# SPHERIC newsletter

19th issue – January 2015

*SPH European Research Interest Community*

http://wiki.manchester.ac.uk/spheric/

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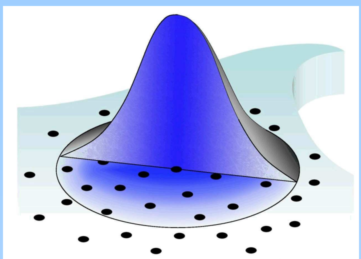



## *Editorial: 10th anniversary SPHERIC workshop*

The 10th international workshop organized by the Smoothed Particle Hydrodynamics European Research Interest Community will be the major event of 2015 in the SPH research field. It will be held in Parma (Italy) from the 16th to 18th June 2015. It will be preceded by a training day (June 15th).

The aim of the workshop is to promote knowledge on SPH research, by focusing on new developments and advanced applications of the SPH method. Hence, the main purposes of the conference are:

- to share SPH experience and developments;
- to create a worldwide and cooperative spirit between SPH researchers;
- to encourage exposure for PhD students in the early stage of their career.

The workshop will cover a wide range of topics in the SPH research, including:

- Computational modelling
- Theoretical and Numerical Aspects (with particular attention to SPHERIC Grand Challenges)
- High-Performance Computing and Hardware acceleration
- Alternative formulations and Particle-Based Simulation Technique
- Hydraulic Applications
- Maritime and Naval Architecture Applications
- Process Engineering
- Geotechnical Applications
- Micro Fluidics, Astrophysics
- Solids and Fracture Mechanics
- Biomechanics
- Disaster Simulations

(*continued next page*)

To celebrate the 10th edition, the Joe Monaghan Prize will be awarded during the workshop to the researchers who made outstanding advances in one or more SPHERIC Grand Challenges. Moreover, the Libersky student prize will be awarded to the best student contribution. A book of proceedings and a PDF version on a USB stick will be delivered to participants during the workshop.

Parma is an elegant city located in the heart of the food valley. It is a vital town where art, music, literature, history, traditions and good life are strictly linked together by a refined atmosphere that can only be breathed in a 'petite capitale'.

Besides the historical centre, the surroundings of Parma are scattered with castles built by noble families between the 14th and the 15th century: a visit to food museums in the countryside unravels the secrets and the history of the worldwide famous gastronomy products (Parmigiano Reggiano cheese, Parma Ham, Salame, Tomato and pasta). The beauty of the landscape and the cultural heritage are the right ingredients to make a visit in the territory of Parma a lovely experience.

Additional information (registration and accomodation, abstract submission and templates, scientific commit-tees, scientific and social program) can be found on the workshop website (see below).

Important dates to remember:

- 13 February 2015 – Abstract Submission
- 13 March – Announcement of Selected Abstracts
- 6 April – Early Registration Deadline
- 27 April – Final Paper Submission
- 15 June – Training Day
- 16–18 June – Workshop

For further information, check:

http://www.spheric2015.unipr.it/

Welcome to Parma.

*Renato Vacondio*
*chair of the Local Organizing Committee*

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## *Coming workshops on SPH and meshfree methods*

Two events will soon be organized on SPH and other meshfree methods. They are briefly introduced below.

### *24th International Conference on Discrete Simulation of Fluid Dynamics*

*13th–17th July 2015, Edinburgh, Scotland*


Topics emphasised at these meetings include lattice Boltzmann schemes, dissipative particle dynamics, smoothed-particle hydrodynamics, direct simulation Monte Carlo, molecular dynamics, quantum Monte Carlo methods, multiparticle collision dynamics and hybrid methods. There will be sessions on advances in both theory and computation, on engineering applications of discrete fluid algorithms, and on fundamental issues in mathematical modelling, numerical analysis, statistical mechanics, kinetic theory and hydrodynamics and their applications in microscopic, nanoscale and multiscale physics for emerging technologies. Other topics of interest include theoretical and experimental work on interfacial phenomena, droplets, free-surface flow, and micro- and nanofluidics.
http://www.dsfd2015.ed.ac.uk/home

### *36th IAHR World Congress*

*28th June – 3rd July 2015, The Hague, the Netherlands*

This is a biennial worldwide event on hydraulics. The 36th IAHR World Congress will provide special emphasis on cross-cutting themes related to Deltas of the Future, looking at what happens upstream, linking hydro-environment research to engineering practice, and reaching out to the developing world. Other conference topics will be Hydro-environment, Sediment management, Water engineering, Flood risk, Hydroinformatics, Extreme events, etc.

