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SPHERIC
NEWSLETTER
33rd issue
SPH rEsearch and engineeRing International Community

SUMMARY

16th SPHERIC International Workshop, Catania, Italy (7-9 June 2022)

Giuseppe Bilotta, Annalisa Cappello, Gaetana Ganci
giuseppe.bilotta@ingv.it
Istituto Nazionale di Geofisica e Vulcanologia — Osservatorio Etneo,
piazza Roma, 2, 95125 Catania

The 16th edition of the SPHERIC International Workshop (SPHERIC 2022) will be held in Catania from June 7 to 9, 2022, co-organized by the Osservatorio Etneo, Catania section of the Italian National Institute for Geophysics and Volcanology, and by the Department for Mathematics and Computer Science of the University of Catania. The event will be preceded by an optional Training Day on June 6, 2022, to introduce young researchers to the theory and applications of the SPH method.

As the global epidemic subsides and restrictions are relaxed, the event is being organized in-person, with the main venue at the Monastery of San Nicolò l'Arena in the historical city center, one of the largest Benedictine monasteries in Europe and currently housing part of the University of Catania. Current regulations require proof of vaccination and the use of masks in indoor settings. We are closely monitoring the situation, and will keep the event website https://www.spheric2022.it up to date with the most recent information.

The SPHERIC International Workshop is the annual global forum for the development and application of Smoothed Particle Hydrodynamics (SPH) and related methods, gathering researchers and industries involved in the development and application of SPH to share

Figure: Etna Volcano Eruption January 12th 2011 View from the East side.

Key dates

March 18, 2022
Announcement of Selected Abstracts

April 22, 2022
Full Paper Submission Deadline

April 22, 2022
Early registration deadline

May 6, 2022
Presenter registration deadline

June 6, 2022
Training Day

June 7-9, 2022
SPHERIC Workshop

the latest advances and use-cases of the method. Topics for the workshop will cover a wide variety of theoretical and practical aspects of the SPH method, including, but not limited to: convergence and consistency, turbulence, viscosity and non-Newtonian rheological models, boundary conditions, high-performance computing, alternative formulations, and industrial applications, spanning fields such as civil waterworks, naval architecture, medical devices, geophysics and disaster simulation.

Only a limited number of papers will be accepted, so there will be no parallel sessions. For the accepted contributions, submission of the full paper will be required by the deadline of April 22. Keynotes from Qiang Du, Fu Foundation Professor of Applied Mathematics at Columbia University, and Paul Cleary, Chief Research Scientist at CSIRO, Canberra are also scheduled for the conference.

The Libersky prize will be awarded to the best student contribution. Students who wish to be nominated for the Libersky prize should specify so when submitting the final version of the paper. This edition of the workshop will also see the presentation of the 3rd Joe Monaghan prize, devoted to journal articles published between 2013 and 2018 which demonstrate a clear advantage on one of the Five SPHERIC Grand Challenges.

The training day will see morning lectures by Robert A. Dalrymple, introducing the history of SPH and its applications in computational fluid dynamics, and Chun Hean Lee, presenting SPH methods for solid mechanics. The afternoon session will provide hands-on experience with version 6 of GPUSPH, an open source implementation of weakly-compressible SPH optimized for execution on GPU.

Updated information on 2022 SPHERIC Xi'an International Workshop Xi'an, China (28 Mar.-2 Apr. 2022)

Fei Xu
xufei@nwpu.edu.cn
Northwestern Polytechnical University

The 2022 Xi'an SPHERIC International Workshop (SPHERIC Xi'an 2022) will be held at Northwestern Polytechnical University in Xi'an, China during March 28th – April 2nd of 2022: www.npuicma.cn/spheric2022/.

On September 1, 2021, the SPHERIC Xi'an 2022 opened the call for abstracts and not only received a positive response from SPH researchers in China, but also made an impact globally. As of December 10, 2021, SPHERIC Xi'an 2022 had received a total of 87 abstract submissions, 66 from China and 21 from outside China. This is an encouraging result for the call for abstracts, indicating that more and more people in China and around the world are getting involved in the research of SPH method and its applications.

