A Preliminary Study on the Hydrodynamic Interaction between the Wave, Current and Body

by

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The results of a preliminary study of the hydrodynamic interaction between the wave, current and body will be presented. A two-dimensional linear diffraction problem was considered in the presence of uniform current.

The study is concerned about the motion and force arising from the hydrodynamic coupling between the wave and the current in the presence of a moored body. Interaction between the incident wave and uniform current in the absence of body lies in the realm beyond our interest, as do the effects of the viscosity of the fluid.

A Fredholm integral equation of the second kind was employed in association with the Haskind potential [1] for a pulsating source located below the free surface in uniform current in deep water.

There are three-dimensional studies, Ref. [2], [3] and others relevant to the present problem published in the past few years. A two-dimensional experimental study for a slender submerged horizontal cylinder in the uniform current and wave in finite water [4] was reported.

The present study was planned to investigate the following items:

1) The hydrodynamic pressure distribution and forces on the body surface and wave elevations at the near- and far-field points.
2) Surface waves such as the reflected and transmitted waves.
3) The relation between the wave-making damping and amplitude of the radiated waves.
4) Examination of the Haskind-Newman method for evaluating the wave-exciting force.
5) Mean second order lateral and vertical forces.
6) The responses of a moored cylinder in waves and current.
7) Evaluation of the relative motion between the adjacent wave surface and body.

The first item, 1) in the foregoing has been investigated as preliminary, the results of which include the behavior of the exciting forces on a surface-piercing (Figs. 1a-2b) and on a submerged circular cylinder (Figs. 3a-3b) and dynamic swells near the hull contour on the free surface (Figs. 4a-4b).
Also, mean lateral drift force on a restrained ship model (Lewis form section, area coeff.=0.933) was evaluated (Figs.5a-5b).
Each response was investigated both for the wave direction opposite to current (Case I) and for the wave and current in the same direction (Case II).
Conclusions were drawn from the study:

1) The current effect on all responses is generally negligible in the low frequency region.
2) The heave exciting force on the surface-piercing body slightly increases in Case I and decreases in Case II.
3) The sway exciting force on the surface-piercing body slightly decreases in Case I and increases in Case II.
4) The heave and sway exciting force on the submerged circular cylinder have the same magnitude with phase shift. The phase angle of the heave exciting force leads that of the sway exciting force by 90 degrees.(case I)
   The exciting force increases in small frequency region and decreases in relatively large frequency region in Case I, as the current speed increases, and vice versa in Case II.
5) The dynamic swell on leeward side decreases as the current speed increases in Case I. The dynamic swell in Case II decreases on weather side as the current speed increases.
6) The lateral mean drift force on a ship section increases in Case I and decreases in Case II, as the frequency and current speed increase.
7) It was also found that the magnitude of the convective hydrodynamic pressure is negligibly small compared to the local pressure.

References:

[1] Haskind, M.D., "On the Wave Motion of Heavy Fluid", PMM, Vol.18, No.2, 1954
[2] Kobayashi, M., "On the Hydrodynamic Forces and Moments Acting on an Arbitrary Floating Body with a Constant Forward Speed", Journal of Society of Naval Architects, Japan, 1981
[3] Yeung, R.W. and Kim, S.H., "A New Development in the Theory of Oscillating and Translating Slender Ships", 15th Symposium on Naval Hydrodynamics,

Session III, Sept.4, 1984 Hamburg
[4] Chandler, B.D. and Hinwood, J.B., "Combined Wave-Current Forces on Horizontal Cylinders", 18th Int. Conference on Coastal Engineering, pp.2171-2188

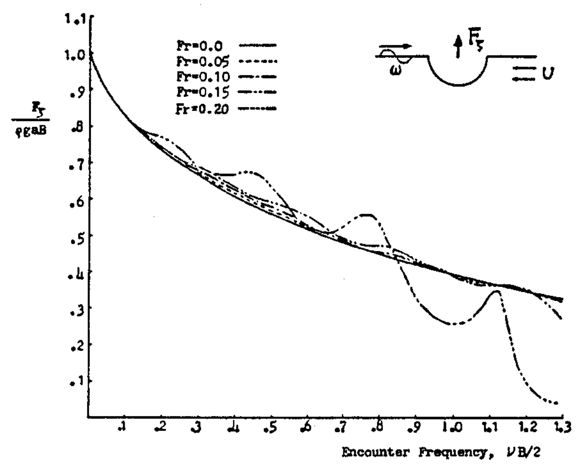

FIG. 1a HEAVE EXCITING FORCE ON A SURFACE-PIERCING BODY (I)

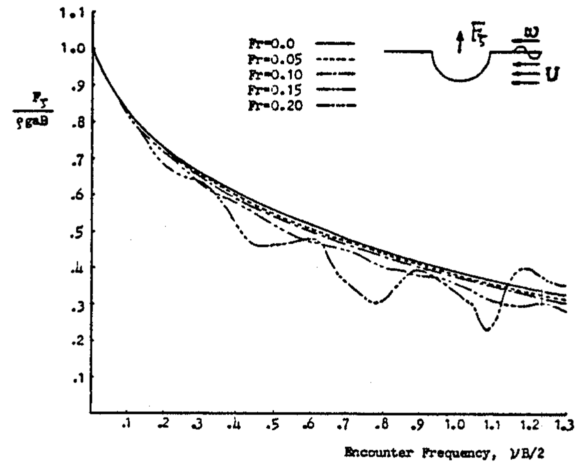

FIG. 1b HEAVE EXCITING FORCE ON A SURFACE-PIERCING BODY (II)

