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Airgap Prediction from Second-order Diffraction and Stokes Theory

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ABSTRACT

The airgap of a specific semisubmersible platform subjected to irregular waves is considered. Detailed model test results for both motions and airgap time histories are used to verify analysis results. The effects of various methods of including second-order diffraction contributions are demonstrated. A new method is proposed for use in post-processing second-order hydrodynamic transfer functions in which those transfer functions that are unavailable or believed to be unreliable are replaced with those of an undisturbed second-order Stokes wave.

INTRODUCTION AND BACKGROUND

Airgap modeling is of concern for both fixed and floating structures, but it is particularly challenging in the case of floating structures because of their large volumes and the resulting effects of wave diffraction and radiation. Standard airgap response prediction uses linear theory, which generally does not effectively reproduce measurements from model tests. First-order diffraction is considerably less demanding than second-order, so use of only first-order diffraction merits some consideration. Second-order diffraction effects are expected to better reflect observed data. However, these radiation/diffraction panel calculations are very sensitive to the numerical modeling.

The cost of increasing the airgap for a semisubmersible is considerably higher than that for a fixed structure. Hence, instead of increasing the still-water airgap, it may be less expensive to strengthen the underside of the deck to withstand rare negative airgap events. In order to know the wave load and location of impact, reliable prediction tools are important. Model tests are often performed as part of the design of a new semisubmersible. If so, these calculations are needed to determine the locations for placement of airgap probes on the model.

Here, the numerical impact of modeling second-order diffraction effects is assessed by comparing various predictions of the statistical behavior of the free surface with model test results. Diffraction results come from an industry-standard, state-of-the-art computer program that applies second-order panel diffraction theory. All analysis and model test results presented here are relevant to the Veslefrikk semisubmersible, whose plan view is shown in Fig. 1. Other relevant particulars for the vessel as analyzed include: draft, 23 m; displacement, 40,692 t; airgap to still-water level, 17.5 m; and water depth on location, 175 m.

AIRGAP NOTATION AND VESLEFRIKK MODEL

The airgap, $a(t)$, can be considered a linear combination of 3 terms: a_0, the still-water airgap distance; $\eta(t)$, the wave surface elevation at a particular location along the structure measured with respect to a fixed observer; and $\delta(t)$, the corresponding vertical motion of the platform.

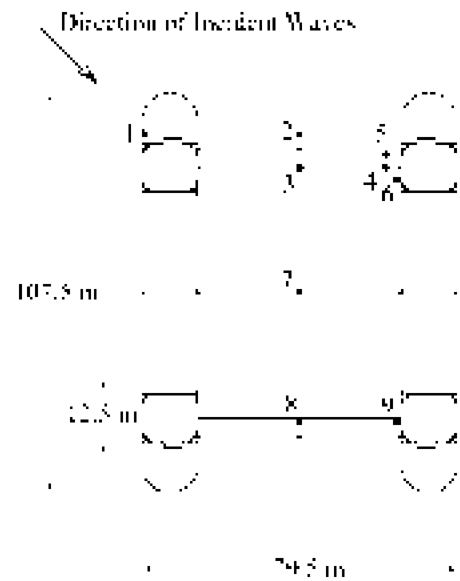

Fig. 1 Plan view of Veslefrikk platform and location of airgap probes

Among the various terms in the equation $a(t) = a_0 - [\eta(t) - \delta(t)]$, the vertical offset due to the vessel's rigid body motion, $\delta(t)$, is perhaps the most straightforward to model. Linear diffraction theory may often suffice to accurately model this offset. In contrast, the free-surface elevation, $\eta(t)$, generally shows nonlinear behavior—and hence represents a non-Gaussian process. Modeling attention is thus focused here on $\eta(t)$.

Specifically, $\eta(t)$ is assumed to be a sum of incident and diffracted waves, η_i and η_d, each of which is a sum of first- and second-order components. This assumption is applied in the panel-diffraction analysis and is consistent with most state-of-the-art nonlinear hydrodynamic analyses, which generally employ second-order perturbation solutions.

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