A High Order Boundary Element Model for 2D Wave Tank Simulation

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ABSTRACT

A 2D numerical wave tank model based on a Boundary Integral Equa-
tion Method is presented. In order to simulate some non linear phenomena occurring in real tank, boundary conditions are developed to first, second and third orders and the problem is solved in the time domain. Distributions of Rankine singularities are interpolated using high degree polynomials to increase the number of unknowns at each node of the mesh. It is then possible to ensure the continuity of high order derivatives of the potential that arise in right hand sides of second and third orders boundary conditions. Computation of free surface oscillations in a rectangular tank is compared with first and second order analytical solutions. Wiggles that arise with linear distributions on second order free surface intersections with rigid boundaries are significantly reduced when using high degree polynomials. Tests in regular waves have been carried out at the wave tank of the Ecole Centrale de Nantes and some of the measurements have been compared to the numerical results. For moderate wave steepness, results given by the second order model are in good agreement with waves measurements and second order phenomena such as return current due to mass transport, free waves generated by the wavemaker, can be observed. Far from the wavemaker a phase shift appears due to third order nonlinearities which modify the wavelength of the first and second order solutions. As expected the third order model reduces this phase shift but introduces significant error on the wave amplitude because of the secularity of the solution.

KEY WORDS

Numerical Wave Tank, Boundary Element Method, Stokes Waves, Second and Third Order Expansions.

INTRODUCTION

During wave tank experiments some undesirable phenomena occur such as wave reflexion at the end of the tank, natural modes excitation due to wave front propagation, return current due to mass transport or free waves generated by the wavemaker. In order to improve our knowledge of these phenomena and eventually to reduce them a 2D numerical wave tank based on a Boundary Integral Element Method (BIEM) is developed. Non linear approach received a lot of interest and an exhaustive review of existing models and recent progress in numerical wave tank has been given by Kim [1995]. CPU times required for these non linear simulations are generally dissuasive for parametric studies concerning for example the wave absorption condition or the wavemaker motion in order to reduce natural modes excitation or free waves generation. Another approach is to develop the boundary conditions using Taylor series expansions about the mean position of the boundaries to reduce the spatial domain to a time-invariant one. Under the assumption of small wave steepness a perturbation scheme is used to obtain linear boundary conditions and different problems at successive orders are formulated. First order problem is well known and efficient models for 2D and 3D simulations exist but the above phenomena can be described with at least a second order model. A third order model is also of great interest to describe wave propagation far from the wavemaker in a long tank. A third order model has been developed by Büchmann [1995] using linear interpolation of sources and normal dipoles between the nodes of the mesh. Near the free surface and rigid boundaries intersections, difficulties have been shown to calculate the potential and its derivatives. He proposed different correction methods for an accurate estimation of these unknowns using extrapolated values at the intersections or following Otta [1992] with a boundary condition correction method. Another approach presented in this paper is to use higher degree polynomials to increase the number of unknowns at each node of the mesh. It is then possible to ensure the continuity of high degree derivatives of the potential at the nodes. Computation of free surface oscillations in a rectangu-