HYDRODYNAMIC FORCES ON SHALLOWLY OR PARTLY SUBMERGED 2-D BODIES

Jacek S. Pawlowski
National Research Council Canada
St. John's, NF.

Piotr Waclawek
NORDCO Limited
St. John's, NF.

In (1) and (2), a boundary element algorithm is presented which models in the time domain the propagation of steep, but not breaking, waves and their interaction with fixed and floating bodies performing large motions. The question arises if the method can be applied reliably in its current or a suitably extended version to model fully the capsizing in waves of ship-like forms.

Of particular interest is what seems to be the critical phase of capsizing when the deck is to a large extent or just entirely submerged. The sharply varying added mass, reaching negative values, and large damping forces, which are known to occur on heaving bodies in such circumstances, e.g. (3) and (4), and the disappearance of restoring forces, suggest a dynamics of body motion significantly different from the better known conditions for surface piercing bodies.

Prior to an attempt to perform the nonlinear time domain modelling, a series of frequency domain linear computations was carried out to examine possible stringent gridding requirements hinted at in (3). The nonlinear time dependent algorithm was reduced to an algorithm for a fixed control domain with the boundary determined by the free surface and two vertical control boundaries which extend to depth π/k, where k is the wave number. The bottom boundary was removed. The linear frequency domain free surface condition was imposed, and the time domain condition on the control boundaries was reduced to $\partial\phi/\partial n = ik\phi$. As before the boundary element governing equations were used, with the fundamental solution ln r (P,Q) and constant density centrally collocated panels.

A series of computations was performed, of added mass and damping coefficients for the shallowly submerged square body of half breadth B. In Fig. 1, the results of a convergence test are shown, in which, for the body submerged at h=0.1B, a fine grid was applied on the body and on the free surface above the body, 1xB, and then extended on the free surface in both directions. Results were insensitive to further refinements of the grid. The test shows that the influence of the flow features pertinent to the space above the body, extends to a distance comparable with the dimension of the body. In Fig. 2 a comparison with the close-fit method computations presented in (3) shows a good compatibility.

In Fig. 3, the forces exerted on the oscillating square are shown as composed of contributions from excitations applied on the top and bottom surfaces. The forces on the oscillating body are closely approximated by those due to the excitation on the top surface. However, it is interesting to observe that the peak of the damping coefficient and zero of the added mass coefficient correspond to the resonant response to the excitation at the bottom, and therefore to the resonant response in the gap above the body. The negative damping coefficient due to the excitation at the bottom does not have the surprising physical meaning. The damping coefficient for the force exerted on the bottom is positive as follows from Fig. 4.

The amplitude and phase patterns of the potentials generated on the free surface by the excitation at the bottom, at the frequencies corresponding to the characteristic features of the curves of damping coefficients, Fig. 4b, are shown in Fig. 5a and 5b respectively. The body extends between grid points 86 and 95. The phase angles are α -180°, with α given in Fig. 5b, then the phase of -180° refers to quantities in phase with the acceleration. It is seen that a perfect trapping mode of response, with the zero damping coefficient at the bottom, is achieved at KB = 0.1473. The standing wave patterns extend approximately over the distance of 3xB on both sides of the body. This corresponds to the fine discretization region which provides sufficient convergence of the added mass and damping coefficients, Fig. 1.

For the excitation applied at the deck, Fig. 6a and 6b, the standing wave patterns do not extend over the entire breadth of the body but change into a long wave (small local wave number) patterns in the 3xB vicinity of the body. The phase angles are α -180° for $0 \leq \alpha \leq 90$ and α for $\alpha < 0$, with α given in Fig. 6b. The phases of the wave patterns are shifted by approximately 100° with respect to the corresponding bottom induced patterns. Since the deck excitation dominates the generated forces, this results in the characteristic shape of added mass and damping curves shown in Fig.2.

REFERENCES

1. Sen, D. and Pawlowski, J.S., "Two-Dimensional Numerical Modelling of Large Motions of Floating Bodies in Steep Waves", Third International Workshop on Water Waves and Floating Bodies, Woods Hole, Mass., 1988.

