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Linear and Nonlinear Analysis of Hydrodynamic Loads on A Flared Axisymmetric Body Oscillating in a Free Surface

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Abstract

The knowledge of hydrodynamic loads acting on the bow flare of a ship operating in severe seas is of critical importance in ship design. The nonlinear free-surface flows caused by large-amplitude bow motions and the associated impact phenomena are extremely complicated. In order to understand these complex phenomena and to facilitate design applications, detailed numerical study is performed to evaluate the hydrodynamic loads on a flared axisymmetric body, as shown in figure 1, oscillating vertically in a free surface. Different levels of numerical methods — linear, body-nonlinear, and fully-nonlinear — are applied and evaluated in this study. In addition, the numerical results are compared with detailed time-domain experimental data recently published by Troesch & Wang (1994), and Maskew et al. (1994) to assess the accuracy and range of validity of each method.

A three-dimensional time-domain large-amplitude motion and load program, LAMP (Lin & Yue 1990, 1992; Lin et al. 1994), is used for the linear and the body-nonlinear computations. In the body-nonlinear approach of LAMP, the body boundary condition is satisfied exactly on the instantaneous underwater surface of the moving body while the free-surface boundary conditions are linearized. The problem is solved using a time-dependent free-surface Green function source distribution on the instantaneous submerged portion of the hull. The motions of the body are either specified or obtained by solving the equations of motion at each time step. For the linear computations, a linearized version of the program (SAMP) is used, wherein the body boundary condition is also linearized on the mean position of the body.

For the fully-nonlinear computations, a mixed Eulerian-Lagrangian scheme employing (vertical) axisymmetry (Dommermuth & Yue 1987) is used. In this approach, Rankine ring sources are used in a Green's theorem boundary-integral formulation to solve the field equation; and the free surface is updated in time following Lagrangian points. To allow for long-time simulations, the nonlinear computational domain is matched to a transient linear wave field outside. When the matching boundary is placed at a suitable distance (depending on wave amplitude), numerical simulation can be continued indefinitely in time. Tank wall effects (which turned out to be important for the wave elevation measurements in the experiments of Troesch & Wang (1994)) can also be considered if a solid boundary instead of a matching boundary is placed at the far end of the computation domain.

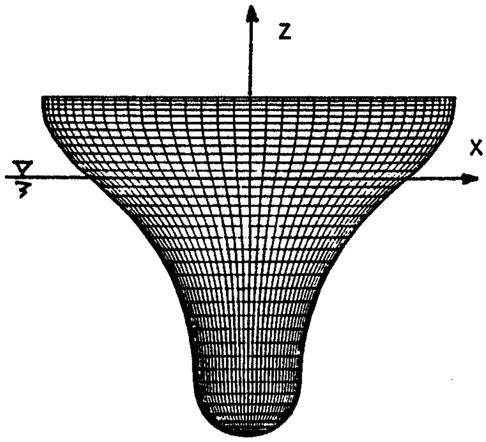

Figure 1: Panel Representation of the Flared Axisymmetric Body (Troesch & Wang, 1994).

Results from these different levels of numerical computations are compared with experimental data of Troesch & Wang (1994) for a heaving axisymmetric flared body. In this experiment, the time histories of the prescribed motions, wave elevation, and hydrodynamic forces were measured. The flared body was forced to oscillate (sinusoidally) with varying frequencies and amplitudes to cover a broad range of wave steepnesses including situations where local wave breaking, spray sheets, and so on, could be observed. Both the deck dry condition and green-water-on-deck experiments were done. In the current study, we focus comparison between numerical computations and experimental measurements only for deck dry cases.

Detailed comparisons and analyses of results will be presented at the Workshop. Discussions will concentrate on the robustness of the panel methods used for large flared body, the relative importance of the nonlinear body boundary condition and the nonlinear free surface boundary conditions, the magnitude and trend of nonlinear effects, the importance of the waterline integral in the body-nonlinear formulation, and the validity of linear and body-nonlinear computations at different frequency and amplitude ranges.

References

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DISCUSSION

Bingham, H. B.: Did the experimenters take any pains to avoid reflections from the tank walls?

Lin, W. M., Xue, M. & Yue, D. K. P.: As far as I know, nothing special was done in the experiment to avoid reflections from the tank walls. More information about the experiment can be found in Troesch and Wang (1994).