Wave-drift force on a rectangular barge by a vertical wall

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At the previous workshop we reported some numerical investigations on the wave response of a rectangular barge in varying bathymetry (Liu *et al.* 2010). We obtained that the wave drift force can be negative (opposite to the wave direction) in some cases. Recently we performed some experiments with a barge model just ahead of an abrupt depth transition, then by a vertical wall. In this abstract we present results from preliminary numerical investigations on the latter case. Results from the experiments will be shown at the workshop.

We consider the same geometry as in Liu *et al.* (2010): the barge has a beam of 1 m, a draft of 0.40 m and the waterdepth is 0.80 m. Its center of gravity is located 0.10 m below the free surface level and its roll radius of inertia is 0.33 m. It is free to respond to the waves. A quadratic viscous damping in roll can be added up to avoid excessive resonance.

The linear radiation-diffraction problem is solved by eigen-function expansions. The drift force is obtained from momentum considerations with two vertical cuts at upstream infinity and at the wall.

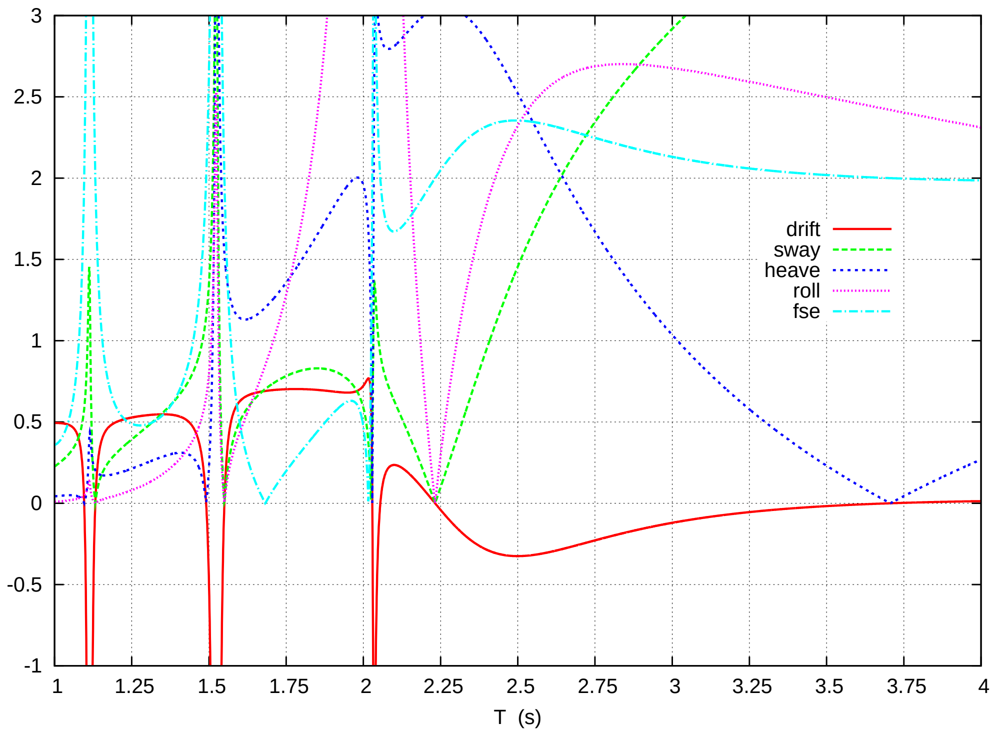

Figure 1: Barge 2 m from the wall. No extra viscous damping.

First we put the barge at 2 m from the fully reflective wall. This distance means that the evanescent modes emanating from the barge do not reach the wall. The extra roll viscous damping is first set to zero: energy is conserved. Figure 1 shows the calculated RAOs in sway, heave and roll, together with the drift force $F_d/\rho\, g\, A^2$ and the RAO of the free surface elevation (f.s.e.) at the wall. The period range is from 1 to 4 s. It can be seen that the drift force changes sign at some wave periods, the largest ones being 3.71 s, 2.23 s, 2.06 s and 2.03 s.

At these periods the free surface elevation RAO crosses the level 2, and, except for wave period 2.06 s near the roll natural period, either the heave RAO becomes nil or both the sway and roll RAOs are nil.

