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The Impact of Extreme Wave Events on a Fixed Multicolumn Offshore Platform

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This paper presents an experimental and numerical investigation into the magnitude and distribution of the hydrodynamic loads affecting a fixed multicolumn offshore platform (rigidly mounted tension leg platform) when subjected to extreme wave events. All wave load components, including wave-in-deck slamming pressures, were predicted using a commercial computational fluid dynamics (CFD) code STAR-CCM+ and compared against experimental measurements. Slamming pressures were calculated using both data obtained locally at discrete points and globally averaged over the whole exposed area of the deck. In all simulated cases, the deck area exposed to a wave-slamming event was found to be in contact with a water–air mixture with a significant proportion of air phase. It was concluded that the slamming pressure data for the exposed area provided better insights into the pressure changes due to air compressibility and its content.

INTRODUCTION

When a large wave (extreme wave event) impacts the deck of an offshore structure, significant wave-in-deck and slamming loads occur. These slamming events could generate major global and local loads, which can cause structural damage to the deck, generating large forces in the tendons and risers and adversely affecting the motions of floating structure such as tension leg platforms (TLPs) and semisubmersibles. The problem of wave-in-deck impact on a floating platform can be quite complicated because of the contributions of many parameters such as the platform offset, set-down, and tendon dynamics (API, 2010).

The simplest way to investigate wave-in-deck impact problems is a simplified rigid model of the deck structure idealized as a flat plate or as a box shape (Baarholm, 2009; Bhat, 1994; Scharnke and Hennig, 2015). Current design practices (API, 2007; DNV, 2010; ISO, 2007) recommend a number of theoretical approaches such as the global/silhouette approach "simplified loading model" (API, 2007) and a detailed component approach, e.g., the momentum method (Kaplan et al., 1995) to evaluate the wave-in-deck loads of fixed platforms. Since such engineering approaches rely on the potential flow theory to calculate the change of fluid momentum during the wave impact, when using wave kinematics of a nondisturbed wave field the effects of diffraction and entrapped air are neglected. Scharnke et al. (2014) found that the recommended simplified loading model (API, 2007; DNV, 2010) underestimates the measured horizontal wave-in-deck loads on the fixed deck of a jacket platform in both regular and irregular wave tests. Although the simplified loading model used wave kinematics obtained by Stokes' fifth-order wave theory, the underestimation of the loads was severe, particularly in irregular waves (Scharnke et al., 2014). The momentum method was also found to underestimate the magnitude of the wave-in-deck forces on a fixed horizontal deck subjected to unidirectional regular waves (Abdussamie, Thomas, et al., 2014). A more realistic investigation into the wave-in-deck problems shall include the effect of substructures on the magnitude and distributions of the deck loads. Scharnke and Hennig (2015) conducted an experimental study by attaching a fixed box-type deck structure to a square column. The authors concluded that the column presence significantly increases the magnitude of global vertical forces and local pressures.

The current engineering knowledge required to accurately predict the resulting global response of a floating structure due to a wave-in-deck impact event remains limited. This fact is reflected in the very limited number of papers reporting on model tests of typical multicolumn floaters currently available in the open literature. Johannessen et al. (2006) and Hennig et al. (2011) investigated the dynamic air gap, wave loads, and floating platform response under extreme wave conditions. Both investigations reported that a wave-in-deck event can lead to an additional extreme response mechanism and a step change in the extreme loading magnitude in tendons. It must be noted that complete and detailed results of these types of experiments are usually subject to project confidentiality requirements and are therefore not available in the public domain.

Model tests are arguably the best approach for estimating wave-in-deck loads (Scharnke et al., 2014). However, model testing is costly and time consuming and involves a number of drawbacks such as scaling effects. It is therefore not surprising that the use of methods based on computational fluid dynamics (CFD) for calculating wave-induced loads on offshore structures has received increasing amounts of attention in later years. Commonly used

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KEY WORDS: Offshore platforms, wave-in-deck loads, slamming pressure.