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ABSORPTION OF WATER WAVES IN A TWO-DIMENSIONAL NUMERICAL FLUME

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Summary. In this work the absorption of water waves in a numerical wave flume is discussed in terms of performance and robustness. A general formulation for the analysis of fluid-structure interaction problems using the Particle Finite Element Method (PFEM)[1] is employed to simulate a numerical wave flume. The implementation of a wave dissipative zone changing the fluid viscosity properties is tested with the goal of absorbing waves reflected by a vertical wall. The accuracy of this method is analyzed testing a set of viscosity distribution inside the dissipative zone using a prototype scale numerical wave flume.

1 INTRODUCTION

In physical and numerical wave flumes used for modelling coastal and offshore phenomena involving waves, incident waves generated by a wavemaker must simulate open ocean conditions as realistically as possible. To ensure these conditions unwanted wave reflection must be avoid. After the wave generation, wave absorber is the most important mechanism in a physical and wave flume.

A common way to absorber waves in physical flumes is to use a dissipative beach with parabolic shape at on end of the flume. In this method wave energy dissipation is obtained inducing wave breaking and can be used in numerical flumes able to simulate wave breaking. This method usually means long wave absorber involving space problems in physical flumes and higher time consumption in numerical flumes.

An advantaged from numerical to physical flumes is the possibility to easily simulate wave propagation in fluids with different physical properties. In this work the dissipation of wave energy due to the passage of waves through a viscous medium is studied.

The layout of the paper is the following: in the next two sections a brief presentation of the PFEM formulation is made and the wave absorber by viscous medium technical is present. Next a set of numerical tests and some results are presented. Then the results are discussed. Finally some conclusions about wave viscosity absorber performance and robustness are presented.

2 THE PARTICLE FINITE ELEMENTH METHOD (PFEM)

The PFEM is a well spread out method in literature[1]. However, some important key features of the PFEM are listed:

- The data between two consecutive time steps is only transferred through nodes, because elements are created again at every time step by the re-meshing process with new conectivities.
- The velocity of every node of the mesh is the same as the velocity of the fluid -or solid- at that point, but every node can have a particular density, viscosity, etc.
- A solid object node is treated exactly as a fluid node, in terms of meshing and data structure but not in terms of calculation. It is known as part of a solid thanks to some ‘flags’ on it, and its velocity is calculated independently from that of the fluid.
- With the capacity of PFEM formulations to simulate solid-fluid interaction the generation of regular and irregular waves by means of different wavemakers types is possible[2]. The wavemakers in the numerical model are simulated by means of solid bodies located at one end of the flume and moving according to the transfer functions, the same ones used in physical hydraulic flumes to determine the wavemaker movement.

3 WAVE VISCOSITY ABSORPTION CONCEPT

The energy dissipated by a wave propagating in a fluid depends on fluid viscosity. Based on this physical principle, we can dissipate energy artificially forcing a wave to pass through a fluid more viscous that one where we want to study the wave action.

4 NUMERICAL TESTS DESCRIPTION AND RESULTS

A numerical prototype scale flume with a 15m constant water depth and 250m length was simulated with PFEM. A regular wave 1.25m height and 6.93s was generated using a numerical piston paddle located at the left end of the flume (see Figure 1). The paddle movement was determined using the first order wavemaker theory. In the side opposite to the wave generation zone a vertical wall 22m height was simulation. The maximum time step used during the simulations was 0.02s and the nodal distance 0.50m corresponding to 17520 initial nodes.

For the same regular wave six different viscosity distributions were tested at the right end side of the flume. These are denoted in this work as case 1, 2, 3, 4, 5, and 6. In Figure 1 the viscosity distribution for the six cases tested is show. In Case 1 a constant viscosity value of

$1\text{x}10^{-3}$ kg/m.s were considered in all flume. From case 2 to case 6 a constant viscosity value of $1\text{x}10^{-3}$ kg/m.s were considered only in the firsts 200m of the flume. For these cases the viscosity increases exponentially from an initial value until $1\text{x}10^{7}$ kg/m.s in the lasts 50m of the flume. From case 2 to 6 the initial values are in kg/m.s $1\text{x}10^{-3}$, $1\text{x}10^{2}$, $1\text{x}10^{4}$, $1\text{x}10^{5}$, $1\text{x}10^{6}$, respectively.

Numerical results are presented in Figures 2 and 3. In Figure 2a) the free surface evolution 150m far from the wavemaker for the six cases is presented. The same kind of results are show in Figure 2b) but that time at 240m far from the wavemaker. The velocity distribution in all flume 100s after the beginning of simulation for the six cases tested are presented in Figure 2c).

In Figure 3 the numerical free surface obtained 150m far from the wavemaker for case 1 and case 4, is compared with the theoretical free surface given by 5th Stokes wave theory for the simulation conditions.

