Safety Analysis for Installation of Offshore Structure based on Proportional-Derivative Control Strategy with Multibody Dynamics

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ABSTRACT
In this paper, safety analysis of the process of installing offshore structures such as manifolds and jacket-type substructures using floating cranes and barges in waves is performed. The safety analysis consists of three components. First, the dynamic responses of the offshore structure, cranes, and barge, all of which are moored and connected using wire ropes, are analyzed. Second, tensions in the wire ropes connecting the cranes and the offshore structures are calculated. Finally, any collision between the offshore structure and the cranes or the barge that transports the offshore structure is detected. Equations of motion of the offshore structure, cranes, and barge are formulated based on multibody dynamics, as well as considering the hydrostatic, hydrodynamic, and mooring forces. Additionally, proportional-derivative control of the tagline between the cranes and the offshore structure is performed to verify the safety of the installation process, as well as for reducing the dynamic response and collisions among them.

KEY WORDS: Marine operation; safety analysis; offshore structure installation; proportional-derivative control; multibody dynamics.

INTRODUCTION

Background
Recently, as oceanic energy is increasingly being harnessed, many offshore structures such as wind turbines, drilling units, plants, and subsea equipment are being installed and operated at sea, as shown in Fig. 1. The installation of such offshore structures warrants the use of floating cranes, barges, or specialized vessels. Given that the operational characteristics of various installation vessels are different, the installation process is analyzed in detail. In addition, there are many additional dangers associated with offshore installation as compared with installation on land because of ocean environmental loads such as waves, currents, and winds. Thus, the dynamic responses of the offshore structure and installation vessels, as well as collisions among them should be analyzed, to ensure that the installation process is safe. If safety cannot be ensured, alternatives should be suggested, i.e., changes to the installation process. In this paper, a simulation strategy based on multibody dynamics for the installation of offshore structures is studied for analyzing installation process’s safety.

Related Work
Cha et al. (2010b) have studied the combined discrete event and discrete time simulation kernel. They developed a lifting and erection simulation framework using floating cranes in a shipyard, and integrated the open-source modules in the framework. Cha et al. (2010c) and Ku et al. (2011) formulated equations of motion for a floating crane and a heavy cargo load based on multibody dynamics. Park et al. (2011) derived the equations of motion for a floating offshore wind turbine with an elastic tower based on flexible multibody dynamics. Lee et al. (2010) studied the hydrostatic and hydrodynamic forces acting on a floating crane and analyzed the tension in the wire ropes between the crane and a heavy cargo load (Cha et al., 2012a). In addition, a stable numerical integration method was devised for the stiff problem of the wire ropes (Cha et al., 2010a). In this study, we simulate the installation of an offshore structure and perform safety analysis based on the abovementioned related works. Furthermore, we propose use of the tagline proportional-derivative (PD) control method for suppressing the offshore structure’s swinging motion.