2. Sen, D. and Pawlowski, J.S., "Simulation and Unsteady Propagation of Steep Waves by Boundary Element Method", Seventh International Conference on Offshore Mechanics and Arctic Engineering (OMAE), Houston, 1988.

3. Newman, J.N., Sortland, B., Vinje, T., "Added Mass and Damping of Rectangular Bodies Close to the Free Surface", Journal of Ship Research, Vol. 28, No. 4, 1984.

4. Hodges, S.B. and Webster, W.C., "Measurement of the Forces on a Slightly Submerged Cylinder", Proceedings of the Twenty-First American Towing Tank Conference, 1987.

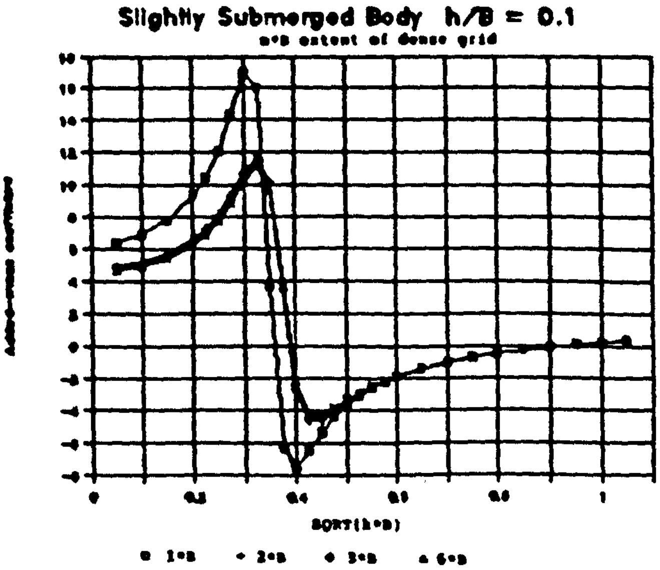