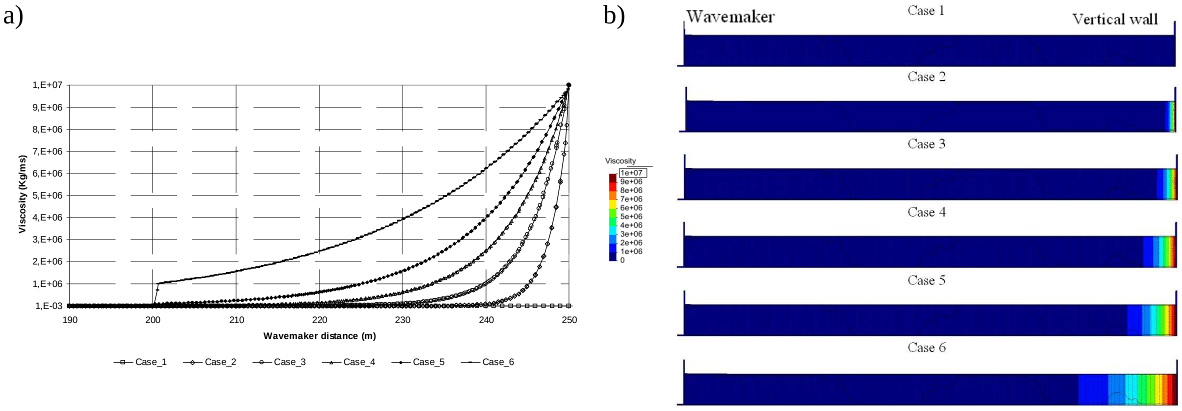

Figure 1: Viscosity distribution a) horizontal profile along the flume b) all flume

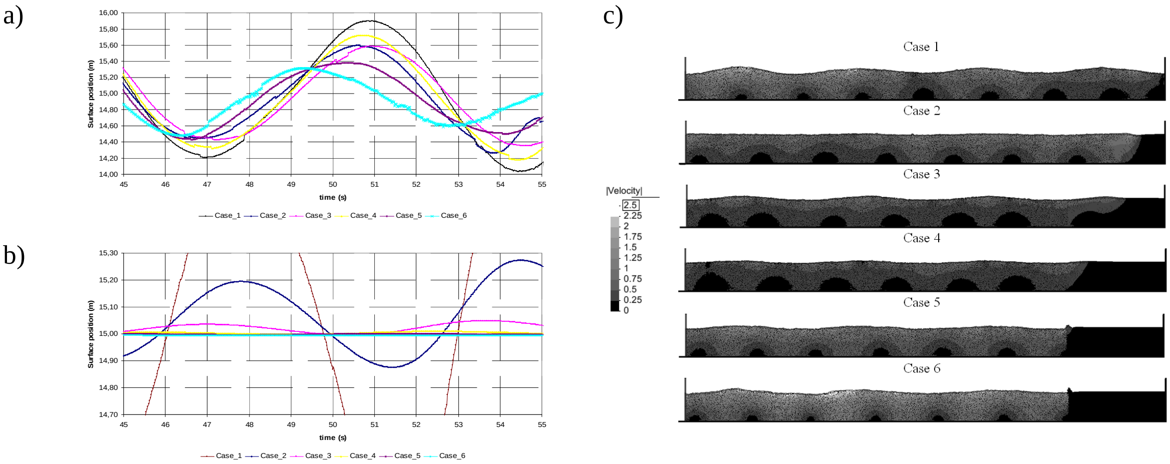

Figure 2: Free surface evolution at a) 150m b) 240m far from the wavemaker. c) velocity (m/s) distribution 100s after the beginning of simulation.

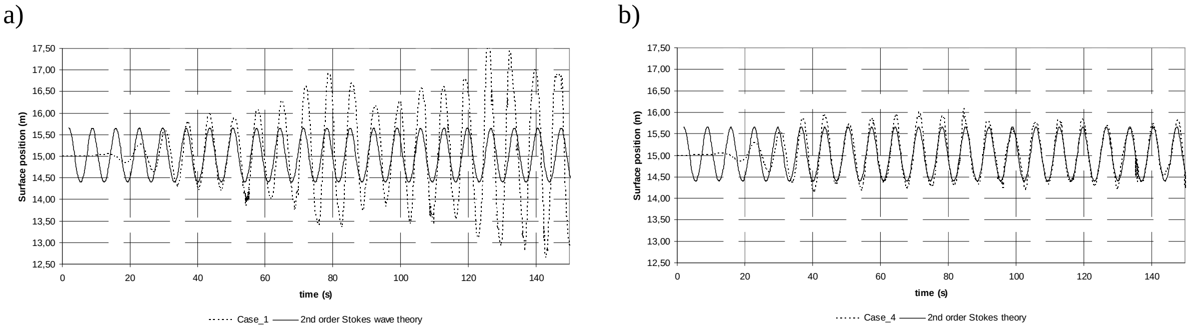

Figure 3: Comparison between numerical and theoretical free surface. a) case 1 b) case 4

5 DISCUSIONS

Observing Figure 2 a) and b) we can see that wave height differ from case to case outside and inside the dissipative zone. Analysing Figure 2 c) is possible to see that for cases 1, 2 and 3 higher velocity values can be found near the vertical wall and in cases 5 and 6 the dissipative zone works like a reflective wall.

As it seen in Figure 3 a) after 60s the numerical free surface starts to be far from theoretical values. On other hand the numerical free surface in Figure 3 b) are in a good agreement with theoretical values during the 150s of simulation. This means that in case 4 the wave reflection verified in case 1 due to the presence of the vertical wall was eliminated.

4 CONCLUSIONS

In numerical flumes based on PFEM formulation wave absorption can be obtained induced waves go through fluids with different viscosities. The accuracy of this method depends on the viscosity distribution in the dissipative zone. Small viscosity values can be insufficient to absorb reflected waves. High viscosity values can induce reflection working the fluid like a wall. In future work the influence of wave height, wave period and dissipative zone length must be studied.

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