulse response function (IRF) method is adopted in the resolution for the 6 DOF vessel motions, and internal liquid sloshing is numerically solved with the boundary element method (BEM). The coupling interaction between vessel motions and internal sloshing is calculated in the time domain through an iteration strategy. For the purpose of validating the code and enabling a perceptual understanding of these coupling effects, experimental tests of a vessel with two rectangular tanks are conducted. The proposed code is also validated by previous numerical and experimental results. In addition, the coupling interaction characteristics of internal liquid sloshing and vessel motions are studied, and the sensitivities of coupling effects to filling levels and wave directions are also analyzed. Decreased natural roll motion frequency and response amplitude are excited in the liquid loading condition more than in the solid loading condition; sway motion has a decreased response in the natural sloshing frequency and a response peak in the frequency region that is higher than the natural sloshing frequency; heave motion is not sensitive to sloshing loads. Phase shift analysis reveals that phase shifts between the wave and the sloshing loads change rapidly near the natural roll frequency and natural sloshing frequency. Furthermore, the natural sloshing frequency varies with changes in the filling level, and the coupling effects become obvious when the natural sloshing frequency is close to main response frequency region of the vessel.