The nonlinear interaction between a free surface potential flow and a submerged cylinder

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The present work studies the interaction of a 2D cylinder with a free surface flow. See Figure 1. The cylinder is entirely submerged, has an arbitrary smooth shape and moves at a prescribed arbitrary path. The flow is a potential flow, over a flat bed, with uniform conditions at both ends, where the surface is flat and the speed is uniform. The surface elevation (η) and uniform velocity (u) at both ends ($\pm\infty$) can take different constant values at each side: $\eta_{-\infty}$, $u_{-\infty}$, η_{∞} and u_{∞}. It is also possible to superimpose a linear shear current (with constant vorticity) to the flow.

For the boundary value problem sketched above we prescribe an initial condition that can either be a wavy or a flat surface.

The subsequent surface movement is solved by a Boundary Integral Method that is essentially that described in (Dold & Peregrine, 1986) with extensions and modifications to allow for the presence of the cylinder and the arbitrary uniform currents at the extremities.

The code has been extensively checked, by comparison with other unsteady codes performing similar functions, and by the use of steady solutions. It is comparatively economic in CPU time.

Several problems have been or are currently been studied:

i) A cylinder in a uniform flow for several sizes and positions of the cylinder and speed of the flow. It has been noticed that the Froude number with respect to the distance between cylinder and free surface is the most relevant parameter in the experiments. A typical example of the computations is shown in Figure 2.

ii) The towing of a weir at the bed of a tank. These experiences have been carried out in connection with investigation of bores appearing upstream a moving obstacle in a channel. We are particularly interested at the results for $F \approx 1$. See Figure 3.

iii) The generation of solitary waves, or wave trains by the movement of the cylinder. Several types of waves can be generated on a free surface by the movement of a cylinder. We have been looking at wave trains generated by the translation of the submerged cylinder over a circular path, with prescribed frequency. It has been noticed that waves can be generated towards only one side depending on the aspect ratio between cylinder radius (r_c) and the radius of the circular movement (r_p). In the cases when this ratio , r_c/r_p, is big, the surface on one of the sides is flat; see Figure 4. The behaviour of the wave trains generated in this way can be subsequently investigated by withdrawing the cylinder; problems like solitary wave generation (just one cicle of revolution) or the modulation in wave trains can be studied and better understood.

In all the problems described above the force history on the cylinder can be found.

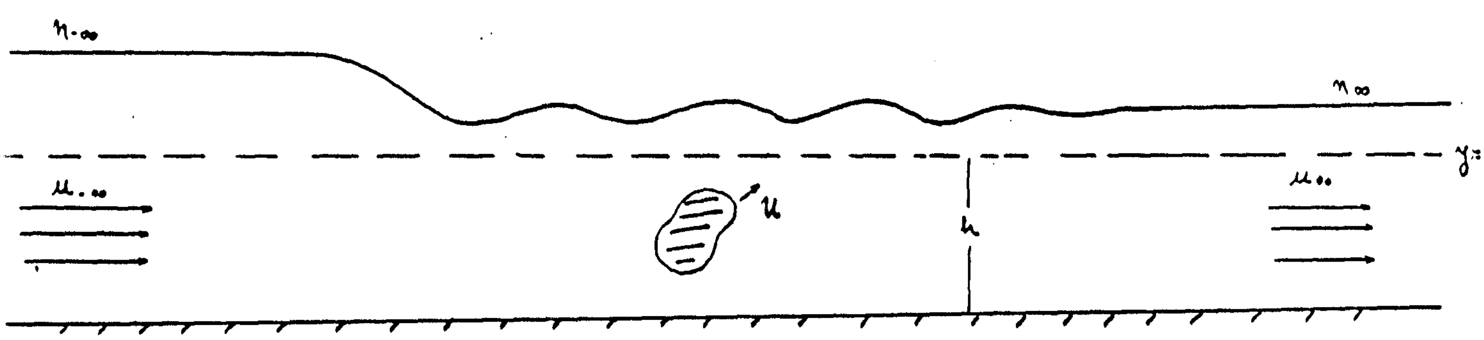


Figure 1. Sketch of the physical problem: $\eta_{-\infty}$ and $u_{-\infty}$ are the elevation and uniform speed upstream; η_∞ and u_∞ are elevation and speed downstream. U is the velocity of the cylinder.