Fig. 1a

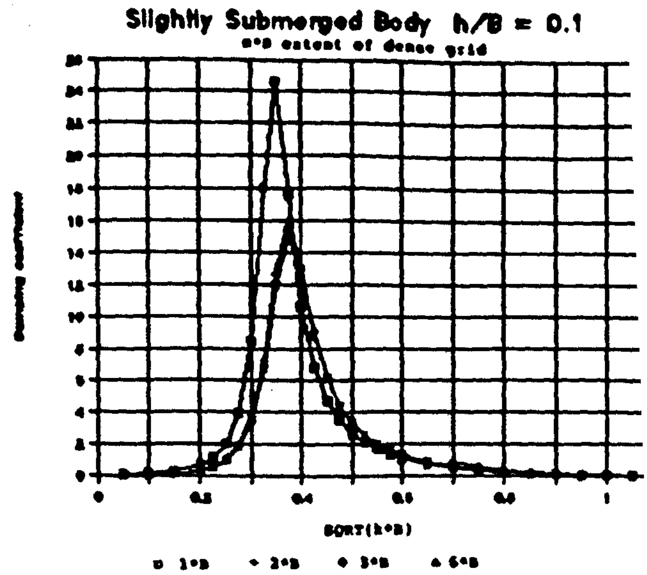

Fig. 1b

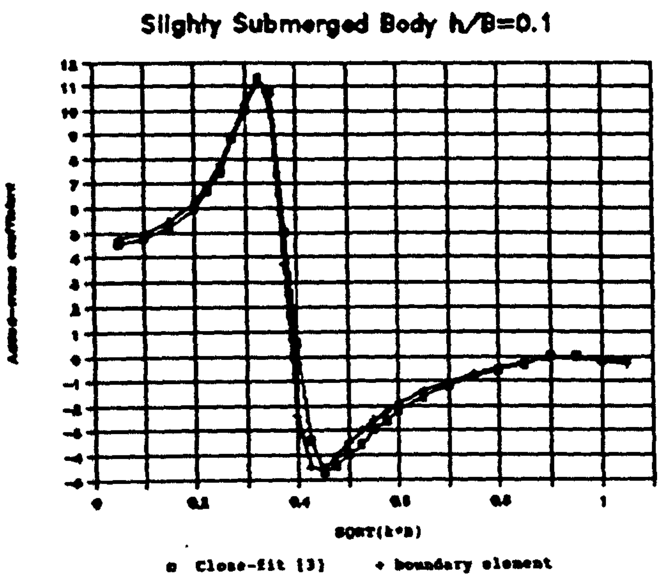

Fig. 2a

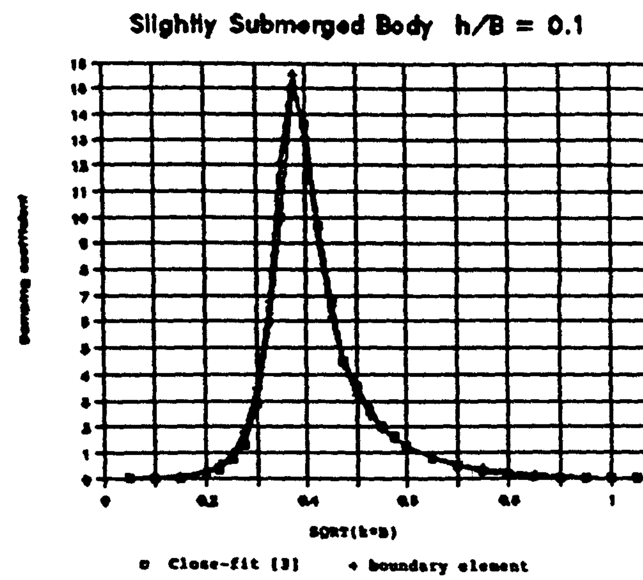

Fig. 2b

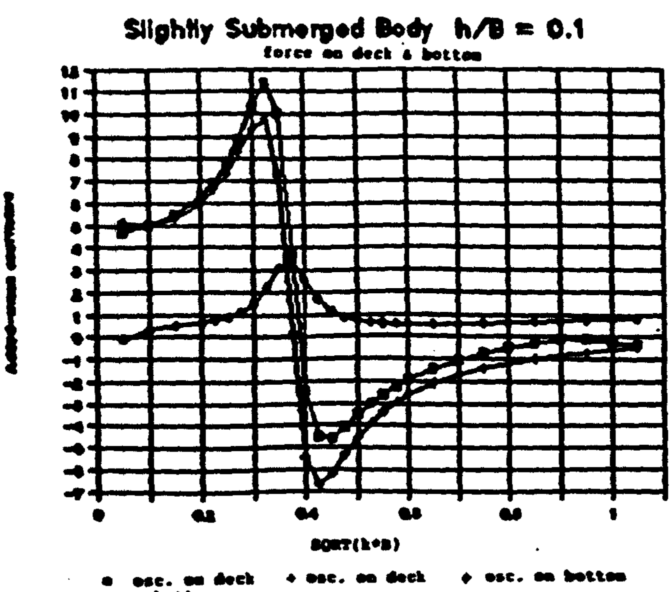

Fig. 3a

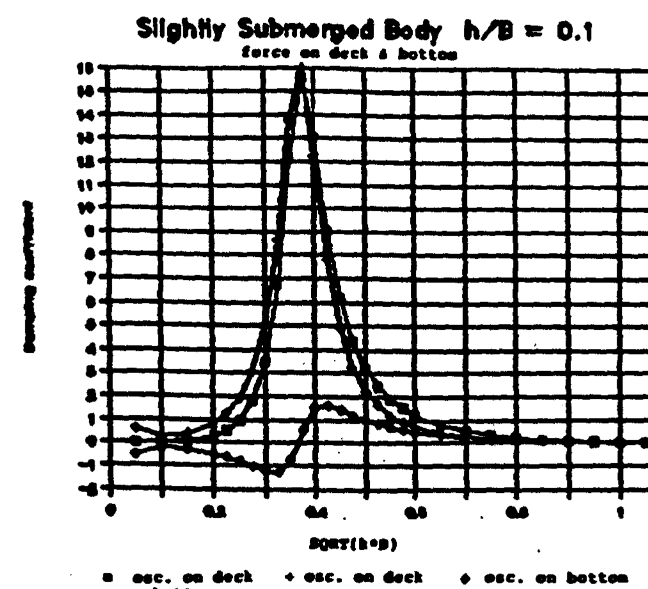

Fig. 3b

