More than 120 delegates attended this 12th consecutive workshop held from June 13th to June 15th 2017. The workshop was preceded by a training day attended by 30 participants. After an introduction to the SPH method by Dr Ben Rogers (University of Manchester, UK) taking both beginners and experienced practitioners through the basics of SPH, Dr Alex Crespo (Universidade de Vigo, Spain) presented the DualSPHysics code. The afternoon session was arranged by the DualSPHysics team and devoted to execution, visualization and analysis of SPH data, based upon practical examples with the open-source SPH solver DualSPHysics, but using the new graphical user interface DesignSPHysics.

Over the three days, the 16 workshop sessions (see below) gave an excellent overview of the varied SPH activity occurring around the world. The two 45-minute keynote lectures were given at the beginning of the first and second days of the workshop by Prof. Holger Wendland (Universität Bayreuth, Germany) with the title “Kernels and Convergence” and Miguel Angel Celigueta (CIMNE, Barcelona, Spain) with the title “Particle Finite Element Method (PFEM)”. In addition, at the end of the first day, a panel of experts discussed the question “Do we want SPH to be a fully Lagrangian method (for fluids)?”
The banquet took place at the monumental state hotel (“Parador”) in the Monastery of “Santo Estevo de Ribas de Sil”, preceded by a boat cruise on the Sil river.

During the closing ceremony, the Libersky student prize was awarded to A. Ghaïtanellis (1st), S. Braun (2nd) and R. Carmigniani (3rd). A special acknowledgment was made to appreciate the contribution of Dr Damien Violeau as newsletter editor. A short presentation was made to announce that the 13th SPHERIC workshop will be organised by National University of Ireland Galway, Ireland, in June 2018.

The workshop organizers also wish to thank the sponsors: The Municipality of Ourense, ERCOFTAC and EPHYTECH. Contact: alexbexe@uvigo.es

**DAY 1: Tuesday 13 June 2017**

Keynote lecture: Kernels and Convergence, Prof. Holger Wendland Chair: J. Monaghan

Session 1: Convergence and Stability I, Chair: D. Violeau
- Targeting viscous flows around solid body at high Reynolds numbers with the δ-plus SPH model BY P. N. Sun, A. M. Zhang, A. Colagrossi, S. Marrone, M. Antuono
- Consistent Iterative shifting for SPH methods BY R. Vacondio, B. D. Rogers
- A first order correction for the d-SPH scheme suitable for GPU implementation BY M. D. Green, R. Vacondio, J. Peiró

Session 2: Convergence and Stability II, Chair: A. Khayyer
- Mathematical Analysis of Characteristic Generalized Particle Methods for Convection-Diffusion Equations BY D. Tagami
- Improving weakly compressible SPH with WENO reconstruction BY C. Zhang, X. Y. Hu, N. A. Adams
- Investigating prescriptions for artificial resistivity in smoothed particle magnetohydrodynamics BY J. Wurster, M. R. Bate, D. J. Price, T. S. Tricco
- Convergence rate of the SPH Poisson equation on a Cartesian grid BY D. Violeau, S. J. Lind, W. Dehnen

Session 3: Incompressibility, Chair: S. J. Lind
- Study of implicit time-integration in truly incompressible SPH BY M. Hirschler, U. Nieken
- A comparative numerical study of pressure-Poisson-equation discretization strategies for SPH BY J-P. Fürstenau, B. Avci, P. Wriggers
- A fast incompressible SPH solver for free-surface flows on the GPU BY A. D. Chow, B. D. Rogers, S. J. Lind, P. K. Stansby

Session 4: Water Waves, Chair: P. K. Stansby
- Generation of trains of tsunami-like solitary waves in DualSPHysics model BY C. Altomare, J. González-Cao, J. M. Domínguez, A. J. C. Crespo, P. Lomonaco, M. Gómez-Gesteira
- SPH Modeling of Short-crested Waves BY Z. Wei, R. A. Dalrymple
- Numerical modeling of wave propagation in the surf zone and structure-wave interaction using SPH and non-hydrostatic NLSW Equations BY P. St-Germain, I. Nistor, C. Altomare
- Submerged plate wave energy converter SPH simulations: wave mass transport BY R. Carmigniani, A. Joly, A. Leroy, D. Violeau

