SPH energy balance during the generation and propagation of gravity waves

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Abstract: Recently, different works regarding the energy conservation properties of the SPH model have been presented. For example, Antuono et al. [1] analyzed the energy balance in the SPH scheme when a diffusive correction is used in the continuity equation for improving the stability of the scheme. In Cercos-Pita et al. [2] the energy conservation analysis has been extended to the case of moving solid boundaries when the flow is dominated by the viscous effects. In the present work, a further investigation on the energy conservation is discussed for problems where moving solid boundaries interact with an inviscid flow. The solid boundary techniques adopted are: the ghost and the fixed ghost particles. A first problem in which the dynamic is generated by a water patch falling into a still water tank is analyzed. In this case, the dissipation processes due to the diffusive and viscous numerical corrections are investigated. Then, a problem of relevant interest in coastal engineering field, concerning the wave generation and propagation in a wave flume, is studied. Two limit cases are analyzed, the first one is a wave flume with a flat bottom and a vertical wall, representative of a wave reflective condition (Fig. 1a), while the second one is a sloping bottom flume, representative of a wave absorbing condition (Fig. 1b).

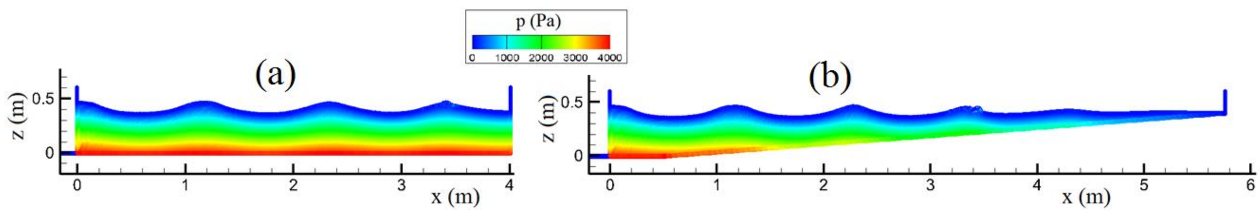

Figure 1: Waves propagation with pressure field for the analyzed cases: in (a) is the wave reflective condition, while in (b) is the wave absorbing one.

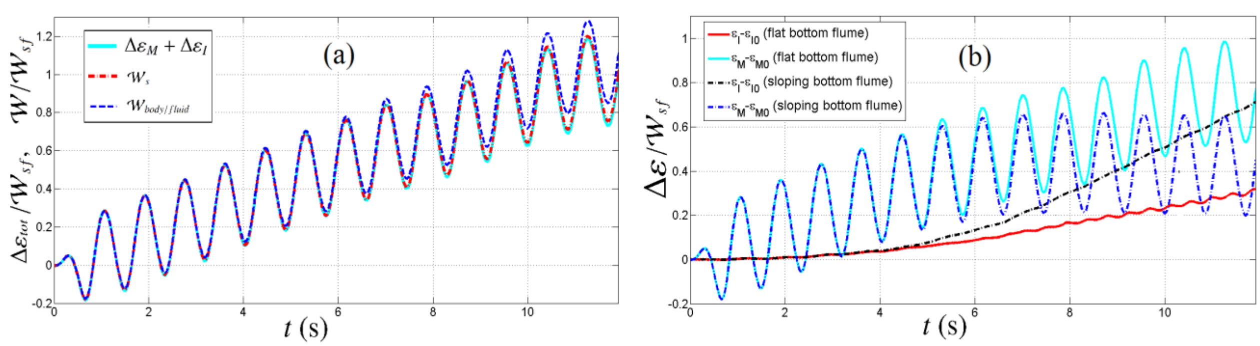

Figure 2: (a) Nominal work, $W_{\text{body/fluid}}$, effective work, W_S, made by the solid boundaries in comparison with the total energy evaluated inside the fluid domain, $\Delta\varepsilon_M + \Delta\varepsilon_I$. (b) Comparison of mechanical and internal energies variations for the flat and sloping bottom flume.

The wave generation is studied considering the work made by the solid boundary on the fluid mass. The nominal work, $W_{\text{solid/fluid}}$, and actual work, W S , are analyzed through a convergence analysis, showing that when the spatial resolution is increased $W_S \to W_{\text{solid/fluid}}$. These results are presented in Fig. 2a, in which it is possible to see that, according with the second law of thermodynamics, W_S equals the variation of total energy (mechanical+internal) evaluated inside the fluid domain $\Delta\varepsilon_{tot} = \Delta\varepsilon_M + \Delta\varepsilon_I$ (being $\Delta\varepsilon = \varepsilon - \varepsilon_0$ with ε_0 the initial energy), while at the same time it underestimates the nominal work performed by the wave-maker. Successively, the dynamics of the wave propagation is analysed from an energy viewpoint, by inspecting the single energy components, namely the potential, kinetic, compressible and numerical-dissipated energies, evaluated inside the fluid domain. Fig. 2b presents the comparison of the time evolution of mechanical, $\Delta\varepsilon_M$, and internal energies, $\Delta\varepsilon_I$, for the reflective and non-reflective cases. Because of the development of breaking waves, in the latter case the mechanical energy reaches quickly a stable condition with oscillations around a constant value.

References

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[2] JL Cercos-Pita, M Antuono, A Colagrossi, and A Souto-Iglesias. Sph energy conservation for fluid–solid interactions. *Computer Methods in Applied Mechanics and Engineering*, 317:771–791, 2017.