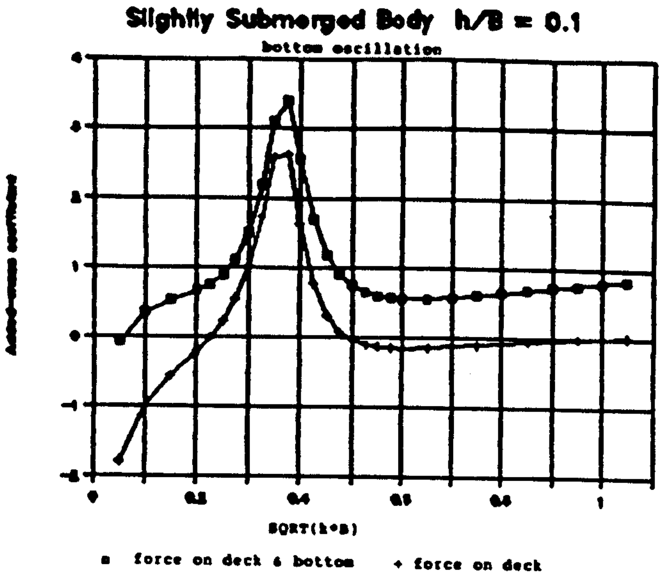

Fig. 4a

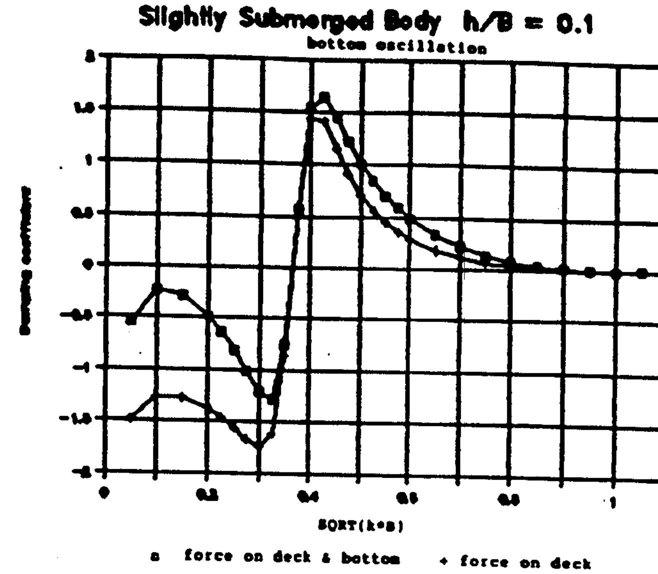

Fig. 4b

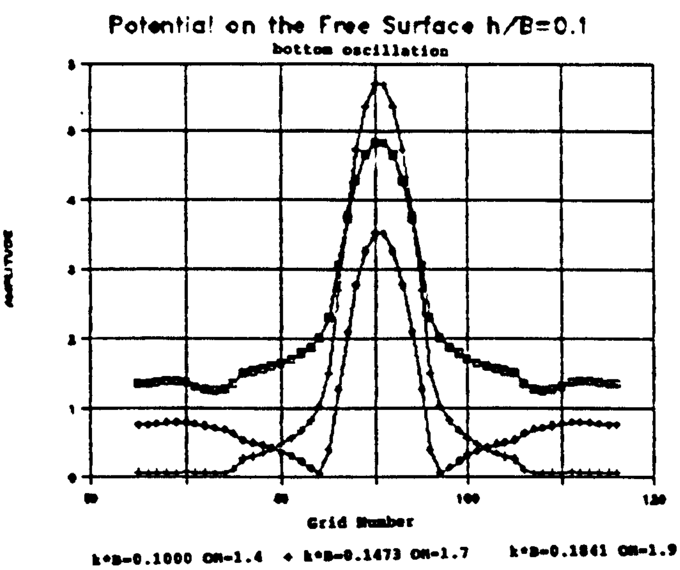

Fig. 5a

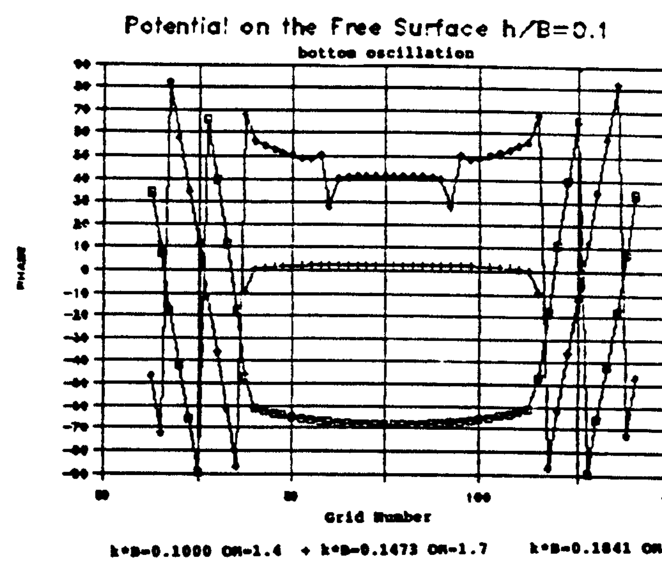

Fig. 5b

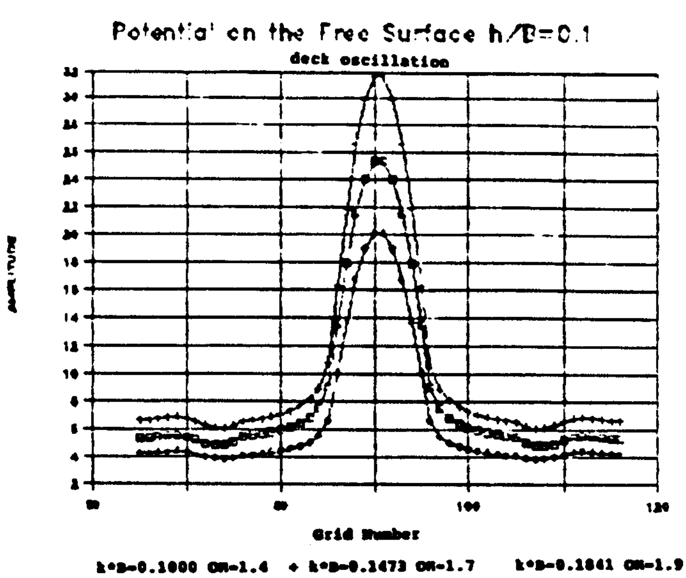

Fig. 6a

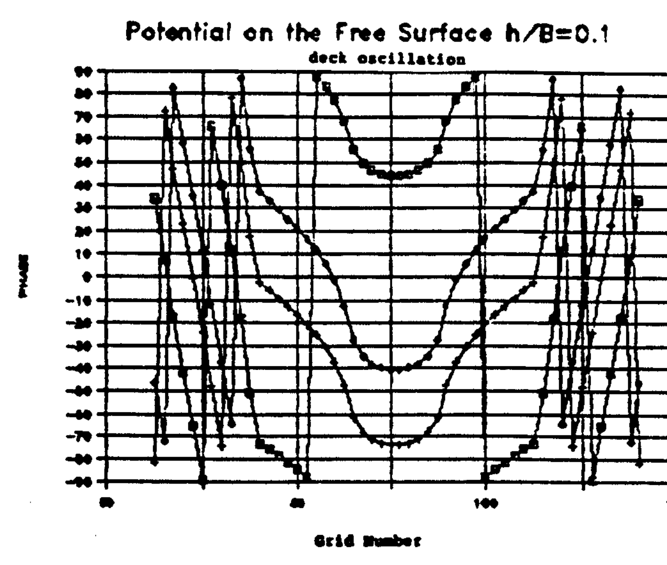

Fig. 6b