Session 5: Coupling to Other Models, Chair: R. A. Dalrymple
- Applicability of source generation (SG) and absorption technique in a highly reflective condition BY A. Usui, J. M. Domínguez, T. Suzuki, C. Altomare, B. Tagliafierro
- A hybrid incompressible SPH - Finite Element 2-D potential flow solver for non-linear free surface flows BY G. Fourtakas, P. K. Stansby, B. D. Rogers, S. J. Lind, S. Yan, Q.W. Ma

Discussion Panel: “Do we want SPH to be a fully Lagrangian method (for fluids)?”
Chair: A. Souto-Iglesias, R. Vignjevic, S. J. Lind, X. Hu, D. Le Touzé

Welcome cocktail
DAY 2: Wednesday 14 June 2017

Keynote lecture: Particle Finite Element Method (PFEM), Miguel Ángel Celigueta
Chair: C. Altomare

Session 6: Multiphase Flow, Chair: X. Y. Hu
- Multiphase modelling of an experimental device for conformal coating of pancreatic islets BY T. Cazzato, F. Colombo, F. Consolo, A. Redaelli, V. Manzoli, A. Tomei, S. Manenti, S. Sibilla
- Study of two-phase flow at low Reynolds numbers: Extension of contact line dynamics to creeping flow BY P. Kunz, U. Nielen
- Two Novel Projection-Based Particle Methods for Multiphase Flows with Large Density Ratios and Discontinuous Density Fields BY A. Khayyer, H. Gotoh, Y. Shimizu, K. W. P. Teng
- Improved elastic-viscoplastic model for SPH simulations of bed-load transport and scouring BY A. Ghaitanellis, D. Violeau, M. Ferrand, A. Leroy, A. Joly
- Efficient Two-Phase SPH for Accurate Wave Slam on Decks BY S. J. Lind, Q. Fang, P. K. Stansby, B. D. Rogers, G. Fourtakas

Session 7: New Applications I, Chair: M. De Leffe
- SPH simulation of Gearbox Lubrication: comparison with experimental results BY M. Z. Mettichi, Y. Gargouri, P. H. L. Groenenboom
- SPH simulation of single-lip deep-hole drilling processes BY D. Schnabel, P. Eberhard

Session 8: Solids and Structures I, Chair: R. Vignjevic
- Friction modelling in particle-to-particle contact BY J. C. Campbell, T. De Vuyst, R. Vignjevic, N. Djordjevic, K. Hughes
- SPH-DEM Coupling for Polyhedral Particles BY I. Kondor, E. Siegmann, R. Scharler, J. G. Khinast
- Simulation of Laser Welding with SPH and a Ray-Tracing Scheme BY H. Hu, P. Eberhard, F. Fetzer, P. Berger
- A stable solid-liquid multiphase flow simulation by projection-based particle method BY N. Tsuruta, H. Gotoh, E. Harada, A. Khayyer

Session 9: Alternative Approaches, Chair: D. Le Touzé
- A hybrid Lagrangian Voronoi-SPH scheme BY D. Fernández-Gutiérrez, A. Souto-Iglesias, T. I. Zohdi
- Vortex interaction with free-surface by a coupled FV-SPH solver BY L. Chiron, S. Marrone, A. Di Mascio, D. Le Touzé
- A Multiscale Model for the Simulation of Sediment Impact Erosion of Metallic Targets using the Finite Volume Particle Method BY S. Leguizamón, E. Jahanbakhsh, A. Maertens, S. Alimirzazadeh, F. Avellan
- Enhancements of the meshless Finite Volume Particle Method (FVPM) for free-surface flows BY N. J. Quinlan

