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Directional Wave Spectrum Estimation Based on Vessel's 1st-order Motions: Field Results

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In this paper, 2 different approaches for estimating the directional wave spectrum based on a vessel's 1st-order motions are discussed, and their predictions are compared to those provided by a wave buoy. The real-scale data were obtained in an extensive monitoring campaign based on an FPSO unit operating at Campos Basin, Brazil. Data included vessel motions, heading and tank loadings. Wave field information was obtained by means of a heave-pitch-roll buoy installed in the vicinity of the unit. Two of the methods most widely used for this kind of analysis are considered, one based on Bayesian statistical inference, the other consisting of a parametrical representation of the wave spectrum. The performance of both methods is compared, and their sensitivity to input parameters is discussed. This analysis complements a set of previous validations based on numerical and towing-tank results and allows for a preliminary evaluation of reliability when applying the methodology at full scale.

INTRODUCTION

The possibility of estimating the directional wave spectrum based on ship motions has been investigated for many years. The idea is to use the vessel as a wave buoy in order to predict the sea characteristics that induced the 1st-order motions measured on board. Undoubtedly, the main appeal of this methodology resides in the operational simplicity of the hardware system required to perform such estimations. A simple set of accelerometers and rate-gyros connected to a PC are all that is needed to perform real-time on-board estimations. However, although some promising results exist, it does not yet appear possible to draw a definitive conclusion concerning the viability of the methodology. The remaining uncertainties may be mainly due to the absence of an extensive real-scale campaign aimed at validation, but they also indicate the inherent complexity of the problem. In order to guarantee accurate estimations, the vessel dynamics must be correctly incorporated by means of its transfer functions of 1st-order motions. This is a particularly difficult task when considering ships in transit, since one has to cope also with variations in speed and heading.

Several estimating models have been proposed based on parametric and nonparametric representations of the wave spectrum. Pascoal et al. (2005) present a good review of previous studies and their main conclusions. In recent years, nonparametric representation has been mostly based on the probabilistic approach of Bayesian estimation. Recent examples of such application can be found in Iseki (2004) and Pascoal et al. (2005). Parametric representation has been used, for example, by Tannuri et al. (2003).

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KEY WORDS: Wave spectrum, estimation, 1st-order motions, FPSO, field data.

This work is part of a research project conducted by the University of São Paulo and sponsored by Petrobras. The aim of the research is to evaluate the viability of estimating the sea spectrum based on the motions of stationary offshore units. Results have been presented by Tannuri et al. (2001, 2003). Estimations were based on a VLCC vessel used as an FPSO unit and on a smaller crane barge. Towing-tank results showed it was possible to accurately estimate the extreme sea states of Campos Basin, which were emulated on a small scale as unidirectional and unimodal sea spectra. Good estimations were obtained based on both parametric and nonparametric representations, although the parametric model was much more time-consuming. A numerical analysis was performed with annual sea states typical of the region, which are usually strongly influenced by swell seas coming from the south. Results indicated cutoff periods below during which the estimation cannot be performed with good accuracy since the ship acts as a low-pass filter. For the VLCC ship, a zero-crossing period of around 7 s seems to define this limit.

The influence of errors in the transfer functions was studied by means of a sensitivity analysis. Results indicated that the Bayesian model was more sensitive to such errors, especially when dealing with bimodal spectra. Also, since the correct definition of the transfer functions is a critical issue, it has been proposed that the roll motion be replaced by the sway motion in the estimations. It was shown that this enhances the reliability of the method since roll motions are strongly influenced by viscous damping, which is nonlinear in nature and difficult to predict. Estimations were then based on heave, pitch and sway motions of the vessels. Incorporating surge and/or yaw motions did not seem to improve the results.

This paper complements the previous study through the analysis of real-scale field data obtained in a monitoring campaign based on one of the FPSO units operating in Campos Basin, the P-35 platform (Fig. 1).