The 87 abstracts were assigned to 28 Scientific Committee members and 20 SPH experts from China. The experts carefully reviewed each abstract and gave scores according to three aspects:(1) Novelty. (2) Applicability & impact. (3) Accuracy and improvements over other methods. After receiving the review scores from each expert, the Local Organization Committee ranked the 87 abstracts according to their total scores and selected the 61 abstracts with the highest ranking to be sent acceptance notices. We would like to thank all the members of the Scientific Committee and the Local Organization Committee for their efforts. Of the 61 abstracts accepted so far, 54 authors have submitted full papers. This means that at least 54 exciting presentations will be presented at the SPHERIC Xi'an 2022. The conference is also sponsored by the Springer Journal (Q1) Acta Mechanica Sinica (AMS), with the intention of 6-8 excellent workshop

Keynote speakers:

Prof. Dongdong Wang

Topic of talk: Galerkin and Collocation Meshfree Methods: Convergence Measuring and Applications.

Dongdong Wang is professor of Xiamen University, Ph.D graduated from University of California, Los Angeles.

Prof. Lin Fu

Topic of talk: SPH for Fluid Dynamics and Beyond.

Lin Fu is currently an Assistant professor in the Department of Mathematics and the Department of Mechanical and Aerospace Engineering at the Hong Kong University of Science and Technology. PhD graduated from Technical University of Munich.

Prof. Ha Bui

Topic of talk: Advances in SPH and its Applications for Solving Complex

Figure: The Qin Tomb Terracotta Warriors

Problems in Geomechanics .

Ha Bui is currently an Associate Professor and ARC Future Fellow at the Department of Civil Engineering, Monash University. PhD graduated from Ritsumeikan University.

papers to be recommended for publication in AMS.

In preparation for the workshop, which will be run as a hybrid event, we also conducted a conference preview and tested the equipment needed for the online conference such as camera, microphone and VooV video conferencing software. Other related work such as conference room reservation, conference manual writing, network test, and AMS special issue is also in order. So far, 10 participants from China and 4 participants from outside China have already paid for the conference. We are delighted to welcome people from all over the world who are interested in SPH to attend the SPHERIC Xi'an 2022 and we look forward to meeting you in Xi'an or online.

During the preparation of the SPHERIC Xi'an 2022, Xi'an was put into lockdown due to the epidemic and everyone stayed home. This made it difficult to organize the conference, but every member of the local organization committee, including the chair, Prof. Fei Xu, overcame the difficulties and actively promoted the conference preparation. During this process, the Chair of the SPHERIC Steering Committee, Prof. Renato Vacondio, along with Prof. Benedict D. Rogers, Prof. Xiangyu Hu and Dr. Pengnan Sun et al., had many discussions with the Local Organization Committee, which greatly facilitated the process of organizing this conference. We would like to express our sincere gratitude to them and to all the people who have helped SPHERIC Xi'an 2022.

Payment of Overseas bank transfer

Name: Northwestern Polytechnical University
Account Number: 102010169938
Address: 127 YOUYI XILU, XI'AN 710072 SHAANXI PROVINCE P.R.CHINA
Beneficiary Bank: NPU SUB-BRANCH BANK OF CHINA
Bank address: First Floor, Innovation And Technology Building, No.127 You Yi Road, xi'an China
SWIFTCODE: BKCHCNBJ620

Please send us an email (spheric2022@163.com) with the copy of the first page of your passport to inform us after your transfer. (Only for overseas)

Payment of Domestic bank transfer (国内汇款)

开户户名：王常悦
银行账号：6217 0042 2006 8519 622
开户行：建行西安劳动路支行
(如需转账到西北工业大学公账，请邮件联系我们)
Note: Please indicate "SPHERIC_your name" when you transfer.

Registration & Payment

Participants in China attend on-site, while participants outside China attend online.

