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A Model Test for Deepwater Lifting and Lowering Operations of a Subsea Manifold

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This paper presents an experimental study of the deepwater lifting and lowering operations of a subsea manifold. A series of model tests with an installation vessel, a crane system, and a manifold were performed at the Ocean Engineering Basin of the Korea Research Institute of Ships and Ocean Engineering (KRISO). The lifting and lowering operations during the crane installation of the subsea equipment were tested under both regular and irregular wave conditions. White noise and regular wave tests were first carried out to investigate the vessel motion and wire tension responses during the deepwater lifting operation. The effect of the equipment weight and water depth was also studied. To overcome the limitation of the water depth in the basin, a new experimental technique using a truncated hoisting system was introduced. The effect of the passive heave compensator on the hoisting wire tension was discussed.

INTRODUCTION

A typical deepwater installation operation consists of four main phases: lift-off from the deck of a transport barge, lowering through the wave zone, deepwater lowering and lifting operations, and touchdown on the seabed and retrieval (DNV, 2011). During the deepwater crane installation operation, the vertical oscillation of the lifted object can be a significant factor to be considered, 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. The horizontal offset and motions of the lifted object, which are affected by the low-frequency horizontal motions of the vessel as well as the ocean current, are also important considerations related to the accurate positioning of the subsea equipment.

During the deepwater lifting operation, a heave compensation system can be employed to mitigate the vertical resonant motion of the lifted equipment, which reduces the dynamic loads in the hoisting wire system. A passive heave compensator (PHC) is a kind of spring-damper system that shifts the resonant frequency of the vertical motion of the hoisting wire system. The passive heave compensator is also designed to reduce impacts on offshore cranes by adding damping in the hoisting wire.

Only a few real-sea observations related to deepwater installation can be found in a literature survey. For example, Chung (2009) measured in 1976 the axial pipe motion and the effects of full-scale heave compensators using a lifting pipe in 5,000 m water depth during the sea operations in the Pacific Ocean. On the other hand, some model tests related to subsea installation or a floating crane can be found in recent studies. Clauss and Vannahme (1999) presented an experimental study of the nonlinear dynamics of floating cranes. Johansen et al. (2004) presented the wave synchronizing crane control during the water entry phase on the basis of the model tests. Fujarra et al. (2008) carried out a series of simplified model tests in order to dimension the launching cables and to define the environmental limit conditions for the subsea installation. De Vries et al. (2011) described the monitoring campaign for a typical example of a deepwater lowering operation. They suggested monitoring the results of the subsea behavior of two suction piles during the installation operation in 2,700 m water depth using a support vessel. They also compared the results from the monitoring with those from numerical models used for dynamic analysis and concluded that dynamic analysis methods can be applied to the prediction of the motion and load for subsea structures in a deepwater installation operation. Recently, Nam et al. (2015) performed an experimental study of the deepwater crane installation of subsea equipment in waves. They carried out a model test for the deepwater installation operation of subsea equipment in waves.

Before the real-sea deepwater installation operation of subsea equipment, a time-domain dynamic analysis has been widely used in the design stage to predict the motion responses of the subsea equipment and determine the capacity of the installation equipment and the weather windows. Chung and Whitney (1981) numerically showed the results of the dynamic vertical resonant stretching oscillation of an 18,000-ft. metric ocean mining pipe, which is a physically similar problem to this study. Clauss et al. (2000) presented a comparative study of the operational capabilities of floating cranes. They also reported nonlinear phenomena of the coupled system of the floating structure and swinging load. Galgoul et al. (2001) described the analyses and all the problems encountered during the installation project of a Petrobas manifold in a 1,860 m water depth. They also pointed out that axial resonance can be a major concern as the installation depths increase to 3,000 m. Ellermann et al. (2002) discussed the nonlinear dynamics of floating cranes. Cha et al. (2009) carried out time-domain simulations of block lifting with a floating crane vessel by using multi-body system dynamics. Kimiaei et al. (2009) presented a simplified numerical model for the accurate estimation

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