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Simulations with a 3D Active Absorption Method in a Numerical Wave Tank

Jesper Skourup and Hemming A. Schäffer
ICCH, Danish Hydraulic Institute
Hørsholm, Denmark

ABSTRACT

The absorption of waves along the lateral boundaries of a wave tank is a challenging problem in physical facilities as well as in numerical models. One method applicable to both types of facilities is to use active wave absorption. Active wave absorption using a wavemaker is a well-known technique in wave flume (2D) tests, and the 2D technique can also be used as a quasi-3D absorption method in a numerical wave tank. A recently developed method for 3D active wave absorption in a wave tank using a number of wavemakers for the absorption has been implemented into a numerical wave tank model based on a boundary element formulation. In the present paper some numerical tests are made in order to assess the accuracy of the method. The numerical tests involve absorption of obliquely incident waves on the active wave absorber and simultaneous generation and active absorption of waves in a 3D numerical wave tank. The numerical results show that the 3D active absorption method works as expected and that it is superior to a quasi-3D method (based on a traditional 2D active absorption method).

INTRODUCTION

An efficient modelling of open boundaries is required in physical models as well as in numerical models simulating a wave tank. The open boundaries should be able to absorb all waves impinging on it without noticeable reflection. These waves are either generated by a wavemaker or caused by a moving body in the wave tank (or a combination of the two). Passive absorbers are often modelled in the wave tank, e.g. by using perforated plates in the physical wave tank and by a sponge layer in the numerical wave tank. For obliquely incident waves a sponge layer may cause unwanted refraction into the sponge layer in both physical and numerical models. Another problem is the spurious re-reflection of waves from the wavemaker which is acting as a fully reflecting wall for waves impinging on it. An active absorption method can be applied as an alternative for absorption of obliquely incident waves and for simultaneous wave generation and active absorption.

A method for active absorption of waves in a flume was developed and experimentally verified by Schäffer *et al.* (1994). This method - called the Active Wave Absorption Control System (AWACS) - is based on the use of recursive filters. At each instant (time-step) these filters require as input the measured and the specified elevation at the wave paddle and the positions of the wave paddle. As output it provides the position of the wave paddle at a subsequent time level. This technique was applied by Skourup and Schäffer (1995) in a numerical wave flume model based on a Boundary Element Method (BEM). Here it was shown that the 2D-AWACS works as predicted by the underlying theory. Further numerical tests with the 2D-AWACS were made by Skourup and Schäffer (1997). An extension to a quasi 3D-AWACS method was made by Skourup (1996) using a model based on a 3D BEM. Absorption of oblique waves where the wave propagation direction was known a priori was made in a numerical wave tank in which the waves were generated along one side of the tank and absorbed along another. Schäffer and Skourup (1996) developed an active absorption system which was sensitive to the wave propagation direction by introducing a two-dimensional digital filter in time and space. Using this formulation they showed by numerical experiments that the new so-called 3D-AWACS outperformed the 2D-AWACS for obliquely incident regular waves. In the present paper numerical tests are made with absorption of obliquely incident waves on the active wave absorber, and with simultaneous generation and active absorption of waves in a 3D numerical wave tank.

MATHEMATICAL FORMULATION

A three-dimensional irrotational flow in a homogeneous, incompressible and inviscid fluid is considered. A velocity potential $\phi(\vec{x},t)$ (where $\vec{x}=(x,y,z)$ is a position vector and t is the time) can then be defined and by use of a continuity condition the governing equation for the velocity potential in the fluid domain becomes the Laplace equation

$$\nabla^2\phi = 0 \tag{1}$$

A calculation domain $\Omega(t)$ bounded by a horizontal bottom, Γ_b, a free surface, Γ_f, and a set of vertical boundaries, Γ_{r1}, Γ_{r2}, Γ_{r3} and Γ_{r4}, which truncate the infinite domain is defined as shown in Fig. 1.