Session 10: Complex Physics & Miscelanea, Chair: R. Vacondio
- Rounding of melting particles BY P. Nair, M. Blank, T. Pöschel
- Implicit integration of the viscous term and GPU implementation in GPUSPH for lava flows BY V. Zago, G. Bilotta, A. Cappello, R. A. Dalrymple, L. Fortuna, G. Gancia, A. Herault, C. Del Negro
- Comparison of mesh-free and mesh-based numerical methods BY J. Gómez-Cao, C. Altomare, A. J. C. Crespo, J. M. Domínguez, F. Zhang, M. Gómez-Gesteira
- Viscous flow past a circular cylinder close to a free surface: results from a benchmark between SPH and mesh-based solvers BY A. Colagrossi, G. Nikolov, P. N. Sun, D. Durante, A. Souto-Iglesias

Steering Committee Meeting
Boat cruise & Banquet
DAY 3: Thursday 15 June 2017

Session 11: High Performance Computing, Chair: A. J. C. Crespo

- GPU-SPHEROS: A GPU-Accelerated Versatile Solver Based on the Finite Volume Particle Method BY S. Alimirzazadeh, E. Jahanbakhsh, A. Maertens, S. Leguizamon, F. Avellan
- Towards an HPC-based coupling tool for Eulerian-Lagrangian simulations BY J. M. Zavala-Aké, M. Rivero, D. Mira, M. Vázquez, G. Houzeaux
- HPC Predictions of Primary Atomization with SPH: Validation and Comparison to Experimental Results BY S. Braun, S. Holz, L. Wieth, T. F. Dauch, M. C. Keller, G. Chaussonnet, C. Schwitzke, R. Koch, H-J. Bauer
- Efficient Particle Ordering with Space-filling Curves for Incompressible Smoothed Particle Hydrodynamics BY R. Fair, X. Guo, T. Cui

Session 12: Adaptivity & Boundary Conditions, Chair: B. D. Rogers

- A new parallel framework for SPH method with adaptive smoothing-length BY Z. Ji, L. Fu, X. Y. Hu, N. A. Adams
- An Adaptivity Criterion for Smoothed Particle Hydrodynamics Fluid Simulations Based on Spatial Discretization Error BY F. Spreng, R. Vacondio, P. Eberhard, J. R. Williams
- Accurate and efficient SPH open boundary conditions for real 3-D engineering problems BY A. Tafuni, J. M. Domínguez, R. Vacondio, A. J. C. Crespo
- AQUAgpusph: The SPH of the researchers, by the researchers, to the researchers BY J. L. Cercós-Pita, I. Zisis, J. Calderón-Sánchez, R. Messaheh

Session 13: Pre-processing and Visualisation, Chair: J-C. Marongiu

- SPHStudio: A ParaView based software to develop SPH simulation models BY C. Sur, B. vaan Beest

Session 14: Hydraulic Applications, Chair: A. Colagrassi

- Solid particle transport in SPH in order to estimate erosion BY W. Boden, S. Aubert, R. Perkins, J-C. Marongiu
- Forced vibration response of a fluid filled cylindrical container BY T. De Vuyst, J. C. Campbell, R. Vignjevic, N. Djordjevic, K. Hughes

Session 15: New Applications II, Chair: M. Gómez-Gesteira

- SPH simulations of Magneto rheological Abrasive Flow Machining at a microscopic scale BY S. Mohseni-Mofidi, C. Nutto, H. Lugger, C. Bierwisch
- Patient specific systolic blood flow simulations with SPH: modelling and clinical validation BY O. Amoignon, P. H. L. Groenboom, A. Kamoulakos
- Integrated Numerical Simulation of Anaerobic Digestion Process Using Smoothed Particle Hydrodynamics BY M. Rezavand, D. Winkler, W. Rauch
- A single-phase SPH model for evaporation and condensation phenomena BY J. Calderón-Sánchez, D. Duque, A. Souto-Iglesias

Session 16: Solids and Structures II, Chair: S. Sibilla

- Development of solid SPH solver with fluid-structure interaction within SPHysics: Application to cavitation erosion BY S. Joshi, G. Ghigliotti, J-P. Franc, M. Fivel

Closing & Awards
Improved elastic-viscoplastic model for SPH simulations of bed-load transport and scouring

A. Ghaïtanellis, D. Violeau, A. Leroy & A. Joly, LNHE & LHSV, EDF R&D, 5 quai Watier 78400 Chatou, France

M. Ferrand, MFEE, EDF R&D, 5 quai Watier 78400 Chatou, France

The modelling of granular materials raises many scientific and technical issues. One major difficulty is that they can behave like liquid or solid under slightly different conditions. Regarding bed-load transport, a common approach is to model the sediment as a viscoplastic material. Thus, it is assumed that, under a critical shear stress (so-called the yield stress), no significant motion can occur within the material. When the yield stress is exceeded the material flows according to a non-Newtonian rheological law.