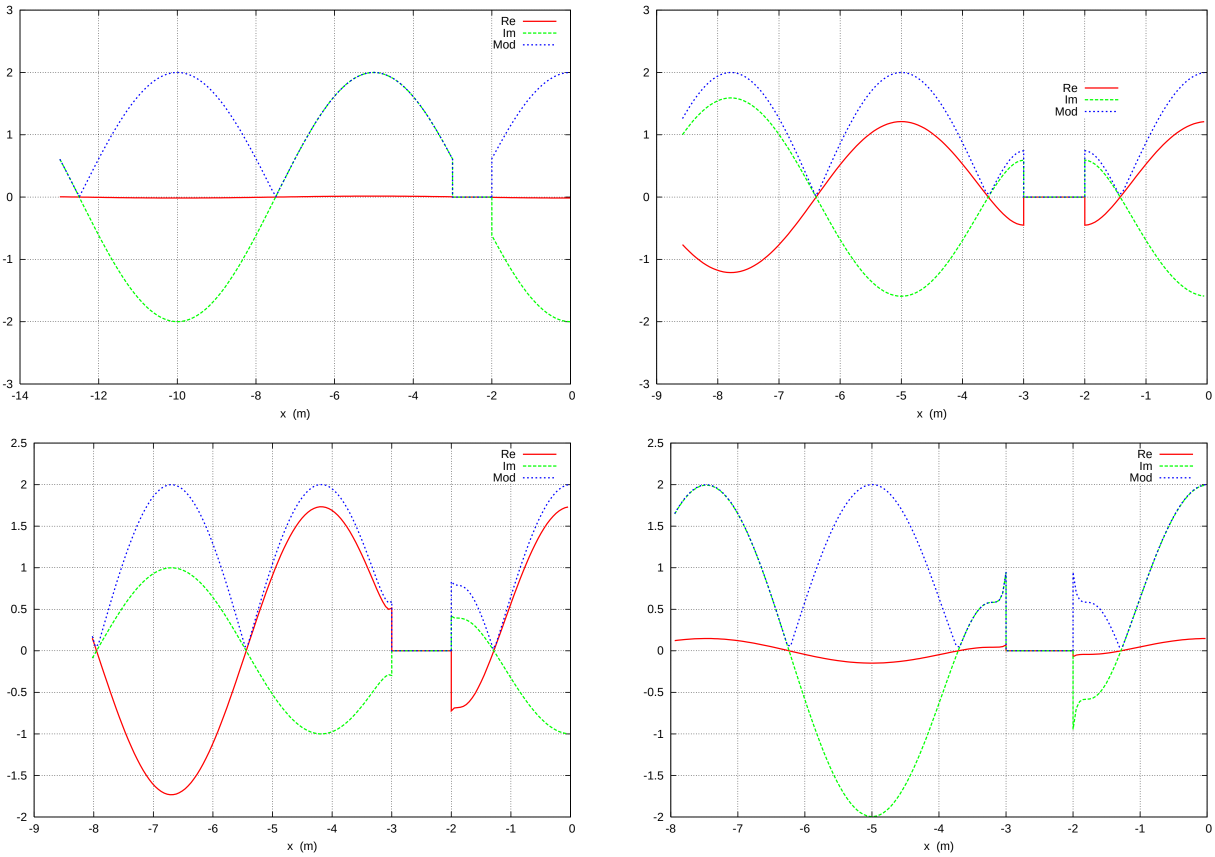

Figure 2: Free surface profiles for $T = 3.71$ s (top left), 2.23 s (top right), 2.06 s (bottom left) and 2.03 s.

Figure 2 shows the free surface profiles at the 4 larger wave periods where the drift force is zero. At $T = 3.71$ s and $T = 2.03$ s (zero heave), the profiles are antisymmetric with respect to the barge. At $T = 2.23$ s (no sway nor roll) they are symmetric.

All these results make sense: for the drift force to be zero the transmission coefficient must be equal to 1, meaning the same incident wave (but with a phase lag) arrives at the wall and is reflected (hence the RAO equal to 2 at the wall). If the barge is only heaving it is obvious that the transmission coefficient will be the same in both directions. When the barge is only swaying and rolling this is less obvious. The less expected case is the 2.06 s wave period where all degrees of freedom participate to render the transmission coefficient equal to 1, in both directions, albeit the free surface profiles clearly show no symmetry nor antisymmetry.

In figure 3 we show the same results as in figure 1 with some added viscous damping in roll. The peaks and fast oscillatory behaviors near $T = 2$ s have disappeared together with the interesting $T = 2.06$ s case, but the plots are identical with the previous ones everywhere else. The roll motion radiates little wave unless its amplitude be completely unrealistic.