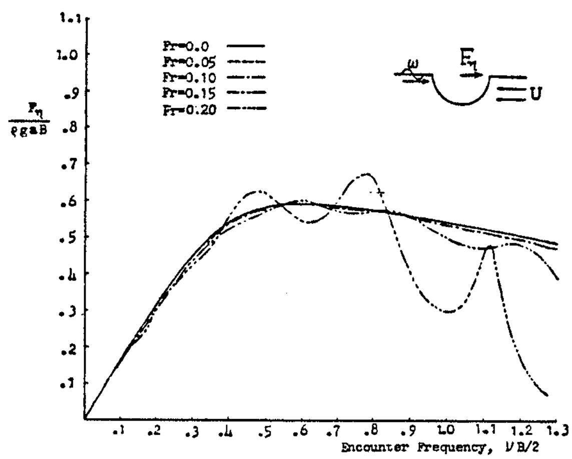

FIG. 2a SWAY EXCITING FORCE ON A SURFACE-PIERCING BODY (I)

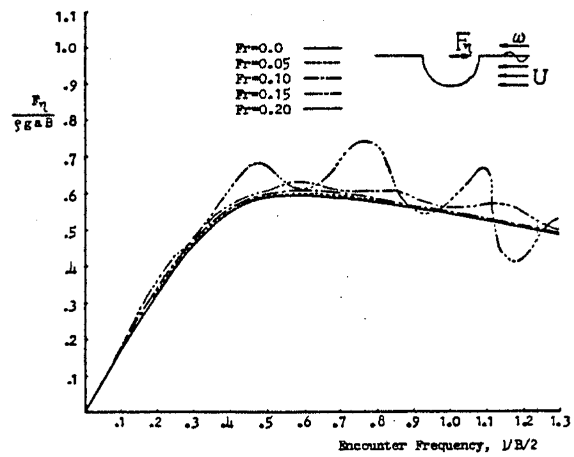

FIG. 2b SWAY EXCITING FORCE ON A SURFACE-PIERCING BODY (II)

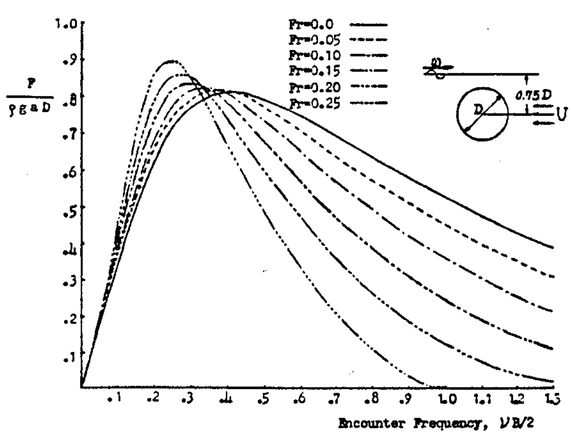

FIG. 3a EXCITING FORCE ON SUBMERGED CIRCULAR CYLINDER (I)

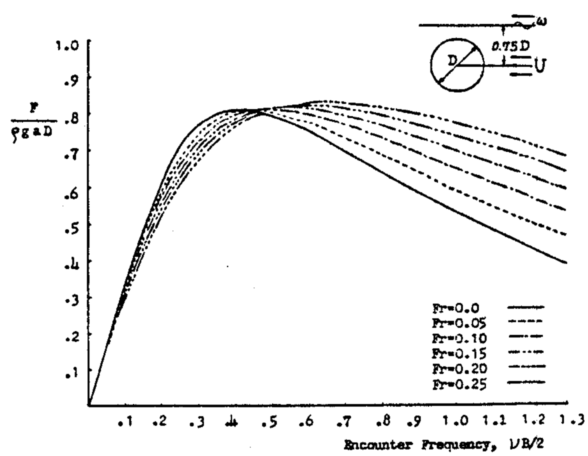

FIG. 3b EXCITING FORCE ON SUBMERGED CIRCULAR CYLINDER (II)

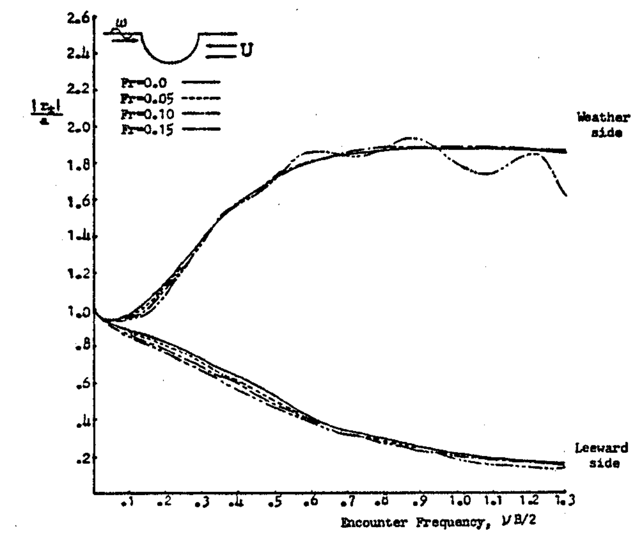

FIG. 4a DYNAMIC SWELL (I)