For practical reasons, the solid state is usually approached by a highly viscous state. This approximation has the advantage of getting rid of the solid-liquid discontinuity: the material is always modelled as a fluid whose viscosity is governed by a continuous shear-thinning rheological law. Such an approach has been successfully applied to the modelling of bed-load transport with SPH (Fourtakas and Rogers, 2016) but also with MPS (Nabian and Farhadi, 2016) and finite volumes (Morichon et al., 2013). However, these pseudo-viscoplastic models depend on user numerical parameters that have non-negligible effects on the results. The most important one is the maximum value of the viscosity that has to be large enough to guarantee that no significant motion occurs in unyielded regions. This is particularly important regarding erosion and scour development for which a proper treatment of motionless regions is essential to correctly estimate the bed evolution. Thus, it is necessary to ensure that results do not depend on the chosen maximum viscosity. But in practice, the maximum value of viscosity is actually limited for explicit time integration schemes, because of computational cost.

In this work, a different approach is tested. The model of Ulrich (2013) is implemented in the framework of a proper multi-fluid formulation, and adapted to USAW boundary conditions. The sediment is treated as an isotropic linear-elastic solid in unyielded regions, and as a shear thinning-fluid in yielded regions. A continuous transition between the two states is ensured by a blending function of the yield stress and of the strain rate magnitude. In other words, the granular material is treated as a continuous medium whose behaviour law changes according to the dynamic (shear stress) and kinematic (strain rate) conditions.

A particular attention is paid to the liquid-solid transition. A strain rate threshold (referred to as the yield strain rate) calculated from the yield stress and the physical properties of the material is proposed. The yield stress is obtained according to the Drucker-Prager criterion that depends on the effective pressure and on the material internal friction angle. The latter being a constant, the proper calculation of the yield stress mostly depends on the effective pressure. Several attempts have been made to compute effective pressure in SPH, either detecting the sediment-water interface (Manenti et al., 2011) or using a modified state equation (Fourtakas and Rogers, 2016). However, the latter can lead to inaccurate results when the interface is highly deformed, while the former leads to oscillating effective pressure field. Thus, in this work, a reliable method is proposed to compute effective pressure in SPH, solving a Laplace equation. This method leads to a proper lithostatic effective pressure field in any circumstances.

The yield strain rate is then related to the yield stress through a yield viscosity. In Ulrich’s (2013) model, this parameter is chosen in a trial and error approach, increasing incrementally its value until obtaining satisfying result. Here the yield viscosity value is...
calculated from the physical properties of the material so that the model is free of numerical parameter.

This elastic-viscoplastic model was tested on a two-dimensional soil collapse test case. Figure 1 shows the simulation results at four physical times. It can be seen that the proposed method leads to a proper calculation of the yield stress. In figure 2, the surface configuration at the end of the experiment, as well as the failure line, are compared with numerical results obtained at 1.50s and a good agreement is found.

The model was also applied to a two-dimensional dam-break wave on movable beds. Two different materials were tested, i.e. sand and PVC pellets. Figure 3 shows a comparison of the experiment and the SPH simulation carried out for the sand. We can see that the dynamics of the flow is qualitatively well reproduced by the model. Numerical free-surface, moving-soil/water and motionless/moving sediment interfaces were compared to experimental data (see figure 4). A good agreement is found for the sand and the PVC. Furthermore, for both materials, the total mass of eroded sediment is predicted with a correct order of magnitude when the SPH particle size does not exceed three times the grain size.

Figure 3 – Dam-break wave on sand bed – Qualitative comparison of experimental and numerical results.

