LABORATORY EXPERIMENTS AND SPH MODELLING OF REGULAR BREAKING WAVES

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INTRODUCTION

The Smoothed Particle Hydrodynamics (SPH) is a lagrangian mesh-free particle model which was introduced by Gingold and Monaghan (1977) in the field of astrophysics. For thirty years SPH has been a major numerical tool in studies on the evolution of galaxies, galactic collisions, and bolid impact. Since its introduction, it has been modified for use in solid mechanics (such as impact problems), and fluid mechanics. Monaghan (1994) showed that SPH could be used for free surface flows and it has the advantage that no special treatment is needed at the free surface and thus there are no imposed boundary conditions.

The present paper presents the modelling of the propagation of regular and breaking waves using the SPH approach. It is applied to the modelling of water waves generated in the wave flume of the Water Engineering and Chemistry Department laboratory of Bari Technical University (Italy). The comparison with physical model tests shows satisfactory agreements between the simulated and the experimental observed wave motions.

ABSTRACT

The Smoothed Particle Hydrodynamics (SPH) is a relatively new method for examining the propagation of linear and breaking waves. The development of the SPH model is still ongoing and the numerical model results require further analysis and detailed comparison with other numerical models and experimental data. Comparisons with physical model runs demonstrate the potential uses of SPH as an engineering tool. The implemented numerical code was first tested using physical experiments on wave motion fields by Mossa and De Serio (2006).

The experiments were performed in a wave channel 45 m long and 1 m wide located in the Water Engineering and Chemistry Department laboratory of Bari Technical University (Italy).The iron frames supporting its crystal walls are numbered from the shoreline up to the wavemaker (section 100), thus locating measurement sections which have a center to center distance equal to 0.44 m. From the wave paddle to section 73 the flume has a flat bottom, while from section 73 up to the shoreline it has a 1/20 sloped wooden bottom. A sketch of the wave flume is shown in Fig. 1.

Further details about the experimental tests carried out can be found in De Serio and Mossa (2006).

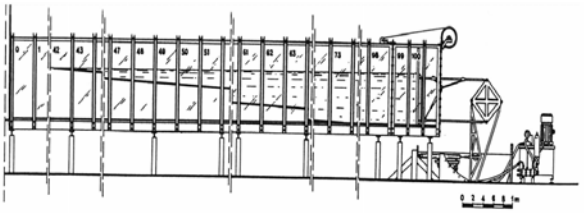

Figure 1. Sketch of the wave flume

The simulations in the present paper used an artificial viscosity, following Monaghan (1992). However, there were some difficulties in establishing the correct value of the fluid viscosity.

The empirical coefficient α, used in artificial viscosity (Monaghan, 1992), is needed for numerical stability in free-surface flows, but in practice it could be too dissipative. The artificial viscosity term becomes particularly strong and is characterised by large number of particles which results in too much damping. Several improvements that we have made in the same fluid viscosity with different numbers of particles are presented here.

Particles were initially placed on a staggered grid with zero initial velocity. Each wall in the tank was built with two parallel layers of fixed boundary particles placed in a staggered manner described by Dalrymple and Knio (2000). In this approach the boundary particles share some of the properties of the fluid particles, but their velocities are zero and their positions remain unchanged.

The initial particle spacing is taken as $\Delta x = \Delta z = 0.022\,\text{m}$ and thus approximately 30,000 particles are used. A smoothing length of $h = 0.0286\,\text{m}$ was considered in these simulations.

The choice of initial particles spacing $\Delta x = \Delta z$ depends on the physical process of the problem and the desired computational accuracy and efficiency. For a comparison between computational accuracies, we used other particle spacing $\Delta x = \Delta z = 0.019\,\mathrm{m}$ and $\Delta x = \Delta z = 0.024\,\mathrm{m}$ and, thus, approximately 40,000 particles with a smoothing length of $h = 0.024\,\mathrm{m}$ and 20,000 particles with a smoothing length of $h = 0.031\,\mathrm{m}$ were used (Table 1).

Table 1 - Characteristics of SPH simulations

Test	**Time simulation [s]**	**Coefficient in the artificial viscosity (α)**	**Particle number**
1	20	0.055	20,000
2	20	0.055	30,000
3	20	0.055	40,000

In all three simulations, the water depth, the wave height and the period were equal to 0.70 m, 0.11 m and 2 s, respectively, in section 0.5 m offshore the section 76 (Fig. 2).

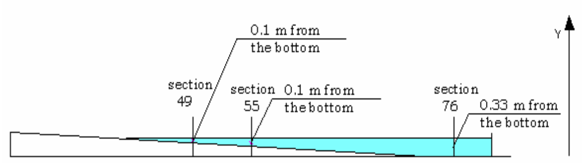

Figure 2. Measurement sections.

The study made particular reference to the velocity and free surface elevation distributions with the aim of analysing the fluid viscosity and the number of particles in terms of stability and dissipation in the fluid. The final model is shown to be able to reproduce the experimental propagation of regular and breaking waves.

CONCLUSION

The importance of experimental measurements is highlighted in order to calibrate and quantitatively validate the SPH numerical model. The choice of initial particle spacing $\Delta x = \Delta z$ and the empirical coefficient α depends on the physical process of the problem and the desired computational accuracy and efficiency. The artificial viscosity term, which depends on the α–parameter, becomes extremely strong with very large numbers of particles. Therefore, no matter what artificial viscosity term is selected, the model results depend strongly on the values of $\Delta x = \Delta z$ and as a consequence, on the particle numbers. In the runs of the present paper (Table 1), we observed that the cases with the higher (40,000) and lower (20,000) number of particles revealed that the numerical wave height was not in good agreement with the experimental ones (Fig. 3).

The same figures indicate that the results with 30,000 particles show a better reproduction of the experimental values.

These results highlight the fact that, for a certain value of artificial viscosity, it is important to define and use a correct number of particles in the model.

Therefore, generally speaking, an appropriate number of particles should be used for a settled value of α and consequently that of the artificial viscosity.

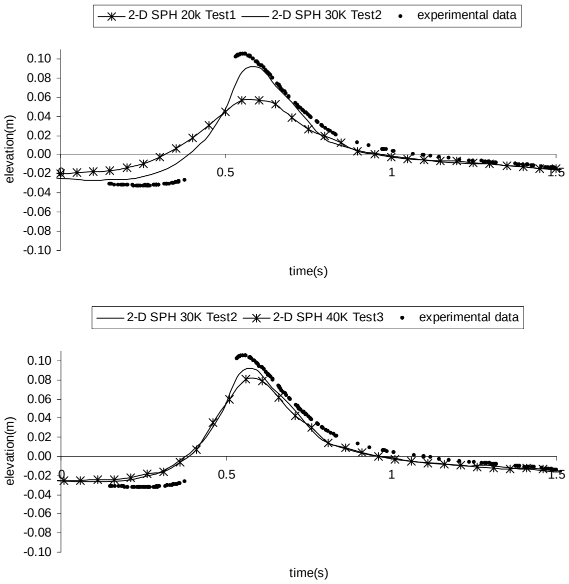

Figure 3. Comparison of 2-D SPH with experimental data (section 49)

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