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Experimental and Numerical Study on Docking Operations of a Transportation Vessel for Float-over Installation

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This study investigates the performance of docking operation in a float-over installation by using both experiments and numerical calculations. It is assumed that a host structure is a fixed jacket platform, and a deck transportation vessel carried an integrated topside module to be mating with the jacket structure. In the docking operation, the transportation vessel should enter into the jacket slot safely with the help of fenders, mooring, and tether lines. To experimentally evaluate the performance of the docking operation, a series of model tests were carried out at ocean engineering basin of the Korea Research Institute of Ships and Ocean Engineering. During the model test, vessel motion, line tensions, and fender forces were directly measured, and various irregular wave conditions were considered in both head and beam seas. To validate the experimental data, numerical simulations were performed using a nonlinear time-domain simulation method that is based on general floating-body dynamics for the transportation vessel and generalized spring-damper model for connectors. Through the analysis of the results, the motion responses of the transportation vessel are discussed in relation to the line tension and fender reaction forces. Especially with regard to beam sea conditions, the effects of fender gap and docking configuration are further investigated by using the numerical simulations.

INTRODUCTION

To install a heavy topside module on a jacket platform, two typical installation methods, crane lifting and float-over methods, have been widely used in the offshore field. Regarding the crane lifting method, the installation procedure and operation schedule can be limited by the lifting capacity of available floating cranes. When the appropriate crane vessels are not available or when a heavy integrated topside module is desired to be installed at once, the float-over installation method can be used instead. The most important advantage of the float-over method is that the overall installation procedure can be performed only by using a transportation vessel without floating cranes. Float-over installation method is typically divided into five stages: standby, alignment, docking, mating, and undocking operations. Among them, the mating and docking operations are the most critical stages. In the mating operation, the topside load is transferred from the transportation vessel to the host structure. In this case, dynamic loads acting on the interface units such as leg mating units (LMUs) and deck support units (DSUs) should be carefully checked. Also, the docking operation is another important stage that is closely related to operability and workability in the float-over installation. In this stage, tether, warping, mooring lines and fenders were used to help the entry of the transportation vessel. Duquesnay et al. (2013) summarized the issues of docking and undocking operations including the complexity of float-over hardware and component according to slot configuration (i.e., tight slot and loose slot). They also defined a complex fender system, which is applied in tight slot condition.

Regarding the float-over operation on a jacket structure, dynamic simulations and model tests are mainly used to evaluate the design load and operability prior to real-sea operations. Jung et al. (2009) evaluate the impact loads on LMUs, DSUs, and fenders with nonlinear time domain analysis by using the commercial software SIMO. They modeled several boundary springs as linear, bilinear, or nonlinear springs and reported the impact forces in docking and mating stages. Yuan et al. (2014) described the rational analysis method and its application in the LW3-1 CPP Topsides. They pointed out the sway fender impact loads by varying the gap in docking, mating, and undocking simulation. Zhou et al. (2014) carried out the model tests. They performed five types of tests: hydrostatic tests, mooring position-keeping tests, docking tests, mating tests, and undocking tests. They reported the movements of LMU mating cones; impact loads on LMUs, DSUs, and fenders; line tensions; etc. They reviewed the fender gap effects as they did in numerical simulations for LW3-1 CPP Topsides. Kocaman and Kim (2008) compared the model tests results with numerical simulation under various wave headings according to LMU loads. They predict workability to estimate the project cost and schedule using weather data. Duquesnay et al. (2013) suggested the one-body-panel model for transportation vessel modeling, the compression-only gap springs for fender systems, and the tension-only springs for mooring lines in docking operations. Yuan et al. (2013) presented some challenges of the transportation and installation design of a fully integrated SHWE topside and described the barge strength under transport and float-over analysis under long swell waves. They reported the main results, which are checked by the design criteria regarding engineering design. They also described the analysis techniques related to numerical modeling.

In this study, model tests, as well as numerical simulations, were carried out to evaluate the performance of the docking operation in the float-over method. In the docking operation, a deck transportation vessel with a heavy topside module enters into the jacket slot, and various interface units such as sway fenders and mooring and mating lines help the safe docking operation. A series of model tests for the transportation vessel were performed under various irregular wave conditions. Time-domain

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