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Estimation of Low-Frequency Motion Damping and Response of a Deep-Draught Floater in Waves

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INTRODUCTION

The Royal Norwegian Council for Scientific and Industrial Research (NTNF) recently organised a comparative evaluation of computer programs as part of its FPS 2000 research programme. This project revealed a number of interesting problems, particularly those of estimating low-frequency motion damping and extreme responses. The present paper describes results from a follow-up study, showing how changes in the assumptions and procedures affected the results.

The problem posed by NTNF was to calculate wave forces on, and motions of, two vessels in regular and irregular waves; to estimate maximum responses in a storm of six hours' duration for first- and second-order motions separately, and then for the combined process. The two vessels were a turret-moored production ship (TPS) and a four-column deep-draft floater (DDF), the latter being a very large semisubmersible type structure of 150-m draft. The following discussion is limited to the DDF.

The results in this paper were obtained using the NMIWAVE computer program, which is based on first-order wave diffraction theory, and uses a conventional three-dimensional source/sink model at zero forward speed. NMIWAVE also computes mean and low-frequency, second-order wave forces and responses.

Further details of the calculation procedures are given by Standing (1990a, b). This technical brief is an amended version of a workshop note by Standing (1990c). Nielsen et al. (1990) give further details and results of the comparative study itself.

FIRST- AND SECOND-ORDER FORCES AND MOMENTS

The first-order hydrodynamic forces, coefficients and responses were insensitive to facet mesh discretisation and will not be discussed further here.

The second-order forces were found to be much more sensitive to the mesh discretisation chosen. There were unexpectedly large differences (Fig. 1) between second-order force spectra calculated using the quadratic transfer function (QTF) method and the Newman approximation. The Newman formula should, in theory, approach the QTF formula at low frequencies, whereas the two curves shown in Fig. 1 remain well-separated. A key factor, however, is that the QTF result was obtained using the direct pressure integration or near-field method. The Newman estimate was based on the alternative momentum based or far-field estimate of mean forces.

In this example, considerations of numerical accuracy seem to be as important as theoretical differences between the QTF and Newman formulae. The QTF and direct pressure methods not only add to computer run times, but also seem to require a finer facet mesh in order to obtain comparable numerical accuracy. There are, of course, several other considerations in deciding between the various available methods, such as the natural period of the motion (theoretical considerations suggest that the Newman approximation is more likely to be valid when the natural response period is long), and whether motions in the vertical plane are required (often more readily obtained using the direct pressure method).

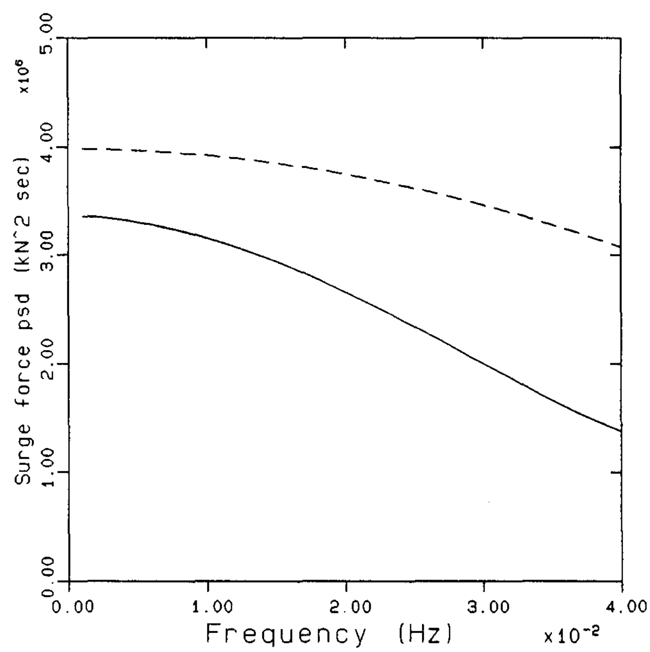

Fig. 1 Second-order low-frequency horizontal force spectra; H_s = 6.0 m. ———— QTF method; - - - - - Newman approximation.

The second-order response spectra (Fig. 2) were typical of lightly damped, resonant systems, and care had to be taken to make the frequency resolution δf fine enough to define the spectral shape. The resolution was chosen to satisfy $\delta f < \min(\xi f_o, 0.2 f_o)$, where ξ is the damping ratio, and f_o is the natural frequency (Dacunha et al., 1981).

LOW-FREQUENCY MOTION DAMPING

The estimation of low-frequency motion damping remains a major area of uncertainty in predicting responses of floating structures.

When estimating first-order responses, it is often sufficient to use the wave radiation damping calculated by a standard diffraction-type program. At low frequencies, however, the wave radiation damping is very small, and other sources of damping have to be considered, such as:

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