Registration Fees for participants **in China (on-site)**		
	Non-Student	Student
Early-Bird (Before Jan 15th, 2022)	2,600 RMB	1,300 RMB
Regular (Before Mar 15th, 2022)	3,200 RMB	1,600 RMB
On-site (Mar 28th, 2022)	3,800 RMB	1,900 RMB
Training Day	400 RMB	
Conference dinner for accompanying person	300 RMB	

Registration Fees for participants **outside China (online)**		
	Non-Student	Student
Early-Bird (Before Jan 15th, 2022)	$150	$75
Regular (Before Mar 15th, 2022)	$250	$100
On-site (Mar 28th, 2022)	/	/
Training Day	$25	

Workshop programme

Time	Mar 29th Training Day
8:30 - 10:00	Morning Lecture1
10:00 – 10:20	Coffee Break
10:20 – 11:50	Morning Lecture2
12:00 – 13:00	Buffet
13:00 – 15:00	Hands-on Practice Session 1
15:00 – 15:20	Coffee Break
15:20 – 17:20	Hands-on Practice Session 2
19:00 – 21:00	Welcome Cocktail
21:00 – 22:00	SC meeting

Time	Mar 30th Workshop	Mar 31st Workshop	Apr 1st Workshop
8:30 – 9:00	Welcome		
9:00 – 9:50	Keynote 1	Keynote 2	Keynote 3
9:50 – 11:00	Session 1	Session 7	Session 11
11:00 – 11:20	Coffee Break		
11:20 – 12:30	Session 2	Session 8	Session 12
12:40 – 13:40	Buffet		
14:00 – 15:10	Session 3	Session 9	Session 13
15:10 – 16:20	Session 4	Session 10	Session 14
16:20 – 16:40	Coffee Break		
16:40 – 17:50	Session 5	SC meeting	Presentation of Prize and Closing Ceremony
17:50 – 19:00	Session 6	Excursion	
19:10 – 20:10	Buffet		Banquet

Virtual 5th DualSPHysics Users Workshop

Dr. Corrado Altomare
corrado.altomare@upc.edu
Universitat Politècnica de Catalunya – BarcelonaTech (Spain)

The 5th DualSPHysics Users Workshop was initially foreseen to be an in-person event held at the Universitat Politècnica de Catalunya – BarcelonaTech, Spain. However, in light of global precautions to combat the COVID-19 outbreak, the workshop was finally moved to an Online event. The workshop was celebrated on the 15th to 17th March 2021.

DualSPHysics Users Workshops are meant to bring together a growing community of users and developers of the open-source DualSPHysics code (https://dual.sphysics.org/). They represent unique opportunities for the end-users to discuss with core developers, enabling users to discuss performance of the latest versions and features and suggest new areas for development and improvement. DualSPHysics Users Workshop are events for peer discussion and

Workshop chair, Dr. Corrado Altomare, announces the opening

Workshop Organizer

The Workshop was organized by the Maritime Engineering Laboratory of the Universitat Politècnica de Catalunya – BarcelonaTech (LIM/UPC) and the DualSPHysics Team and supported by the Marie Sklodowska-Curie Action “DURCWAVE”, funded from the European Union’s Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No.: 792370.

Next DualSPHysics Workshop

Next DualSPHysics workshop will be held at UPC in Barcelona in collaboration with Vigo University, on 25th – 27th October 2022. Further information can be found here: https://dual.sphysics.org/6thworkshop/

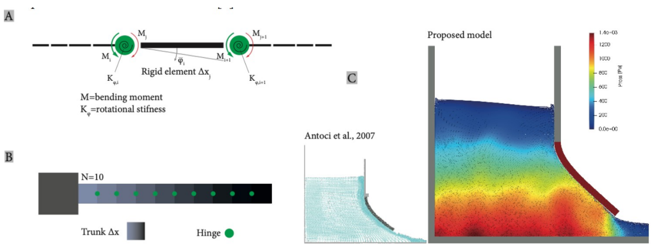


Figure 1 - a) Beam discretization generic scheme, consisting of trunks and hinges; b) wedged beam representation, where N stands for the number of trunks; and c) dambreak with elastic gate comparison, 0.12 s after the start of the simulation.

