Wave-structure interaction.

The effective prediction of wave-in-deck loads.

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Abstract

The safe and efficient design of many offshore structures is critically dependent on the accurate prediction of the applied wave loads. In analysing these loads, the contribution arising at or close to the instantaneous water surface is particularly significant. The reasons for this relate to moment arm effects leading to large contributions to the total overturning moment, to the uncertainty in the predicted kinematics and hence the applied loads and, perhaps most significantly, to the occurrence of wave-in-deck loads. The imposition of ever more stringent design conditions implies that the prediction of wave-in-deck loads (leading to a step change in the applied loads) is a major issue for both the design of new structures and the reassessment of existing structures. In the case of new structures, design procedures seek to avoid the occurrence of wave-in-deck loads by attempting to maintain a sufficient air-gap; whilst for existing structures it is essential to understand the loads that may arise. In both cases, one must understand the nature of the incident waves and the subsequent wave-structure interaction.

The present thesis is concerned with both modelling extreme ocean waves and their interaction with offshore structures; the ultimate aim being to predict the wave loads arising close to the water surface. Wave-structure interaction effects due to two different types of irregular incident waves are investigated. Focused wave events that simulate the largest waves in a sea state replicating extreme or 'freak' waves are considered experimentally. These are compared to the largest crests generated in long random simulations and to numerical simulations using a Boundary Element Method (BEM). This is followed by an assessment of which wave events impose the largest loads and under what circumstances. This is achieved by considering the most critical wave crests expected in a storm with a given return probability, and quantifying the consequent wave loads on a range of model platforms of increasing complexity. First, the loading on various elements of a simple deck with no underlying structure is investigated; enabling the loads due to the incident waves when there is no prior wave-structure interaction to be determined. Next, the effect of different underlying columns is examined. The global wave-in-deck loads on a model deck with a jacket sub-structure are then investigated, and finally, the loads on both the deck and underlying columns of a model Gravity-Based-Structure (GBS) are quantified. At each stage the sensitivity of the loads to a range of wave conditions and deck parameters is revealed. Additionally, representative wave kinematics are compared to the measured loads and found to correlate well with standard slamming coefficients. Comparisons to other simple predictive methods currently used by industry are also made.

This study has shown that the highest wave crest is not necessarily found at the centre of a nonlinear wave group. Indeed, an asymmetrical profile has been found to occur in steep random sea states, and can cause much larger wave-in-deck impact loads than a symmetrical profile of similar height. The incident wave profile has a massive effect on the measured loads; breaking waves just prior to overturning producing the largest loads. Finally, it has been shown that it is not always possible to avoid wave-in-deck impacts completely, especially for large volume structures that significantly alter the incident waves. Indeed, wave-structure interaction effects have been shown to cause substantial wave impact loads on the deck of a large volume structure at almost twice the maximum incident surface elevation.