Now we put the barge very close to the wall, with a separation distance equal to 0.125 m. Results for the normalized drift force and RAOs are given in figure 4. Some roll viscous damping has been accounted for but it affects the drift force and RAOs only in a small neighborhood around $T = 2$ s.

As a consequence of the short distance from the barge to the wall, a strong piston mode resonance takes place and evanescent modes come into play. As the drift force crosses zero at $T = 1.39$ s, the sway and roll RAOs are not exactly nil but they are close to zero; the RAO of the free surface elevation is slightly above 3. At the other wave period $T = 1.07$ s where the drift force cancels out, the heave RAO is almost zero and the free surface elevation RAO very close to 2: the evanescent modes hardly come into play.

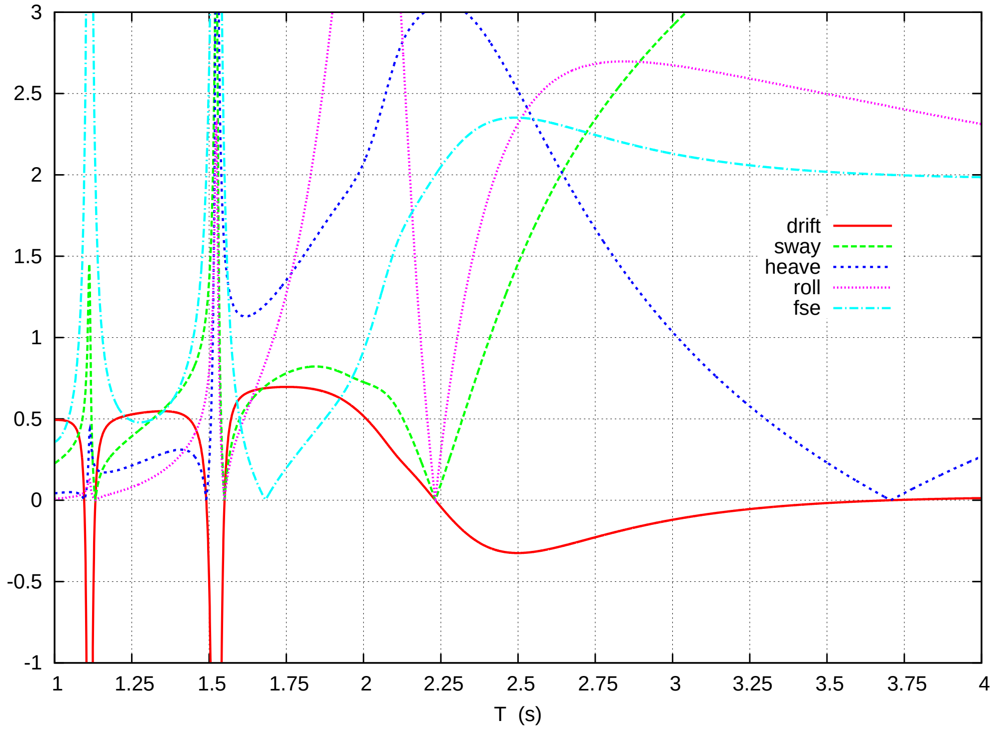

Figure 3: Barge 2 m from the wall. With viscous damping in roll.