During the conference, a double session on SPH and meshfree methods will be organised by D. Violeau (12 oral presentations & papers). Abstract submission is closed, but attendees are welcome to register!
http://www.iahr2015.info/

## AQUAgpusph: A free SPH software accelerated with OpenCL

***J.-L. Cercos-Pita***, *Technical University of Madrid (UPM), Naval Architecture Faculty (ETSIN).*

AQUAgpusph, a new free SPH solver, licensed under GPLv3, and accelerated with OpenCL, has been recently released. The source code along with developers' documentation, a gallery of images, videos, validation cases and a news blog, is available for downloading at http://canal.etsin.upm.es/aquagpusph/.

An application of the solver to modelling of the sloshing flow inside a Lead-cooled Fast Nuclear Reactor during an earthquake (see Figure 1), focusing on the evaluation of the loads caused by the fluid on the structure, is documented by Cercos-Pita (2015). In the same reference, a performance comparison with two other main available GPU-accelerated SPH codes is also provided.

The code can be compared with existing free GPU-accelerated alternatives, namely the CUDA-based GPUSPH and DualSPHysics codes. The main features of AQUAgpusph are as follows:

1) AQUAgpusph is highly modifiable,

2) AQUAgpusph is accelerated with OpenCL,

3) Most commonly used boundary conditions have been implemented, including boundary integrals,

4) AQUAgpusph is Python extensible, which allows users to customize and couple solid body motions.

All the differential operator computation and the time integration is performed on the server side, which is the part of the code that is executed using OpenCL to accelerate the process.

The key features that led to the use of the OpenCL instead of other alternatives like CUDA, OpenMP or MPI (all successfully used in other SPH implementations), can be summarized in the following list:

1) More powerful devices at lower costs: Using the CUDA framework, only NVidia devices can be used, while with OpenCL other vendors' devices can be applied, that may result in a really significant cost difference. Actually, AMD commercializes graphic devices that are approximately 50% more powerful and 50% less expensive than the NVidia ones. Costs and processing differences are really volatile, being dependant on the general TIC market, but illustrate the importance of not restricting your developments to a unique vendor.

2) Hardware diversification: OpenCL is not restricted to GPUs, CPUs, or IBM Cell architecture, but is able to deal with all of them. This feature must be taken into consideration when a framework is selected, not only because the architecture may not be the best one, but also because OpenCL is likely easier to adapt to new architectures that will be created in the future. Other SPH developments require 3 different versions of the software: a serial CPU version, a parallel CPU version and a CUDA-based version for GPUs. With OpenCL standard, a unique version of the code can cover all these versions, and moreover, it can do it simultaneously, allowing the use of GPUs and CPUs in the same simulation.

3) Highly modifiable application: OpenCL is based on the GLSL working method, where the codes that will be executed in the computation device can be loaded and compiled in run time, allowing to rely on external files.

4) Python scripting has been integrated in the solids motion interface.

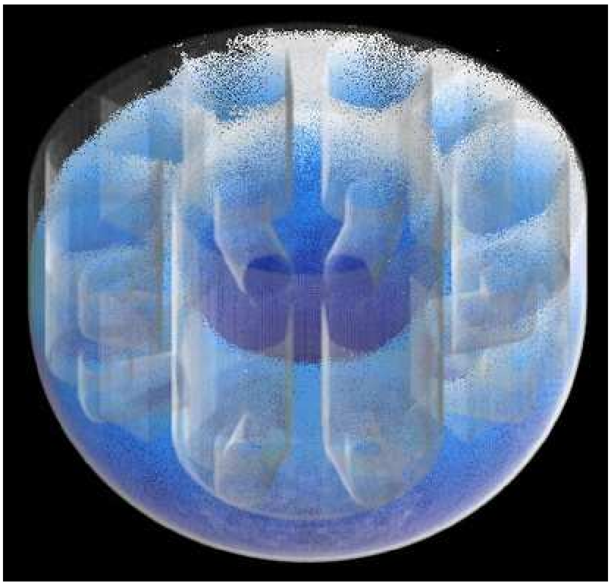

**Figure 1** – Nuclear reactor simulation with AQUAgpusph, showing the *z*-coordinate of the particles (source: Cercos-Pita, 2015).

