NON-LINEAR ANALYSIS OF OSCILLATING WATER COLOUMNS.

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When a confined volume of fluid is connected to a semi-infinite region by a relatively narrow passage, and a free surface is present in both domains, exitation of resonant behaviour of the fluid in the confined region, due to waves in the outer region is possible. Several examples are given in the literature, some of which are: oscillating water coloumns for wave energy absorbtion, problems related to ships close to a quay, problems with large volume structures situated close to a free surface, moon-pool problems and problems related to ship motion in a side-by-side configuration of offshore loading systems.

In most of the problems indicated above the wave damping due to wave radiation is that small that linear theory predicts unrealisticly large response at resonance. For wave energy devices the resonant behaviour is damped by the energy absorbtion; for the other cases one has to take into account non-linear effects as finite free-surface elevation in the confined region, viscous skin friction and vortex shedding effects to get realistic solutions.

Marthinsen and Vinje (1985) introduced the effects of finite free-surface elevation in the gap between the two ships in a side-by-side offshore loading configuration. In addition skin friction at the vertical walls in the gap was accounted for. They found that the effect of the finite free-surface elevation was far the most important effect of the two introduced. On the other hand, they did not include vortex shedding in connection with the flow at the mouth of the gap between the two ships. This is expected to be the most important visvcous effect, and thus Marthinsen and Vinje's investigation is not conclusive.

In the present paper the two dimensional problem of a vertical flat plate, of finite draft, situated close to a vertical wall is regarded. The region between the plate and the wall forms a confined volume where local resonance may take place.

The formulation of the problem follows closely that of Marthinsen and Vinje (1985), applying the method of matched asymptotic expansions of the solutions in the three domains (as shown on Figure 1):

1) The domain within the gap.

2) The domain in and at the mouth of the gap.

3) The outer, far-field domain.

The exceptions are that the problem will be solved entirely in time domain, the excitation is caused by an incoming sinusoidal wave in the outer far-field and that vortex shedding from the sharp corner of the flat plate is included in the formulation (but not included in the simulations). The inclusion of the vortex shedding effect is done by introducing the single vortex consept of Brown and Michael (1955) (see Graham (1977)). In this model the strength and the position of the vortex are determined from the Kutta condition and a requirement of no net force on the vortex and the branch cut (between the vortex and the sharp corner).

The effect of finite free-surface elevation in the gap is investigated, as well as the effect of skin friction. The response differs significantly from the linear solution even for moderately small incoming waves, and the nonlinear effects act differently for different frequencies. The conditions for getting limit cycles are discussed together with the time history of the surface elevation in the gap when limit cycles are achieved. A qualitative discussion of the effect of the vortex shedding on the solution is given.

REFERENCES:

Marthinsen and Vinje (1985): "Non-Linear Hydrodynamic Interaction in Offshore Loading Systems", 4th BOSS Conference, Delft, July 1985.

Brown and Michael (1955): Nat. Adv. Comm. Aero., Tech. Note 3430.

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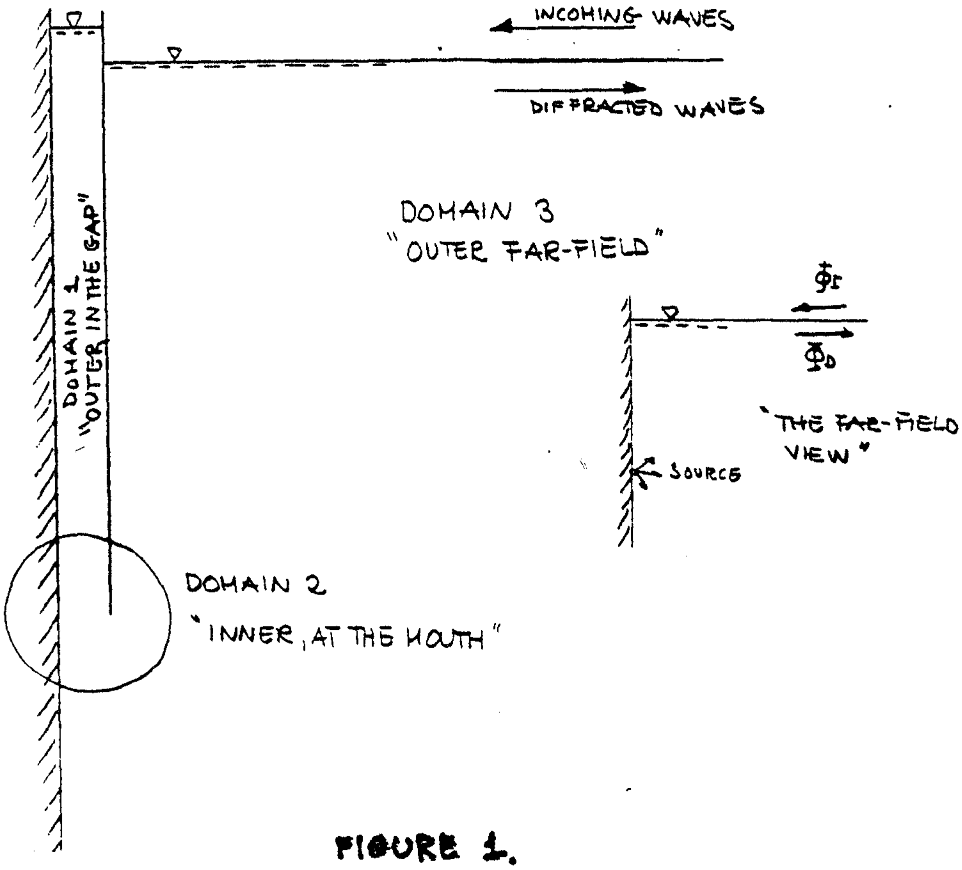

FIGURE 1.

Discussion

X.J. Wu: There exist some useful references in this topic. For example, by Lighthill ("Two-dimensional analysis related to wave energy extraction...", JFM, Vol. 91, 1979) and Knott ("Measure of energy losses in oscillatory flow through a pipe exit", Applied Ocean Research, No. 4, 1980, also Phil. Trans. Roy. Soc., Series A, 294, 1980).

In the case of wave energy devices our model measurements indicate that the effects of the energy transfer machine on the top of the oscillating water column and the vortex shedding around the exit of the column dominate the damping in the water column elevation.