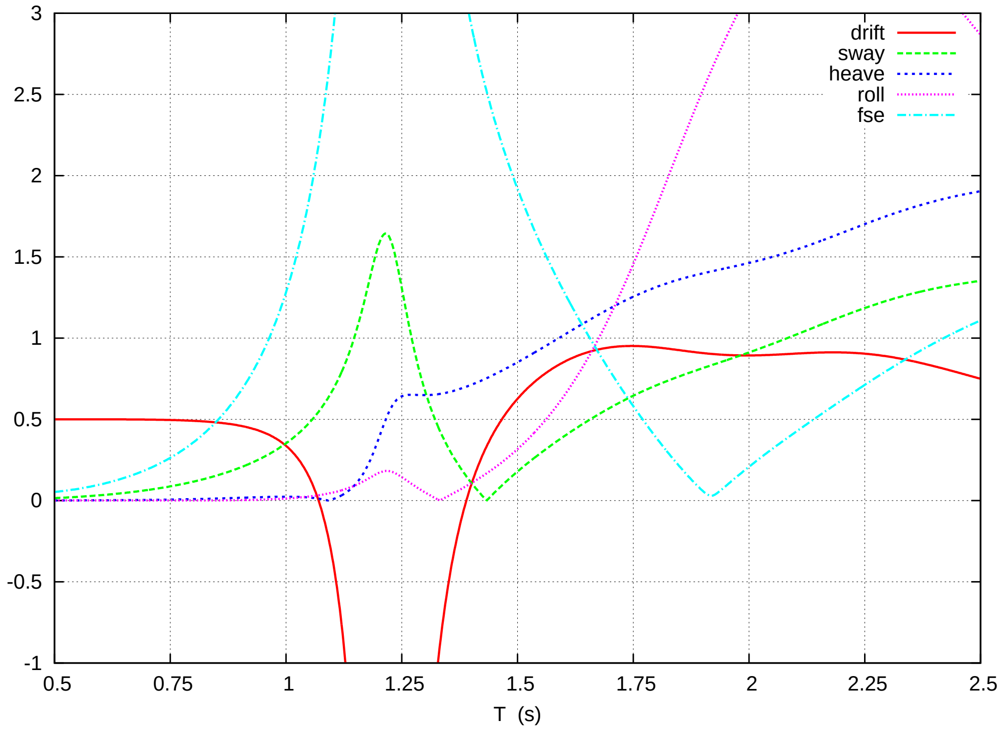

Figure 4: Barge 0.125 m from the wall. With viscous damping in roll.

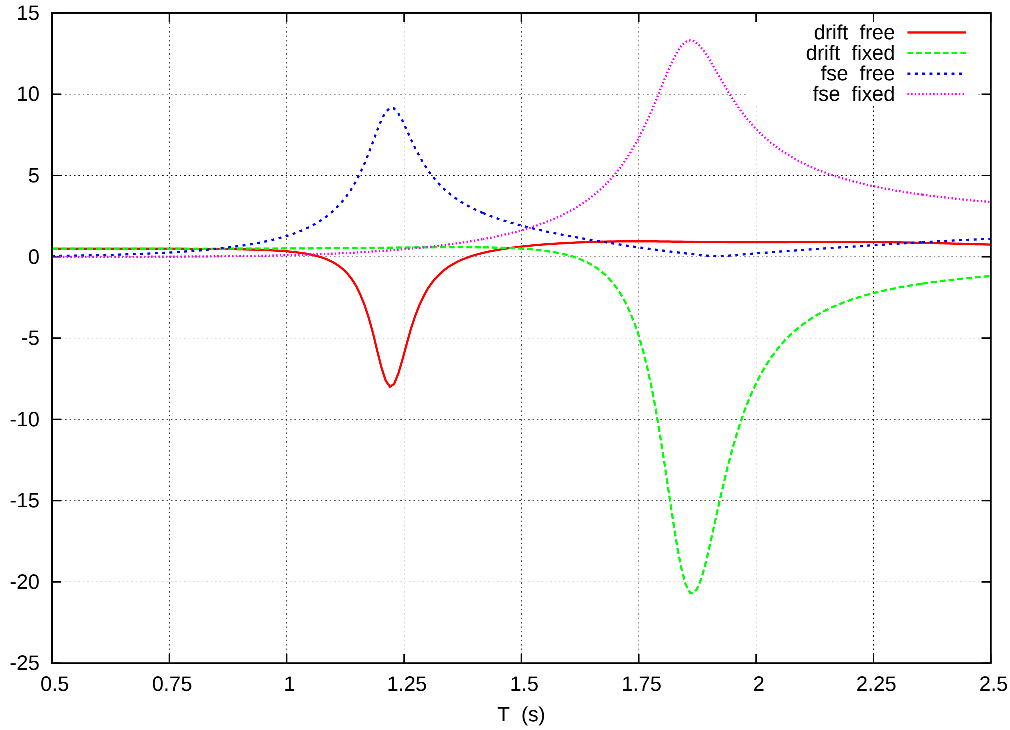

Figure 5: Barge 0.125 m from the wall. Non-dimensional drift force and RAO of the free surface elevation at the wall. Fixed and freely floating cases.

Finally in figure 5, still for the 0.125 m separation distance, we show the drift force and RAO of the free surface elevation at the wall, in the freely floating and fixed cases. In the fixed case the piston mode resonance appears at a somewhat larger period and the peak RAO value gets higher than in the freely floating case. Still the obtained values for the free surface elevation RAO are quite unrealistic in both cases and flow separation at the barge bilges will strongly damp out resonance, as shown in Kristiansen & Faltinsen (2008, 2011) where numerical methods to account for this viscous effect are proposed. Another technique, used in Diodore, consists in putting a massless lid at the free surface and allocating it a quadratic damping force (Molin *et al.* 2009).

References

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