Contact: alex.ghaitanellis@edf.fr

References


Figure 4 – Dam-break wave on sand beds – Comparison of experimental (dotted lines) and numerical results (solid lines).
HPC Predictions of Primary Atomization with SPH: Validation and Comparison to Experimental Results

Institut für Thermische Strömungsmaschinen, Kaiserstraße 12, 76131 Karlsruhe, Germany

The minimization of harmful emissions is one of the major development goals of modern civil aircraft engines. The key aspect to fulfill future legal requirements is an optimized combustion process inside the combustion chamber and, therefore, a well-defined atomization of the liquid fuels. However, reliable numerical predictions of the fuel spray generation by air-assisted atomizers have not been feasible due to the enormous computational costs which are associated with this multi-scale phenomenon. In the present paper, the first successful numerical prediction of air-assisted atomization is presented.

Figure 1 – visual comparison of Breakup events

The main findings of the paper are the following: A 2D comparison of SPH to commercially available grid-based multiphase solvers (VoF) reveals a very similar breakup behaviour for a generic air-blast configuration. The variation of the spatial resolution of a 2D SPH simulation between 20 and 1 microns shows a log-law convergence rate. The chosen convergence criterion is the occurrence of single-particle-droplets. For the given setup, the mass fraction of these under-resolved liquid droplets drops below 1% of the entire atomized mass, if a resolution of 5 microns is chosen. The 3D simulation already presented by Braun et al. (2016) is qualitatively and quantitatively compared to the corresponding experimental investigation of a generic air-blast atomizer. The simulation consists of more than 1.2 billion particles. 1.1 million time steps could be computed within 60 days on 2560 cores of the Tier-2 super-computer ForHLR I. Due to the limited number of simulated main breakup events, the breakup and spray statistics are investigated event by event. Qualitatively, the simulation is capable of phenomenologically capturing the experimentally observed breakup mechanisms. In Figure 1, three arbitrary top view snapshots obtained with the high speed camera and with the SPH simulation are depicted. Quantitatively, the simulated spray characteristics, expressed by volumetric median diameters and the Sauter mean diameter, virtually coincide with the experimental findings. The presented simulation is the first of its kind, demonstrating that an accurate prediction of air-assisted atomization is feasible. Major advantages of the SPH method are the non-diffusive behaviour of the phase interface and the exceptional computational efficiency. With respect to comparable 3D multi-phase predictions, the authors found that SPH is about 10 times faster than VoF and at least 30 times faster than Level Set methods.

Due to the high efficiency of the code and, therefore, the ability to successfully handle large-scale simulations, SPH gained noticeable attention in the super-computing community. Recently, the atomization related work has been awarded with the “HLRS Golden Spike Award” of the High Performance Computing Center Stuttgart. Furthermore, the front covers of Nagel et al. (2016) and the HLRS online magazine InSiDE (Klank 2017) are embellished by good-looking SPH results (Figure 2).

Contact: samuel.braun@kit.edu

References
Waves above a submerged plate: wave mass transport

R. Carmigniani, A. Joly, A. Leroy & D. Violeau, EDF & Saint-Venant Laboratory for Hydraulics, University Paris-Est, Chatou, France.

Waves interacting with a submerged plate will generate a local current around the structure. A pulsating flow develops under the submerged plate in the opposite direction to the incident waves. One could take advantage of this phenomenon to generate or amplify currents.

This phenomenon was first observed by Dick (1968) while looking at porous submerged breakwater. In this work, SPH is used to investigate the origin of the circulation. First the simulations are validated by comparing our simulations with experimental data for the current under the plate (Murakami et al., 1992) (see Figure 1). It is observed that SPH correctly captures the wave-structure interaction though it under-estimates the dissipation in the case of Brossard et al. (2009). For the mean velocity the agreement is good for the three different resolutions tested (in the figure coarsest to finest).

![Figure 1](image1.png)  
Figure 1 – Mean horizontal velocity under the submerged plate for 3 resolutions compared to Murakami et al. experimental results.

To capture all the desired physics of this 2D flow, it is necessary to capture the boundary layer effects. In the case of Murakami et al. (1992) a simulation is performed with a particle size of about $\delta/3$, where $\delta = (2\nu/\omega)^{1/2}$, represents the boundary layer characteristic size. The vortex shedding is captured at the leading and trailing edges of the plate (Figure 2).

