SAFETY OF CAISSON TRANSPORT ON A FLOATING DOCK


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ABSTRACT

When caissons are mounted on a floating transportation barge and towed by a tug boat in waves, the motion of the floating dock creates inertia-gravity induced slip force on the caisson. If its magnitude exceeds the corresponding friction force between the two surfaces, a slip may occur, which can lead to an unwanted accident. In oblique waves, both pitch and roll motions occur simultaneously and their coupling effects for separation and friction forces become more complicated. With the presence of strong winds, the separation force can significantly be increased to make the situation worse. In this regard, we investigate in this paper the safety of the transportation process of a caisson mounted on a floating dock for various wind-wave conditions. This is to figure out whether the transportation process is safe or not under the given system and environmental conditions. The analysis can be done by either frequency-domain approach or time-domain approach. In the frequency-domain analysis, it is difficult to include nonlinear wave contributions, higher-order terms in equations of motions, and nonlinear viscous drag forces. In time-domain approach, they can be more straightforwardly included. In both frequency- and time-domain approaches, there exist phase differences between the wind force, 6DOF inertia loadings, pitch-roll gravity-slip forces, and friction forces. Therefore, special attention needs to be paid to find the actual instantaneously maximum separation and minimum friction forces. In Seok et al. (2010), the frequency-domain analysis was based on displacement-velocity-acceleration RAOs, and thus phase effects were not accurately considered, which leads to more conservative predictions. In this paper, however, all the phase information between motion displacements, velocities, and accelerations are exactly taken into consideration so that the frequency-domain results for the separation and friction forces exactly coincide with the time-domain results when only linear wave exciting forces are applied. A similar analysis procedure can also be used for the design of top-side tie-down structures and equipment of floating drilling and production platforms (Yang, et al, 2010).

KEY WORDS: Caisson transport, Floating barge, Safety, Separation force, Friction force, Inertia/gravity effects, higher-order terms, roll-pitch coupling, Frequency-domain and time-domain analysis.

INTRODUCTION

Caissons are used for various coastal structures. In particular, box-type caissons are popular as base unit for harbor walls and breakwaters. They can be built on land, inside dry-docks, or on floating barges and are typically transported to the installation site by floating transportation barge and tug boat.

When caissons are mounted on a floating transportation barge and towed by a tug boat in waves, the motion of the floating dock creates inertia loading on the caisson. In addition, the inclination of the floating dock generates gravity-induced slip forces. The inertia and gravity-slip forces are resisted by the friction force between the surfaces of floating-dock and caisson in the absence of any blockage or supporting lines. As sea environments get more severe, the motions are increased, and the resulting separation force may exceed the resisting friction force. In this case, the slip and collision may occur. In oblique waves, both pitch and roll motions occur simultaneously and their coupling effects for separation and friction forces become more complicated. With the presence of strong winds, the separation force can significantly be increased to make the situation worse. In this regard, we investigate in this paper the safety of the transportation process of a caisson mounted on a floating dock for various wind-wave conditions. This is to figure out whether the transportation process is safe or not under the given system and environmental conditions. The analysis can be done by either frequency-domain approach or time-domain approach. In the frequency-domain approach, they can be more straightforwardly included. In both frequency- and time-domain approaches, there exist phase differences between the wind force, 6DOF inertia loadings, pitch-roll gravity-slip forces, and friction forces. Therefore, special attention needs to be paid to find the actual instantaneously maximum separation and minimum friction forces. In Seok et al. (2010), the frequency-domain analysis was based on displacement-velocity-acceleration RAOs, and thus phase effects were not accurately considered, which leads to more conservative predictions. In this paper, however, all the phase information between motion displacements, velocities, and accelerations are exactly taken into consideration so that the frequency-domain results for the separation and friction forces exactly coincide with the time-domain results when only linear wave exciting forces are applied. A similar analysis procedure can also be used for the design of top-side tie-down structures and equipment of floating drilling and production platforms (Yang, et al, 2010).

In the frequency-domain analysis, a 3D diffraction/radiation panel program (Lee, 1995) based on BIEM (Boundary Integral Equation Method) and linear potential theory was used. In the time-domain simulation, a hull-mooring coupled dynamic analysis program including viscous effects and various nonlinear contributions was used. The time-domain multi-vessel-mooring-riser coupled dynamic analysis program, HARP/CHARM3D, has been developed by the research group of the second author during the past decade (Ran, 2000; Kim et al., 2001; Tahar and Kim, 2003; Kim et al., 2005; Koo and Kim, 2005). The developed analysis/simulation methodology is used here for the safety assessment of the towing operation of barge-mounted caissons for any given sea environments.

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