The spinning dipole: an efficient unsymmetrical numerical wavemaker.

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The simultaneous generation and absorption of waves remain an open problem in physical and in numerical wave tanks as well. Various solutions to the problem of numerical wave absorption alone has been proposed in the past decade. Let us just briefly cite some of them: Orlanski or DtN boundary conditions, numerical beach, mesh stretching, active piston absorber, ... among others.

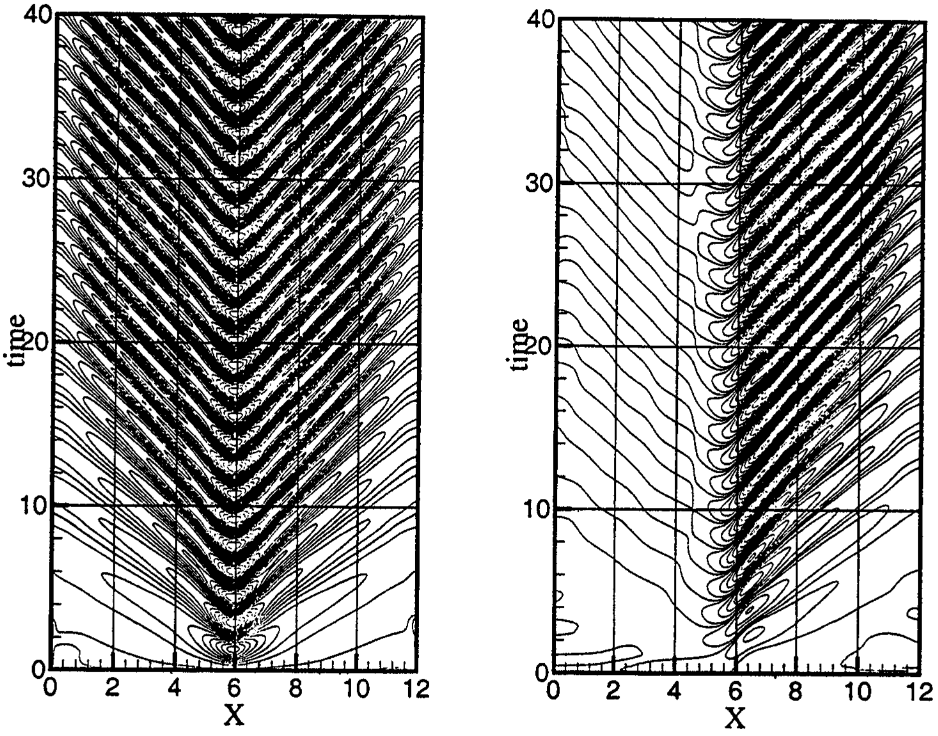
In the 2D numerical wave tank (CANAL) developped in our LMF laboratory since the eighties, a hybrid technique was finally chosen [1]. An active piston wave absorber is coupled to a numerical beach in time-domain fully nonlinear simulations. The main advantage of this hybrid technique is that these two "devices" have complementary bandwith in the frequency domain. The piston is a good (even asymptotically perfect) absorber for the long waves, while the numerical beach of fixed horizontal extent (here 2 times the water depth h) works fine in damping the short waves. When associated in the time-domain, both techniques take advantage of this synergy and very high absorption coefficients are obtained (never less than 93% in the whole frequency range). This technique has proved its efficiency in different applications of our code ([2, 3]), and in other ones [4].

The next challenge was to devise a technique which should be able to simultaneously generate the right wave in the basin, and to absorb spurious waves reflected by the body under testing in the middle of the basin.

Such absorbing wavemakers have been developped as physical wave tank equipments ([5]). They are based on the well known transfer function of the ideal wave-absorber in the frequency domain, in linear potential theory. They have been applied also in numerical time-domain simulations [9], but with the same validity range as in the physical application. Their efficiency as absorber decrease severely in low frequency range due to practical limitations of the physical system (filtering), whereas such limitations does not apply in the numerical applications under consideration.

Here we have the opportunity to separate the wave generation function from the wave absorption function, provided they are able to coexist at the same end of the numerical wave tank. We thus prefer the method of discrete internal singularities proposed by Brorsen and Larsen (1987)[6] (see also [7],[8]).

In this method, a set of discrete sources are added in the fluid domain of the numerical wave tank. Their locations are fixed, and their intensities are determined to approximate the flux accross the vertical surface they are lying on. This method, combined with the coupled piston-beach absorber described above, or equivalently with a combination of sponge layer+Sommerfeld condition give excellent results for combined generation and absorption, even for nonlinear high amplitude waves (see [8]).