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### *References*

Cercos-Pita, J.L. (2015), *AQUAgpusph, a new free 3D SPH solver accelerated with OpenCL*, Comp. Phys. Comm. (accepted for publication).

Cercos-Pita, J.L., Gonzalez, L.M., Moreno, A., Guerrero, A., Salgado, S. (2014), *Simulation of earthquake sloshing loads in a nuclear reactor*, Proc. 9th Int. SPHERIC Workshop.

# *Evaluation of the extreme loads on flap-type energy converters through SPH*

***S. Marrone, A Colagrossi**, CNR-INSEAN, Rome, Italy*
***D. Le Touzé, V. Baudry**, LHEEA Lab., Ecole Centrale Nantes / CNRS,Nantes, France*

The French national project EMACOP (Marine Energies in coastal regions and harbours) aims at studying the feasibility and relevance of combining wave energy converters with coastal structures such as dikes. The survivability of those wave energy converters combined to coastal structures is one of the main issues addressed by the project. In this framework the objective of the present study is the evaluation of the extreme loads on a flap-type energy converter through numerical simulation. To this aim the SPH model can be an optimal candidate: its Lagrangian character allows for an accurate description of the extreme breaking wave acting on the structure while its meshless feature permits an easy interaction of the fluid with moving rigid bodies such as the rotating flap converter.

For the present study the SPH-Flow code, a massively parallel SPH solver, co-developed by Ecole Centrale de Nantes and HydrOcean, is adopted. As a first approach, extreme wave characteristics have been computed using statistical offshore wave elevation data. Then, the wave has been generated in a 2D numerical wave tank through a piston wave-maker (see Figure 1). Loads on the flaps are computed and analysed considering a moving or fixed flap. A sensitivity analysis of the results has been performed considering different impact dynamics (*e.g.* wave impact occurring before or after wave breaking). The most critical cases found in the 2D analysis have been reproduced with a fully 3D SPH model.

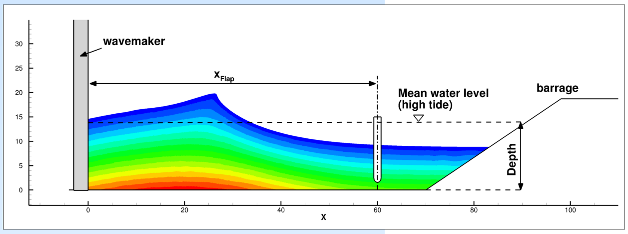


**Figure 1** – Numerical domain including the wavemaker, the flap energy converter and the dyke behind.

Quite different impact dynamics are obtained depending on the wave shape at the impact instant. In figure 2 an example of the global loads recorded on the flap in terms of horizontal force and torque around the hinge are reported as a function of the flap position with respect to wave breaking. In most of the simulated cases the maximum values of the force and torque observed are around 0.5 MN and 1 MN·m respectively (in real-scale simulations). However, in some cases much larger values are recorded. Specifically, this occurs for test cases where the distance between the wave and the flap is large enough to let the breaking inception occur before the impact.

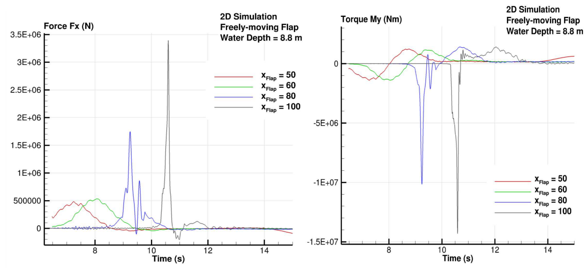


**Figure 2** – Global loads acting on the flap in terms of horizontal force (left) and torque around the hinge (right) as a function of the distance from the wavemaker.