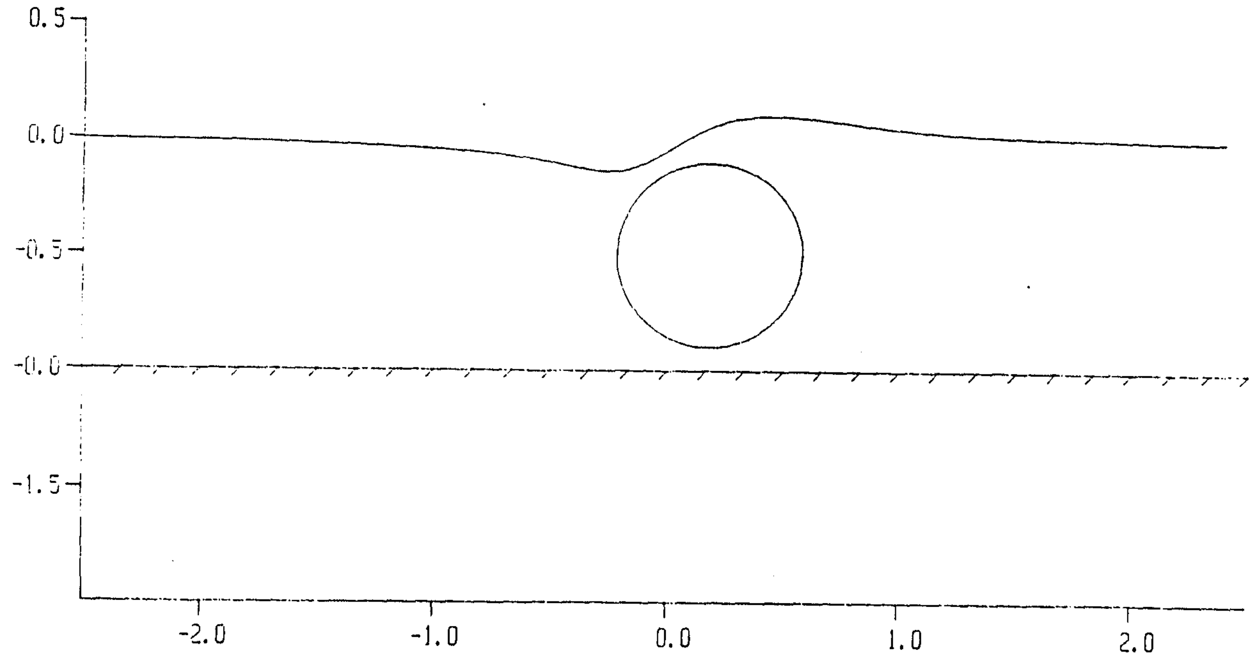


Figure 2. Cylinder stationary in a current, from left to right, speed 1. Depth is 1 and the cylinder has radius 0.4 and when the current started impulsively it was 0.10 distant from the free surface. The figure shows the surface at time 0.18. This is equivalent to impulsive motion of the cylinder in fluid at rest.

