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Wave-in-deck loading on fixed steel jacket decks

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Abstract

For quite some years, wave-in-deck loading has been an issue of concern for engineers dealing with the performance of offshore structures. The topic is particularly relevant for reassessment of existing structures located in subsiding areas. One agrees that wave-in-deck loading is of dynamic nature, and that structural analyses should reflect this. There is, however, no general consensus on the size of the load and the shape of the load time history to be used for such analyses.

In this paper focus has been on finding realistic load time histories for wave-in-deck loading on jacket platforms in the North Sea. A (normalised) time history shape and a simple expression to calculate a reference load (maximum load) to quantify the time history is presented.

The presented 'recipe' for time histories is based on experimental data and is supported by results reported in the literature, comprising relevant computer simulations and model experiments of wave-in-deck loads on fixed offshore structures.

The recommended load time history is intended for analyses where detailed information on the deck load for a given structure is unavailable, and where a simplified 'rough-but-reasonable' estimate can be accepted.

Keywords: Wave-in-deck; Dynamic analysis; Time domain analysis; Pushover analysis; Wave experiments

1. Introduction

Wave-in-deck loads potentially represent treats to offshore platforms in case of wave crests being higher than the crests the platforms have been designed for or in the case of

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subsidence of the seafloor caused by hydrocarbon extraction in the ground. The question of wave-in-deck loading has recently gained interest in the aftermath of hurricane damages in the Gulf of Mexico and for subsiding platforms in the North Sea.

(Re-)analysis of offshore structures, in particular where wave-in-deck loads are expected to be a problem, should include simulation of dynamic structural response under the influence of extreme waves. Wave-in-deck loading may bring the response into the nonlinear domain [1].

For a dynamic analysis of fixed offshore jacket structures exposed to wave-in-deck loading it is not evident which wave (-history) to use. In a static analysis, a worst-case scenario is used, e.g. a 100 years wave (ULS situation, note that a 100 years wave is the wave with an annual probability of exceedance of 10^{-2}) or a 10 000 years wave (ALS situation) with corresponding periods. Typical wave heights and periods for return periods of 100 and 10 000 years in the southern and northern North Sea, respectively, can be as follows [2,3]:

Southern North Sea		Northern North Sea	
$h_{100} = 26\,\text{m}$	$T_{100} = 15\,\text{s}$	$h_{100} = 28\,\text{m}$	$T_{100} = 15.5\,\text{s}$
$h_{10\,000} = 33\,\text{m}$	$T_{10\,000} = 16\,\text{s}$	$h_{10\,000} = 35\,\text{m}$	$T_{10\,000} = 16.3\,\text{s}$.

In the static analysis, these design waves ‘cover’ all smaller waves. In a dynamic analysis, however, a smaller wave with a period that could cause dynamic amplification could theoretically be more onerous, resulting in higher load effects. For an impact load, the form and duration of the load impulse are of main importance [4]. The load history prior to the extreme wave also influences the dynamic response.

1.1. Wave-in-deck load models

There is no general consensus on which method to use to calculate wave loads on platform decks. Several approaches exist, some verified against experimental data, some not. The methods can be divided into two main groups; the global or the silhouette approaches, which use an effective deck area exposed to the pressure from the water particles, and the detailed component approaches where loads on single members are calculated separately. A brief overview of the methods are given in the following. For details, reference is made to [1].

In the *component approaches* one seeks to estimate wave loading on each deck member and all equipment separately, requiring a computer program to model the deck in detail and to carry out the calculations.

- *Kaplan*’*s* [5] model uses stretched [6] linear wave theory.
- *Finnigan and Petrauskas*’ model [7], denoted ‘Chevron model’ in the comparative study[1] by HSE [8], is based on regular Stream function wave theory and Morison equation. Only horizontal loads are addressed.
- *Pawsey et al.* [9] developed a procedure based on Kaplan’s recommendations but modified it to use Stream function wave theory. The integration of the wave-in-deck load module into the wave-load generator in the analysis program is emphasised.

[1]The British Health and Safety Executive has conducted a comparative study of wave-in-deck load models [8], comprising the API model, DNV slamming model, Kaplan model and in-house oil company models.