It appears that the origin of the circulation is primarily due to the linear wave structure interaction and not to the boundary effects. When waves interact with the plate, the linear theory predicts that the amount of mass transport by the wave in the surface layer will increase leading to a suction of water upward. This is visible in our simulations when looking at the mean mass flux (see Figure 3).

![Figure 3](image3.png)  
Figure 3 – Mean mass flux and suction upward at the leading edge of the submerged plate (shaded grey rectangle).

Using the SPH method, we have shed light on this 50-year-old wave-structure interaction problem. Further simulations and experiments are required to model the effect of wave breaking on the circulation.

Contact: rcarmi@me.com

References


As guest editors, we are pleased to announce a Special Issue of *Computers & Fluids* revolving around SPH method development and application to fluid dynamics problems. This Special Issue is meant to address SPH for flows in a wide sense.

Actually, *Computers & Fluids* is a multidisciplinary international journal. The term “fluid” is interpreted in the broadest sense. Hydro- and aero-dynamics, high-speed and physical gas dynamics, turbulence and flow stability, multiphase flow, rheology, tribology and fluid-structure interaction are all of interest, provided that a computer technique plays a significant role in the associated studies or design methodology. Applications will be found in most branches of engineering and science: mechanical, civil, chemical, aeronautical, medical, geophysical, nuclear and marine. The 2016 impact factor of *Computers & Fluids* is 2.3.

As explicitly mentioned in the title of this special issue on “Theoretical, numerical and computational advances of the SPH method for solving fluid dynamics problems”, any advances on the SPH method are pertinent to the issue, not only its application to fluid problems. In particular, it is encouraged to submit papers addressing the 5 grand challenges of SPHERIC:

- Convergence, consistency and stability,
- Boundary conditions,
- Adaptivity,
- Coupling to other models,
- Applicability to industry.

In your submission, particular attention is to be paid to validation and accuracy. *Computers & Fluids* will reject all manuscripts that do not report results with the required assessment of accuracy. Validation against benchmark test cases is also much encouraged. Benchmark solutions are important tools in CFD to assess the accuracy of numerical methods and to validate practical implementation. Among others, the benchmark test cases referenced and described on the SPHERIC website can be used to this purpose.

### Practical information:

- Prior to submitting your paper, please contact any of the 4 guest editors mentioned above via email.
- Your paper will be peer-reviewed exactly as any other paper of *Computers & Fluids*.
- Submission to this special issue will open on Sept. 1st, 2017 and close on Jan. 15th, 2018.
- Publication of the issue is planned around June 2018.
The 2018 Joe Monaghan Prize
A. Colagrossi, CNR-INSEAN, Rome

The Joe Monaghan Prize was created in 2015 to recognize SPH researchers who have made outstanding advances in recent years on one or more of the SPHERIC Grand Challenges:

1. Convergence, consistency and stability
2. Boundary conditions
3. Adaptivity
4. Coupling with other methods
5. Industrial applicability

The prize is named in honour of the unique contributions made by Prof. Joe Monaghan in the foundation of SPH, and in its continuous development since 1977. The next Joe Monaghan Prize will be presented at the 2018 workshop. The prize will be devoted to the journal articles which demonstrate a clear advance on one of the Five Grand Challenges. Peer-reviewed journal articles published from 2011–2015 will be considered eligible. The list of the journal articles which will participate to the competition will be selected by the whole SPHERIC community.

Andrea Colagrossi, a member of the steering committee, will coordinate and collect the different nominations. Each SPHERIC member can send a nomination to the email address andrea.colagrossi@cnr.it before 30 September 2017 providing the following information:

- Bibliographic details, DOI and abstract
- Identify Grand Challenge(s) addressed
- Review of the article (500 words maximum)
- Details of the nominator(s).

The steering committee will confirm eligibility of nominations during the Autumn meeting. A secret ballot of attendees at the 13th SPHERIC Workshop in Galway will determine the winner. Authors of the winning publication will give an invited lecture at a following SPHERIC Workshop.