On the base of the results obtained through 2D simulations, the most critical test cases have been selected to be replicated in the 3D model. However, in order to reduce the CPU costs, this time a varying particle resolution model has been employed. The minimum particle size $\Delta x$ = 0.1 m (the same adopted in 2D simulations) is maintained only in the neighbourhood of the flap position. The particle size is then gradually enlarged both in the $x$ and $y$ directions. The effect on the solution of the multi-resolution scheme has been checked through comparisons of the obtained wave profile between 2D and 3D model. The 3D simulations involved about 10 million particles and ran on 200 cores for about 48 hours. In figure 3 the 3D free-surface evolution is depicted with two different angles of view at the impact instant. As for the global loads the measured forces are lower with respect to the 2D simulations by a factor ranging between 1.4 and 1.8.

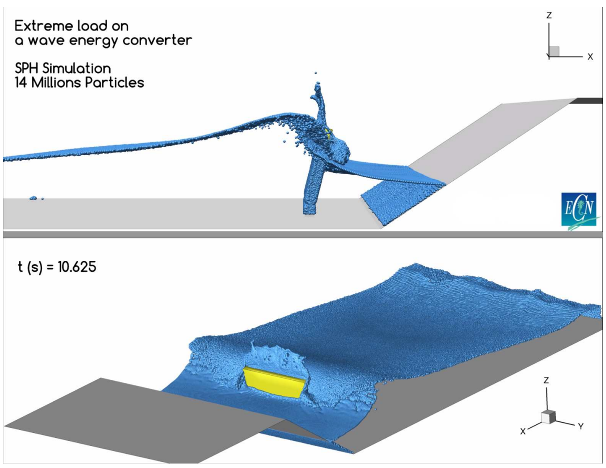


**Figure 3** – Free-surface evolution of the 3D case at the impact instant. Wave strikes the flap just after the breaking inception.

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# *Developing multi-phase SPH simulations accelerated on GPUs*

***B.D. Rogers, G. Fourtakas, A. Mokos, P.K. Stansby*** *Modelling and Simulation Centre (MaSC), School of Mechanical, Aerospace and Civil Engineering, University of Manchester, Manchester, U.K.*
***J.M. Domínguez****, EPhyslab, Universidade de Vigo, Ourense, Spain*

In the past few years significant advances have been made in the acceleration of smoothed particle hydrodynamics (SPH) simulations. This has largely been due to the emergence of graphics processing units (GPUs) whose streaming multi-processor technology has enabled the parallelisation of SPH for desktop applications without the need for massive high-performance computing (Crespo *et al.*, 2011). At Manchester, we have been developing multi-phase SPH codes accelerated by GPUs for applications including wave impact and flows in industrial tanks.

Several GPU-based codes for SPH have now been developed. The DualSPHysics code (www.dual.sphysics.org) has been developed starting from the SPH formulation implemented in SPHysics (Gómez-Gesteira *et al.*, 2012). Using the CUDA programming framework, DualSPHysics has been developed jointly with the Universidad de Vigo (Spain) and other collaborators at the University of Parma and Flanders Hydraulics to be open-source and freely available putting the power of mini-supercomputers in the hands of engineers in industry (Crespo *et al*., 2015).

Many SPH codes, such as DualSPHysics, have been released mainly for single-phase simulations. However, there is a great need within the engineering industry to simulate multi-phase problems where conventional grid-based solvers struggle.

Developing multi-phase SPH to run on GPUs with CUDA is not a straightforward extension of a single-phase code. There are issues that need to be considered in the efficiency of the code for different phases which may have very different physical properties and hence numerical properties (Mokos *et al*., 2013).

At present we have been developing multi-phase DualSPHysics for two separate types of multi-phase flows described briefly here: (i) liquid-gas mixtures, and (ii) liquid-sediment mixtures.