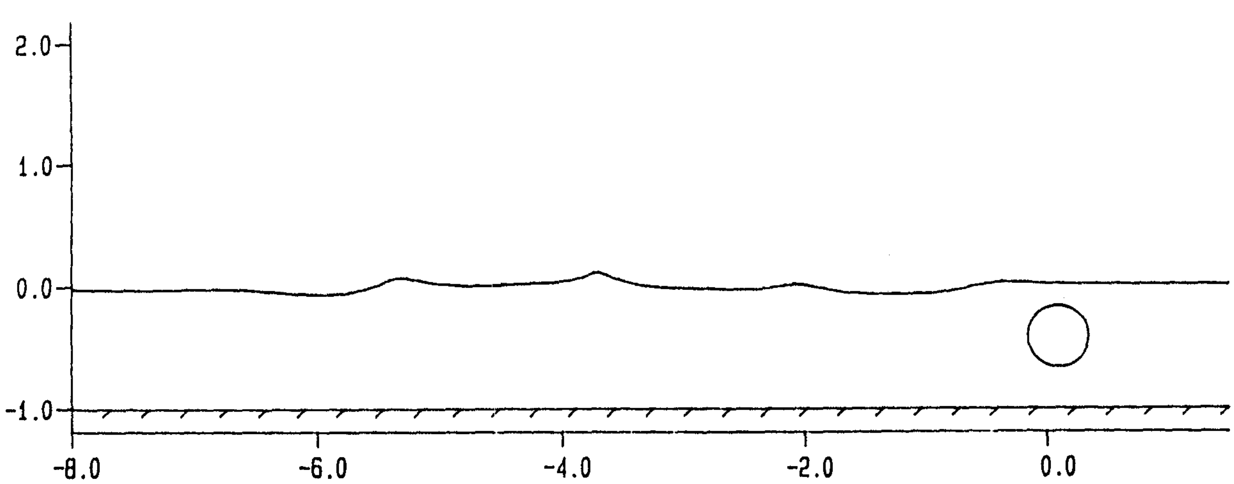
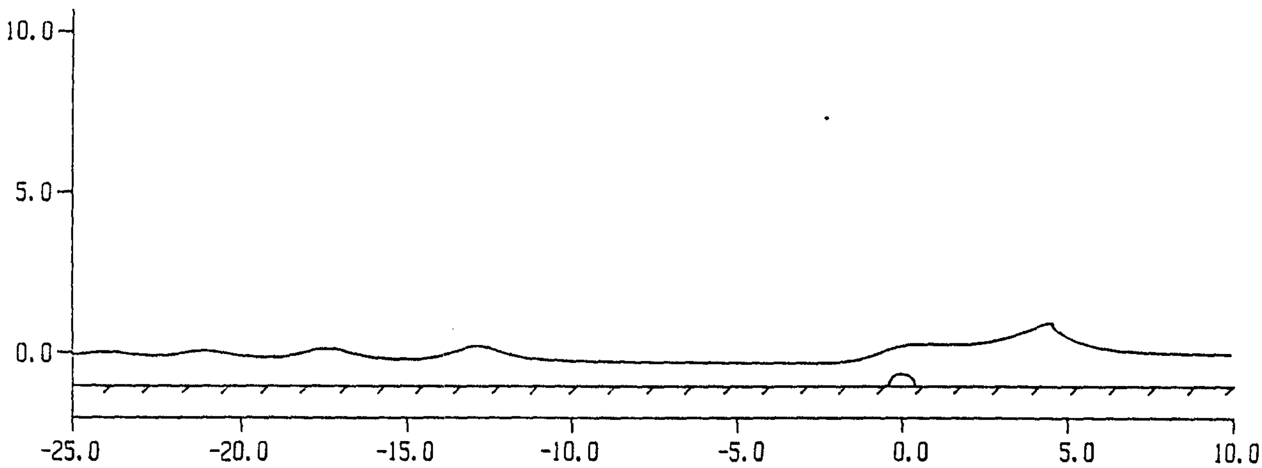


Figure 4. Wave train generated by the circular movement of a cylinder. The cylinder has radius 0.25, moves, anticlockwisely, on a circular path of radius .1 centered at (0,-0.5), with period 2π. The wave train travels towards left, no noticeable waves travels to the right.



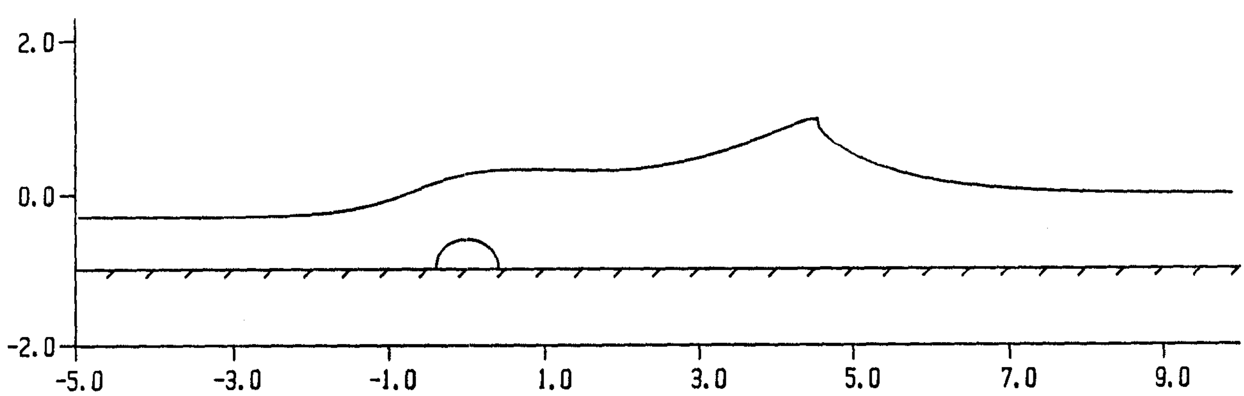


Figure 3. a) Weir of semi-circular shape and radius 0.4 moving with speed 1.1, generating two wave-trains : one upstream that is just breaking and another smoother, undular, downstream from the cylinder.

b) Detail of a).