Numerical Study on the Motion and Drift Forces of Side-by-Side Moored FSRU and LNGC Containing Sloshing

Seok Kyu Cho, Hong Gun Sung, Bo Woo Nam and Hang Shoon Choi*
Korea Ocean Research & Development Institute
Daejeon, Korea
*Seoul National University
Seoul, Korea

ABSTRACT

The motions and drift forces of side-by-side (SbS) moored FSRU (Floating Storage & Regasification Unit) and LNGC (Liquefied Natural Gas Carrier) including sloshing are studied by numerical methods and experiments. FSRU and LNGC have LNG cargo tanks and sloshing affects the motions due to the coupling between sloshing and floating body motions. Gap flow also affects the motions and drift forces of FSRU and LNGC. Sloshing is calculated by the pendulum model and NS (Navier-Stokes) VOF (Volume of Fluid) method. The effect of sloshing on the surge, sway motion and drift forces is confirmed. The numerical results agree with the experiments. It is noted that sloshing occurs in longitudinal mode and affect the surge motion and mooring load.

KEY WORDS: Sloshing; Gap flow; side-by-side; FSRU; LNGC.

INTRODUCTION

The side-by-side offloading operation of LNG can be influenced by many factors; LNG sloshing, gap flow between two bodies, mother ship’s mooring system, Ship to Ship (STS) mooring system, and environments etc. Sloshing affects the motion; particularly roll and sway motion. Gap flow also influences the sway motion and mean drift force. So sloshing and gap flow must be considered simultaneously with ship motions. There are two ways to consider sloshing; model test and numerical analysis. The disadvantages of experiment are the expensive cost, limited test case and difficulty of similarity of LNG. Numerical method has the advantages of the disadvantages of model test.

The coupling analysis of sloshing and motions is studied by many researchers. The representatives are Faltinsen and Timokha (2009), Kim, Nam, Kim and Kim (2007), Kim and Shin (2008), Lee, Godderidge, Tan, Temarel, Turnock and Cowlan (2009), and Gaillarde, Ledoux and Lynch (2004). They show the good results but only are restricted to 1 body. The coupling of sloshing and 2 body is recently reported by Cho, Sung, Hong and Hong (2011). The representative studies for side-by-side transportation are Voogt (2009, 2010), Jeong, Kim, Lee, Kim and Ha (2010), Hansen, Cartensen, Christensen and Kirkegaard (2009), Hong, Wada, Choi and Kim (2009), and Wilde, Dijk, Berg and Dekker (2009). The previous works report the results without sloshing. But Cho, Sung, Hong and Hong (2011) presented that the longitudinal and transverse sloshing affect the motions of SbS FSRU and LNGC. Also the drift forces are changed by the coupled motions with sloshing.

The hydrodynamic problem of gap flow between FSRU and LNGC including internal sloshing is investigated by numerical method. To study the motions and drift forces of SbS moored FSRU and LNGC, we conducted the numerical study considering sloshing simultaneously. Internal sloshing is solved by two methods. One is pendulum modeling method and other is viscous CFD method. The pendulum model and NS VOF model are compared. The sloshing models are coupled with FSRU and LNGC motions in time domain. To solve FSRU and LNGC motions and gap flow, the outer fluid domain is dealt with by higher order boundary element method (HOBEM). The motions of FSRU and LNGC are solved including sloshing and gap flow simultaneously. The numerical results are compared with experimental results and show the agreement. The numerical results show that the longitudinal and transverse sloshing and gap flow affect surge, sway, roll motion and mean drift forces. It is confirmed that the analysis considering sloshing and gap flow is needed to precisely predict the motions and mooring forces of the SbS moored FSRU and LNGC.

NUMERICAL METHOD

To analyze the ship motions, gap flow and sloshing, two programs are used. The generalized mode concept is used for analysis of FSRU and LNGC’s motions and gap flow. The simple pendulum model and NS based VOF method is used for simulation of sloshing. The ship motions and sloshing is coupled to interact with ship motions and sloshing forces mutually.

Ship motion analysis

To analyze fluid field, velocity potential is introduced and boundary value problem is formulated based on generalized mode concept. As a scheme for solving boundary value problem, HOBEM is applied. Hong (2002) showed that the results of HOBEM are more accurate and convergent than constant panel method. For multi-body interactions,