### *(i) Liquid-gas mixtures*

Figure 1 shows a snapshot from a multi-phase dry-bed dam break simulation for the SPHERIC benchmark number 2 test case. The 2-phase simulation uses 3.5 million particles which includes both the water and air phases and particles to represent the boundary. The 2-phase GPU implementation uses the formulation of Colagrossi and Landrini (2003) since this is a straightforward formulation to implement on a GPU. The multi-phase simulation produces close agreement for the impact pressures measured on the block and captures the mixing of the two phases post impact. GPU simulations for millions of SPH particles can now be performed in a matter of hours rather than months using conventional codes.

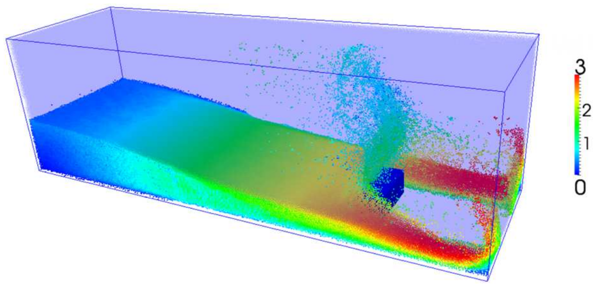


**Figure 1** – 3.5 million particle air-water multi-phase simulation for a dam break impacting an obstacle (Mokos *et al.*, 2013).

### *(ii) Liquid-sediment mixtures*

In the water-sediment model, the liquid is modelled as a Newtonian flow using standard weakly compressible SPH, while the sediment phase is represented by a non-Newtonian Bingham-type constitutive model (Fourtakas *et al*., 2014). For the sediment particles, surface yield criteria are used to initiate movement, while a sediment skeleton lithostatic pressure under the yield surface predicts the state of unyielded particles along with equations to represent the sediment shear layer at the surface and sediment suspension models and seepage forces.

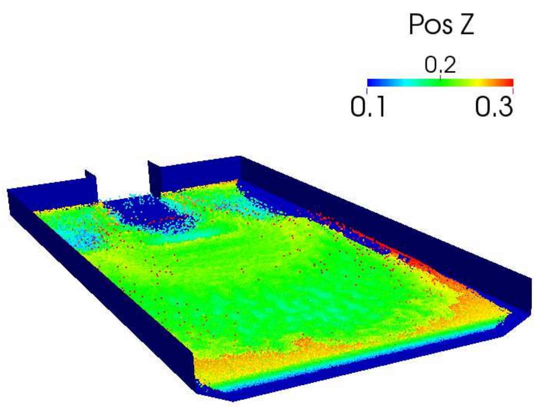


**Figure 2** – 3-D erodible dam break: Position of the bed (Fourtakas *et al.* 2014).

The multi-phase model has been compared with experimental and 2-D reference numerical models for scour following a dry-bed dam break. Figures 2 and 3 shows the snapshots for the position and velocity of the bed sediment for a 3-D erodible bed dam break simulation. The water is released behind the constriction and erodes the sediment. Profiles of the se-

-diment along the tank were measured in the experiment (Soares-Frazão *et al.*, 2012) providing useful 3-D validation data.

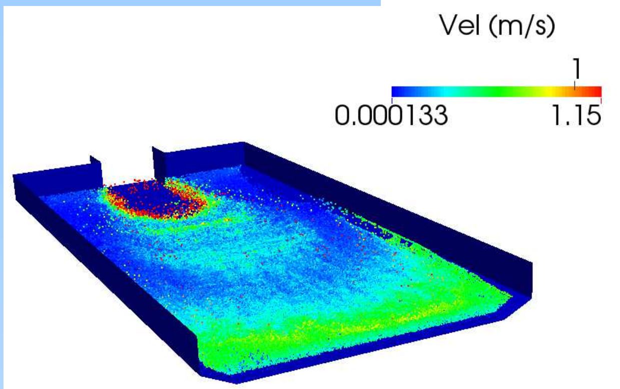


**Figure 3** – 3-D erodible dam break: Position and velocity field of the bed (Fourtakas *et al.*, 2014).

Figure 4 shows comparisons of the bed profile along two sections; the SPH simulation is shown in red and the repeated runs from the experiment in black. The agreement between the SPH and experiment is generally close and is promising for future application and development.

