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Foreword: SPH for free-surface flows

MONCHO GOMEZ-GESTEIRA, *EPHYSLAB (Environmental Physics Laboratory), University of Vigo, Spain. E-mail: mggesteira@uvigo.es*

BENEDICT D. ROGERS, *University of Manchester, UK. E-mail: benedict.rogers@manchester.ac.uk*

DAMIEN VIOLEAU, *Saint-Venant Laboratory for Hydraulics - Université Paris-Est, Joint Research Unit EDF R&D/CETMEF/Ecole des Ponts, France. E-mail: damien.violeau@edf.fr*

JOSE MARIA GRASSA, *CEDEX, Spain. E-mail: Jose.M.Grassa@cedex.es*

ALEX J.C. CRESPO, *EPHYSLAB (Environmental Physics Laboratory), University of Vigo, Spain; University of Manchester, UK. E-mail: alexbexe@uvigo.es*

Smoothed Particle Hydrodynamics (SPH) is a mesh-free Lagrangian method created in the seventies for simulating astrophysical problems (Lucy 1977, Gingold and Monaghan 1977), and has been used in numerous fields during the last three decades. For a detailed description of the method the reader is referred to Monaghan (1992), Monaghan (2005) and Liu and Liu (2003). In the particular case of fluid dynamics, the first attempt to apply the method to free-surface flows was carried out by Monaghan (1994) where importantly it was realised that in contrast to other CFD methods, SPH required no explicit treatment of the free surface. More than a decade later, the method has reached a maturity that allows the quantitative comparison of the numerical experiments with laboratory tests showing a high level of accuracy. This level of maturity is not only reflected in the increasing number of research papers, but also by the creation of international groups to promote new developments in the technique. Special mention should be given to the SPH European Research Interest Community, affectionately known as SPHERIC (http://wiki.manchester.ac.uk/spheric) which fosters scientists from four continents and serves to create synergies among research groups working on SPH and collaborating in the information exchange between academia, science and industry.

The present Special Issue compiles a set of research papers showing different developments of SPH techniques and providing the reader with an overall view of the method and its applications in problems involving free-surface flows. In particular, Gomez-Gesteira *et al.* (2010) present the state-of-the-art of classical SPH for free-surface flows, especially for dam break problems showing the high accuracy reached for the model both for 2D and 3D applications.

The SPH methodology is applied to different topics in this issue, wave generation by submarine landslides (Capone *et al*. 2010); sloshing problems (Colagrossi *et al.* 2010, Bulian *et al*. 2010); wave propagation and flooding (De Leffe *et al*. 2010, Narayanaswamy *et al*. 2010); wave interaction with structures and solids (Groenenboom and Cartwright 2010, Hérault *et al*. 2010, Lee *et al*. 2010, Marongiu *et al*. 2010, Maruzewsky *et al*. 2010, Rogers *et al*. 2010) and hydraulic jumps (López *et al*. 2010).

Different modifications have been considered to improve the accuracy and completeness of classical SPH version. Here, some authors examine alternative formulations to analyze different phenomena. Thus, the movement of a caisson breakwater is studied by Rogers *et al*. (2010), replacing the conventional SPH formulation by an alternative that solves a Riemann problem between each particle pair. This approach is also considered by (Marongiu *et al*. 2010) to simulate free-surface flows encountered in Pelton turbines. Other authors, Colagrossi *et al*. (2010) use an improved SPH method (CSPH) to study sloshing wave impacts.

There is an increasing interest in multiphase SPH, where different fluids, usually air and water, are considered. Here, Capone *et al*. (2010) study wave generation by underwater landslides, where the landslide is modeled as a non-Newtonian fluid.

There is an ongoing debate among the SPH community about the different approaches to treat the compressibility of the fluid in free-surface problems. Thus, the use of a weakly-compressible version (WCSPH) or a fully incompressible version (ISPH) has been compared by different authors (Lee *et al*. 2008). In this issue, Hughes and Graham (2010) compare both approaches arriving at the conclusion that the somewhat simpler WCSPH performs, at least, as well as ISPH and in some respects even better. This is in apparent contradiction with results provided by Lee *et al*. (2010) who simulated 3D water collapse and affirm that ISPH is superior to predict the total strength exerted on the obstacle. This clearly proves that additional research should be conducted to elucidate the pros and cons of the different approaches.

Another open question in SPH is the viscosity treatment. This issue is considered by Lopez *et al*. (2010) who analyze hydraulic jumps using different approaches ranging from the basic artificial viscosity proposed by Monaghan (1992) to k-ε models with a higher computational cost. As an alternative, the authors propose an intermediate approach where the viscosity depends on vorticity.

The capabilities of the SPH methodology can be improved by hybridizing SPH models with classical models. On the one hand, SPH can be coupled to some other methods to provide a better description of the phenomenon under study, especially when analyzing the interaction between water and structures. Thus, Groenenboom and Cartwright (2010) present a hybrid model to study fluid-structure interaction, where the fluid dynamics is described by a SPH model and the structure response by a model based on Finite Elements. Other authors (Marongiu *et al*. 2010) use a hybrid SPH-ALE (Arbitrary Lagrangian-Eulerian) method to analyze surface flows in Pelton turbines. In particular, a boundary treatment based on upwinding fluid information at the boundary surface is settled. Hybrid models can be also be used to speed up calculations, especially when considering large domains where the dominant physical forcing depends on the morphology of the different areas. Thus, Narayanaswamy *et al*. (2010), study coastal wave propagation by coupling a 2D SPH model (SPHysics) and a 1D Boussinesq model (FUNWAVE). The resulting hybrid model (FUN-SPHYSICS) shows an accurate two-way information transfer between both domains.

Finally, one of the main drawbacks of the methodology is its high computational cost when used in 3D applications, especially when a fine spatial description is pursued. This limitation can be partially alleviated by using parallel (Maruzewski *et al*. 2010; Lee *et al.* 2010) and GPU (Herault *et al*. 2010) computing. Maruzewski *et al*. (2010) describe the impact of rigid solids on water using a parallel SPH model involving 8,192 cores. A similar approach, although at a lesser extent, is carried out by Lee *et al*. (2010) who run a parallelized version of their WCSPH on 16 processors. On the other hand, results presented by Hérault *et al.* (2010) show that computations can be speeded up in about two orders of magnitude when running SPH on GPUs (Graphic Processor Units). Although SPH is mostly employed in the context of Navier–Stokes equations, the powerful SPH interpolation approach may be used for other specialized equations for continuous media, such as shallow water equations (De Leffe *et al*. 2010), also in this issue. This approach is especially well suited to describe flooding over complex geometries, where the 3D nature of the flow is not the main issue.

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