International Journal of Offshore and Polar Engineering (ISSN 1053-5381)

Vol. 28, No. 1, March 2018, pp. 40–45; https://doi.org/10.17736/ijope.2018.ts12

http://www.isope.org/publications/publications.htm

Fully Coupled Analysis of an Offshore Deck Mating Operation of a Large Topside Module

Sa Young Hong*, Bo Woo Nam, Yoon-Jin Ha and Seok Won Hong*
Korea Research Institute of Ships and Ocean Engineering
Yuseong-gu, Daejeon, Korea

A fully coupled analysis is carried out to evaluate the offshore mating operation for a large heavy topside module on a deck of floating liquefied natural gas (FLNG). Fully coupled hydrodynamic interactions are considered between a crane vessel lifting the heavy topside module and the FLNG. Multiple crane wires and slings are modeled with linear springs, while the leg mating unit (LMU) guide is modeled with bilinear springs. Special attention is paid to the accurate prediction of coupled hydrodynamic coefficients and pendulum dynamics of heavy hanging objects. Simulation results are validated by comparing model test results on key parameters affecting the deck mating operations on-site. Good agreement has been obtained between the simulations and the model tests.

INTRODUCTION

Because of the increasing need of an environmentally friendly fuel supply, liquefied natural gas (LNG) has become one of the emerging resources to replace oil as well as renewable energies such as solar, offshore wind, etc. The recent drastic fall of oil prices requires a variety of innovations for more economic solutions and earlier first oil. In spite of state-of-the-art exploration technology, it is not uncommon to find oil and gas fields that have much larger or smaller reserves than first estimated. Especially in the case of a gas field of much larger reserves, it is necessary to accommodate additional large topside modules on-site. In such a case, more effective and safer installation scenarios should be prepared. The assurance of safety and operability of installation of the large topside module on-site should be checked under combined wind, wave, and current conditions because the large topside module can cause a serious hazard on the existing floating LNG (FLNG) in case of poor installation scenario and operation.

For the performance evaluation of floating crane operations, the time-domain dynamic analysis has been widely used in the design stage to predict the motion response and determine the capacity of the installation equipment and the weather windows. Clauss et al. (2000) presented a comparative study of the operation capabilities of floating cranes. They also reported the nonlinear phenomena of the coupled system of floating structures and swinging load. Ellermann et al. (2002) discussed the nonlinear dynamics of floating cranes. Cha et al. (2010) applied multibody system dynamics to study the dynamic response simulation of heavy cargo suspended by a floating crane. Similarly, Park et al. (2011) presented the dynamic factor analysis based on multibody dynamic simulations for a floating crane and cargo considering an elastic boom. Nam et al. (2015) developed a time-domain analysis program for floating crane vessel systems. They investigated the effect of a heave compensator during a lowering operation of subsea equipment. Most recent studies, however, have focused on single floating crane operations. In real sea operations, multiple floating bodies should be involved in crane operations, where various mechanical and hydrodynamic interactions occur between the floaters and lifted object. Thus a fully coupled analysis for multiple floating bodies with various connectors is required to analyze the complex floating crane operations in the real sea.

Regarding general multibody hydrodynamic interactions, there have been remarkable studies especially on side-by-side moored floating vessels in which strong gap resonance is included (Huijsmans et al., 2001; Choi and Hong, 2002; Hong et al., 2005; Kashiwagi et al., 2005, Hong et al., 2013). Huijsmans et al. (2001) investigated the effect of artificial suppression of gap resonance flow. Choi and Hong (2002) introduced the generalized model approach combined with a higher-order boundary element method (HOBEM). Hong et al. (2005) showed that HOBEM can give very accurate estimations of hydrodynamic interaction effects for side-by-side moored vessels in an experimental study. Kashiwagi et al. (2005) and Hong et al. (2013) also showed an excellent performance of HOBEM for a case of multibody hydrodynamic interactions.

In the present study, a fully coupled analysis is performed to simulate the offshore mating operation of a large heavy topside module on a deck of FLNG. The fully coupled hydrodynamic interactions between the crane vessel and the FLNG were analyzed using HOBEM. Multiple crane wires and slings were modeled with linear springs, while the leg mating unit (LMU) guide was modeled with bilinear springs. Special attention is paid to the accurate prediction of coupled hydrodynamic coefficients between the crane vessel and nearby FLNG and pendulum dynamics influenced by the hanging heavy topside module.

Simulation results are validated by comparing key parameters with model test results, which affect the deck mating operation of a heavy topside module on the deck of a preinstalled FLNG on-site.

NUMERICAL ANALYSIS MODEL

Multibody Motion Equations

Unlike deck mating operations for a jacket structure in which hydrodynamic interactions between the jacket and a transportation barge are negligible, the hydrodynamic interactions between

*ISOPE Member

Received January 22, 2017; updated and further revised manuscript received by the editors June 22, 2017. The original version (prior to the final revised manuscript) was presented at the Twelfth ISOPE Pacific-Asia Offshore Mechanics Symposium (PACOMS-2016), Gold Coast, Australia, October 4–7, 2016.

KEY WORDS: Offshore deck mating, topside, fully coupled analysis, FLNG, model test, LMU, pendulum dynamics.