With multi-phase SPH simulations accelerated using GPUs, the intention now is to expand the future development of the multi-phase versions of DualSPHysics for a greater range of physical processes and applications incorporating the latest developments in boundary conditions and accuracy improvement. The codes are currently in the process of being prepared for general release as open source which will be available to be downloaded from the DualSPHysics website in 2015.

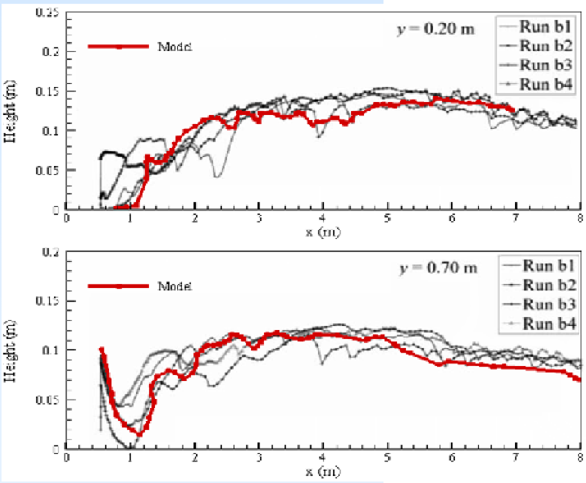


**Figure 4** – Bed profiles at locations $y_1$ and $y_2$ of the experiment (Soares-Frazão *et al.*, 2012) and comparison with the numerical results (Fourtakas *et al.*, 2014).

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## *Sample Recent Publications on SPH*

This is a small sample of journal articles recently added to the SPHERIC online database of SPH literature at http://www.citeulike.org/group/3462. Anybody can access and contribute to this community resource.

This selection is intended to highlight the diversity of SPH research, with an emphasis on new topics and researchers. If you would like to have one of your publications listed, please add it to the SPHERIC database or contact Nathan Quinlan.

Crespo, A.J.C., Domínguez, J.M., Rogers, B.D., Gómez-Gesteira, M., Longshaw, S., Canelas, R., Vacondio, R., Barreiro, A., García-Feal, O. (2015), *DualSPHysics: Open-source parallel CFD solver based on smoothed particle hydrodynamics (SPH)*, Comput. Phys. Comm. **187**:204–216.
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Domínguez, J. M., Crespo, A. J. C., Valdez-Balderas, D., Rogers, B. D., Gómez-Gesteira, M. (2013), New multi-GPU implementation for smoothed particle hydrodynamics on heterogeneous clusters, Comput. Phys. Comm. **184**:1848–1860.
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Zhou, G., Ge, W., Li, B., Li, X., Wang, P., Wang, J., Li, J. (2013), SPH simulation of selective withdrawal from microcavity, Microfluidics and Nanofluidics **15**:481–490.
DOI: 10.1007/s10404-013-1165-1

### *Recent PhD Theses on SPH*

The full texts of the following theses are available to download online through the SPHERIC website at the SPH PhDs link at wiki.manchester.ac.uk/spheric. If you would like to have your PhD thesis listed, please contact Ben Rogers.

Arno Mayrhofer: *An Investigation into Wall Boundary Conditions and Three-Dimensional Turbulent Flows using Smoothed Particle Hydrodynamics*, University of Manchester, 2014.

Jose Dominguez: *DualSPHysics: Towards High Performance Computing using SPH technique*, Universidade de Vigo, 2014.

Swapnadip de Chowdhury: *SPH Simulation of Nonlinear Water Waves*, Indian Institute of Technology Madras, 2014.

Agnes Leroy: *A New Incompressible SPH Model: Towards Industrial Applications*, Université Paris-Est, 2014.

Daniel Barcarolo: *Improvement of the precision and the efficiency of the SPH method: theoretical and numerical study*, Ecole Centrale de Nantes, 2013.

Christian Ulrich: *Smoothed-Particle-Hydrodynamics Simulation of Port Hydrodynamic Problems*, Technische Universitat Hamburg Harburg (TUHH), 2013.