(a) pulsating source wavemaker

(b) spinning dipole wavemaker

Figure 1: monochromatic wavemaking by discrete internal singularities. ($\omega\sqrt{h/g} = 2.$)

However, when only fixed internal sources are used as in the references cited above, the wave field is necessarily symmetric with respect to the position of the source(s). Such a wave field is plotted in Fig.1a as a function of time. A unique fixed source of sinusoidal intensity (with a circular frequency of $\omega\sqrt{h/g} = 2.$) is located at the point (6, -.5) in a canal of length 12 (all lengthes being reduced with the constant water depth h). The coupled *piston-beach* wave absorption technique [1] described above is applied at both ends of the basin. No reflections occur on the end walls, as it can be seen. Due to the symmetry of the wave field with respect to the source location, one must imperatively absorbs it on one side of the source in order to use the other side as the incident wave field for the numerical experiment. We shall see now that this can be avoided by using dipoles instead of sources.

Our implementation of the discrete internal singularities method generalizes the Brorsen's technique as used commonly up to now. First we allow for moving singularities, and furthermore we allow any of the three following singular operators: source, vortex, dipole to be used, alone or in any combination of them. The number, position and characteristics of these singularities are freely defined by the user in CANAL. He is therefore able to create a large variety of free surface flows by simply changing the related subroutine.

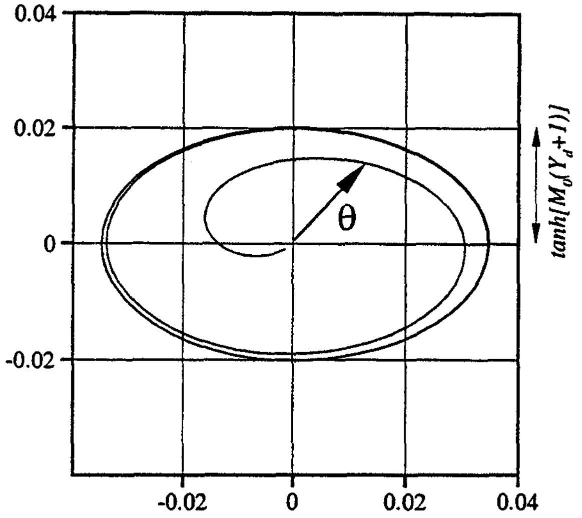


Figure 2: the complex moment of the spinning dipole ($\Omega = 1$, $\lambda/h = 5.237$)

Using this very simple but flexible numerical wavemaker, we have tested a lot of variant which will be presented in more details at the Conference. One of the most interesting among all is what we have named: the *spinning dipole.*

The basic idea is to create a local fluid motion resembling the wave kinematics. In the linear first order Stokes model, the velocity at a given fixed point under the waves is a vector turning at the wave frequency. Hence, instead of a pulsating source as before, let us now introduce a single dipole in the numerical flume. Its location is fixed, but its complex moment is defined by $\mu(t) = m(t)\exp i\theta(t)$ with:

$$\begin{aligned} \tan\theta(t) &= -\frac{\tanh M_0(Y+1)}{\tan\left(M_0X - \Omega t\right)} \\ m(t) &= m_0\left(1 - e^{-\frac{\Omega t}{2}}\right)\sqrt{\sin^2\left(M_0X - \Omega t\right) + \tanh^2 M_0(Y+1)\cos^2\left(M_0X - \Omega t\right)} \end{aligned}$$

in such a way that the end of the complex moment, considered as a vector, describes the trajectory plotted in Fig.2. One can notice the ramp function at the beginning to ensure a smooth transition from the initial state of rest.

It is easy to anticipate that the wave field generated by this dipole in the numerical wave tank will not be symmetric. Such a wave field is plotted in figure 1b with a dipole at the same location than the source Fig.1a, and the same frequency. It can be seen on this figure that the spinning dipole has the remarkable property to generate waves in a single direction only, without disturbing the free-surface on the other side. It is an excellent unsymmetrical numerical wavemaker.

For this reason, it will be prefered to the pulsating source to devise numerical absorbing wavemakers. Because it generates no wave behind, the absorbing system will have to absorb only the waves generated by (e.g) the body under test, preventing the risk of wave breaking by combination of the two wave trains as this can occur when using sources.

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