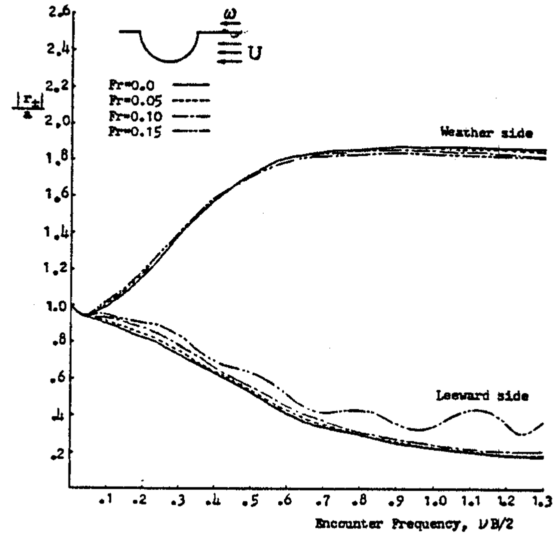

FIG. 4b DYNAMIC SWELL (II)

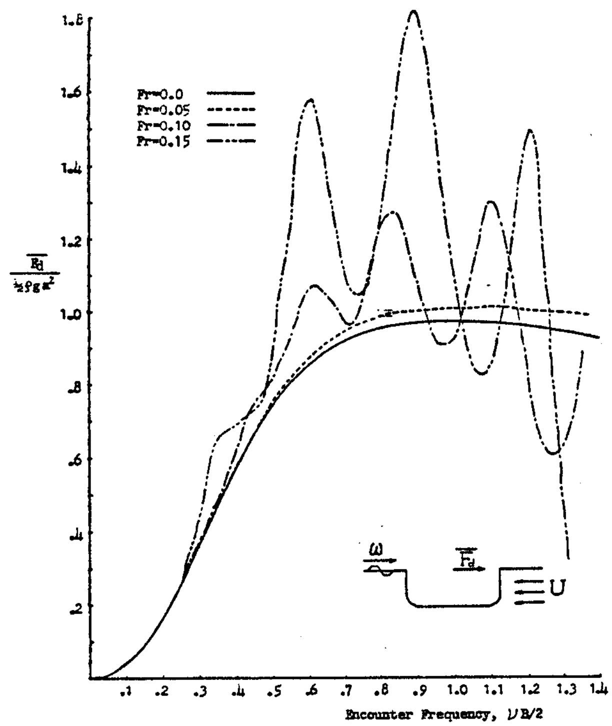

FIG. 5a MEAN LATERAL DRIFT FORCE ON RESTRAINED SHIP MODEL (I)

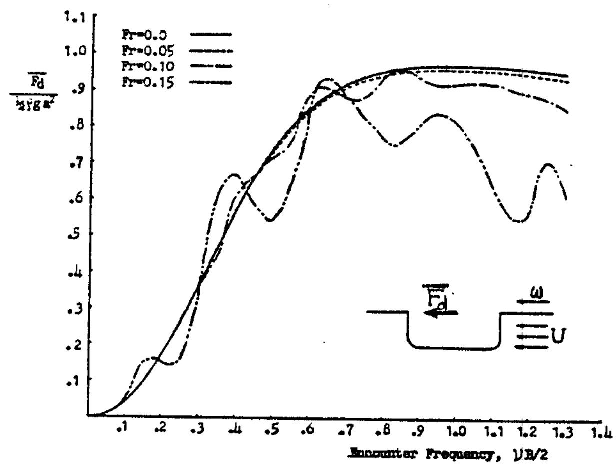

FIG. 5b MEAN LATERAL DRIFT FORCE ON RESTRAINED SHIP MODEL (II)

Discussion

Evans: Since you have two small parameters, the wave slope of the incoming wave and the current speed U, in some sense, presumably you have made some perturbation expansion in these two small quantities, choosing a balance between them which results in the equations you use.

S.C. Lee: Yes, exactly. I have four waves, one from upstream and 3 from downstream.

Newman: There is a power series expansion given in Haskind's original paper. Did you use this expansion or did you use the exact Green function? This problem seems to be well-posed for a submerged body. A surface piercing body is inherently more difficult to do, as it is analogous to the "Neumann-Kelvin" problem which has been studied by Ursell for the same cylinder. Perhaps this, or numerical problems, are responsible for the oscillations as encounter frequency increases?

S.C. Lee: I used the exact Green function. I used only the small velocity from the current. I have some questions about these fluctuations, but for $F_n = 0.05$, the results are good.