Analysis of Lifting Operation of a Monopile Considering Vessel Shielding Effects in Short-crested Waves

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ABSTRACT

This paper addresses numerical simulations of the lifting operation of an offshore wind turbine monopile foundation considering both shielding effects from the vessel and the spreading of the waves. A numerical model of the coupled monopile-vessel system is established. The disturbed wave field near the vessel is investigated and observed to be affected by the diffraction and radiation of the vessel. The shielding effects of the vessel during the lifting operation are accounted for in this study by interpolating fluid kinematics between pre-defined wave points near the vessel using SIMO software and an external Dynamic Link Library (DLL). The effects of short-crested waves on the wave field and on responses of the system are investigated by implementing the directional spreading function in the wave spectrum. Based on the time-domain simulations, the critical responses of the system are investigated by implementing the directional spreading function in the wave spectrum. The results indicate that the effects of the wave spreading are considerable in both incident and disturbed waves. The shielding effects are less significant in short-crested waves than in long-crested waves.

KEY WORDS: Lifting operation; short-crested waves; shielding effect; monopile; time-domain simulation.

INTRODUCTION

Monopile (MP) substructures are the most commonly used foundations for offshore wind farms in water depths up to 40 meters. It has been estimated that more than 75% of all installations are founded on monopiles by the end of 2013 (EWEA, 2014). Monopiles can be transported to site by the installation vessel or a feeder vessel, they can be barged to the site or can be capped and wet towed (Kaiser and Snyder, 2013). An offshore crane is often employed to upend the monopile to a vertical position and lower it down through the wave zone to the seabed. During the lifting operation, the monopile and the installation vessel are coupled through the lift wire and a gripper device which limits the horizontal motions of the monopile during the lowering. The monopile is lowered at a position which is very close to the hull of the crane vessel, so the wave forces on the monopile are affected by the presence of the vessel. Furthermore, since the lifting operation is commonly performed at a relative low sea states, the waves may spread in different directions and affect the motions of the vessel as well as the wave forces on the monopile. Therefore, it is of great interest to evaluate the effects of the wave spreading as well as the shielding effects from the vessel on the behavior of the lifting system.

Studies have been performed to investigate the heavy lifting operations in the oil and gas industry considering shielding effects, such as the lifting of a heavy load from a transport barge using a large capacity semi-submersible crane vessel (Mukerji, 1988; van den Boom et al., 1990; Baar et al., 1992). The studies found that the hydrodynamic interaction had little effect on the responses of the crane tip, but affected the responses of the transport barge and thus greatly affected the lifting operations because of the small dimension of the barge compared with that of the crane vessel (Baar et al., 1992). The sheltering effects from columns and caissons of a gravity-based substructure (GBS) on the barge during a float-over installation were studied (Sun et al., 2012). It has been shown the motions of the barge and the contact forces between the barge the GBS can be amplified due to the hydrodynamic interactions. Therefore, the hydrodynamic interaction between two floaters close to each other should be taken into consideration when estimating responses.

The approach to consider the shielding effects in those studies were to calculate the coupled hydrodynamic coefficients in frequency-domain when all the bodies are at their mean positions. This implies that the motions of all bodies in the system must be very small. However, when considering a continuous lowering operation that the positions of the lifted objects change continuously with time, the above method is not applicable. The main difficulty associated with this process lies in the large motion that the load might experience in waves during being lowered. Bai et al. (2014) introduced a 3D fully non-linear potential flow model to simulate the wave interaction with fully submerged structures either fixed or subjected to constrained motions in time-domain. The scenario of a cylindrical payload hanging from a rigid cable and subjected to wave actions was studied. However, the approach is limited to regular waves up to now and the simulation efficiency is low. The further application on more complicated operations and in irregular waves with longer duration is questionable.