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Performance Evaluation of Active Heave Compensator in Deepwater Installation Operation

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In this study, a series of model tests were carried out to evaluate the performance of an active heave compensator (AHC) in deepwater installation operations. In the tests, a crane vessel and three different subsea structures were examined during deepwater crane lifting operations with an AHC. To validate the experimental results, time-domain numerical simulations were performed with the same AHC control algorithm. First, free-decay tests were conducted to identify the added mass of the subsea structure and the natural period of the hoisting system. Then, the performance of the AHC was evaluated for regular and irregular wave conditions. The effects of winch capacity and installation water depth on AHC performance are discussed.

INTRODUCTION

To install various subsea equipment or structures in deep water, safe and economic installation methods should be taken into account. Among various installation methods for subsea equipment, the conventional crane-wire installation method has been widely used in real-sea operations. Safe crane lifting operations require checking the crane capacity, rigging design, and structural strength of the lifted object. If the weight of the lifted object is considerable, the coupled dynamics of the crane vessel and the lifted object with crane wire become quite important. In particular, it is well known that vertical oscillation of the lifted object can be a significant factor during deepwater crane installation operations, especially for the landing phase. In addition, the resonant vertical motions of the lifted object can cause large dynamic tension of the hoisting wire during the lifting operation.

In the field of subsea installation, as installation depth and weight of installation objects increase, the needs of the heave compensation system increase. Heave compensators can be categorized into two types. One is the passive heave compensator (PHC), which is a kind of spring-damper system that shifts the resonant frequency of the vertical motion of the hoisting wire system. The PHC is also designed to reduce impacts on offshore cranes by adding damping in the hoisting wire. However, it depends on the types of subsea structure and sea conditions. The other type is the active heave compensator (AHC), which compensates for the vertical motion of a lifted object by using either controlled winches or hydraulic pistons with reference signals. The AHC systems generally use information from a vessel motion reference unit (MRU) to control the payout length of the winch line. The AHC system is rather complex and expensive but it is relatively unaffected by the subsea structure type and sea conditions. Also, the control mode can be changed adaptively for varying installation stages.

Many previous studies on deepwater installation can be found via a survey of the literature. To name a few, the amplification of the structure motion and wire tension for a certain wire length are referred to as resonance depth phenomena. Chung and Whitney (1981) numerically showed the results of dynamic vertical resonant stretching oscillation of an 18,000-foot metric ocean mining pipe, which is physically similar to the problem in this study. They identified primary parameters for the pipe stretching and explained basic characteristics of axial oscillation of a deep-ocean pipe for seafloor equipment operation. Rowe et al. (2001) categorized the engineering issues of subsea installation into three parts: lifting and lowering technology, load control and positioning, and metocean effects and weather window requirements. Load control and positioning are concerned with the load distribution of the hook and the wire for the safe installation, positioning, and alignment of the structure. Metocean effects and weather window requirements are related to workability at the offshore site and the required weather window and forecasting. To avoid resonance depth, the heave compensation system was introduced. In 1976, unexpected resonance in the axial pipe motion was measured (Chung, 2009). Cha et al. (2009) conducted a time-domain simulation of an offshore crane vessel with a hanging structure based on multibody dynamics. Nam et al. (2013) developed a time-domain analysis program for floating crane vessel systems. They investigated the effect of the heave compensator during the lowering operation of subsea equipment. Recently, Nam et al. (2015) performed an experimental study on the deepwater crane installation of subsea equipment in waves.

Regarding the AHC, many pioneering works have been done by many researchers. Neupert et al. (2008) investigated the effects of the decoupled controller on the AHC, and they suggested a prediction algorithm of the vessel's motion. Küchler et al. (2011) suggested an AHC for the offshore crane based on the feed-forward controller, and they used fast Fourier transform (FFT) to predict the vessel's motion. They conceived of the AHC as one modular unit that could be applicable to any vessel. Johansen et al. (2003)

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