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Analysis of Heave Compensator Effects on Deepwater Lifting Operation

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ABSTRACT

A deepwater lifting operation using crane vessel is investigated by a time-domain analysis program for floating crane vessel systems. In the analysis, a coupled analysis of floating vessel and lifted object dynamics connected via crane wire are simulated with and without heave compensator. For deepwater installation cases, amplified vertical motion of lifted object is anticipated even under mild sea state due to axial resonance of wire because of elastic property of the wire. The vessel motion of 6 degree-of-freedom is solved in time-domain including memory effect, while 3-d.o.f. motion is considered for lifted structures. The wire is modeled as linear spring and heave compensator is modeled as combination of spring and damper in axial direction. A series of numerical simulations conducted for a wide range of wave periods, and discussions are made for making effective operational range of heave compensator and effectiveness of active heave compensator.

KEY WORDS: Heave compensator; floating crane; wire; deepwater installation.

INTRODUCTION

A typical deepwater installation operation consists of four main phases: lift off from deck of a transport barge, lowering through the wave zone, deepwater lowering/lift operation, landing on seabed and retrieval (DNV, 2011). During the deepwater lifting operation, heave compensation system may be used to control the vertical motion of the lifted object and reduce the dynamic loads in the hoisting system. There are three types of heave compensators that are used in deepwater lifts: Passive, Active and combined heave compensator. A passive heave compensator is a kind of spring-damper system which shift heave natural frequency of hoisting system and reduce dynamic loads. Passive heave compensator is also designed to reduce impacts on offshore cranes by reducing the dynamic force in the hoisting wire. An active heave compensator uses controlled winches, hydraulic pistons and reference signal. Active heave compensation systems generally use information from vessel motion reference unit (MRU) to control payout of winch line.

Clauss et al. (2000) presents a comparative study of the operation capabilities of floating cranes. They also reported nonlinear phenomena of the coupled system of floating structure and swinging load. Shiraishi et al.(2001) suggested a device which decrease swinging of the hanging hook of a floating crane. Than et al.(2002) applied a non-linear dynamic analysis program(FEDEM) to simulate offshore crane operations. This study mainly focused on how dynamic amplification can be reduced by proper operation and design of the hydraulic and control system. Cha et al.(2009) carried out time simulations of the block erection by a floating crane using multi-body system dynamics. Kimiaei(2009) presents a simplified numerical model for accurate estimating of characteristic hydrodynamic force on subsea platforms and compare the results of the DNV guidelines. Chung (2009) presented effects of full-scale heave compensators used in lifting pipe for 4,000m~5,000m water depth. Nam et al.(2012) developed a time-domain analysis program for floating crane vessel systems. He carried out various lowering simulation by floating crane vessel and investigated the effect of heave compensator during passive heave compensator.

In this study, we carried out nonlinear time-domain analysis for deepwater installation problem by using KIMAPS_CRANE program (Nam et al., 2012). In the analysis, we consider a barge crane vessel and two subsea structures which was used in on-going subsea installation project carried out by Hyundai Heavy Industries in 2012. Even though the water depth of this project is about 187m, we considered the water depth until 1000m in the numerical analysis because we want to know the effectiveness of heave compensator on deepwater installation for the future project. In the numerical simulations, we focus on the heave compensator effects on the motion of lifted structure during deepwater lift operation. Fully coupled dynamics of floating crane vessel, crane wire and lifted structure are simulated in time-domain. While a passive heave compensator is modeled as a generalized spring-damper system, an active heave compensator is implemented using classical PD feedback controller. Firstly, the basic characteristics of heave response without heave compensation system are observed. Next, we investigated the effect of heave compensator. Three types of heave compensator, passive, active and combined, are numerically tested and effective zone for heave