Presented work from Capasso et al.: Simulating co-rotating rigid beam with elastic hinges

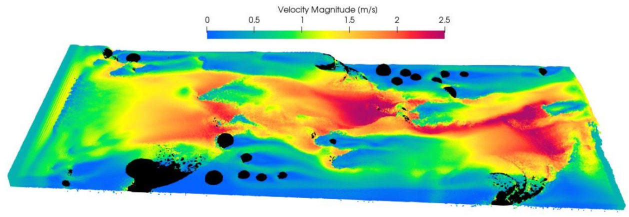


Fig. 1 – Velocity magnitudes in a nature-like fish pass

Presented work from Novak et al.: Numerical modelling of a Nature-Like Fish Pass

feedback. Finally, during the Workshops, the DualSPHysics teams presents the solver latest advances and provides a hands-on practical session.

The 5th Workshop followed the success of the four previous events held in 2015, 2016, 2017 and 2018: 226 registered participants from 38 Countries from all over the World, with an average of attendants connected of 105 during all the sessions (considering the different time zones), 28 delegate presentations, 6 major talks from the code developers and 1 invited Keynote lecture on “Modeling viscous forces in SPH” by Prof. Antonio Souto Iglesias (Universidad Politecnica de Madrid).

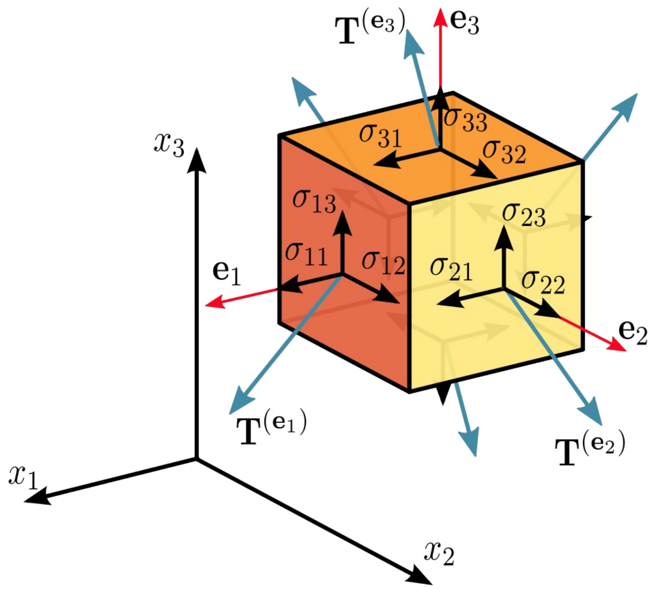
On the first day, about 80 people attended the Practical session for Users, being guided towards the pre-processing, solving and post-processing tools embedded in the DesignSPHysics software, a Graphical Users Interfaces built into FreeCAD (https://github.com/DualSPHysics/DesignSPHysics).

On day two Dr. Corrado Altomare, Workshop Chair, opened officially the event giving a few important announcements: a new DualSPHysics website, new youtube tutorials, latest update of code downloads (77,900) and the recently published new DualSPHysics reference paper (Domínguez et al., 2021). The opening was followed by the keynote from Prof. Souto. The developer talks started with Professor Benedict Rogers (University of Manchester), who provided a general overview of the latest code release, v.5.0. Dr. Renato Vacondio (University of Parma) detailed the new density diffusion term implemented in DualSPHysics. Dr. José Domínguez (University of Vigo) closed the first session of developer talks, describing the latest advances in the pre-processing tool and introducing the new Modified Dynamic Boundary Conditions. The morning was closed by 5 presentations from delegates. Dr. Georgios Fourtakas (University of Manchester) opened the afternoon, explaining the capabilities of DulaSPHysics to model non-Newtonian and multiphase flows. He was followed by Dr. Angelo Tafuni (New Jersey Institute of Technology) who presented the open Inlet/outlet boundary conditions. Finally, Prof. Alejandro Crespo (University of Vigo) closed the developer talk sessions detailing the latest developments and applications of the coupling of DualSPHysics with MoorDyn library and with Project Chrono. The afternoon was closed by 4 delegate presentations. Day three was devoted to delegates, with 19 talks. Closing the workshop, a final discussion chaired by Prof. Rogers was held on questions regarding the topics like emerging themes from the 5th Workshop and needs of DualSPHysics Users.

All developer presentations are available in PDF and the recorder talks from delegates are available in the DualSPHysics youtube channel. All links can be found at: https://dual.sphysics.org/5thusersworkshop/workshop/programme. More information and the presentations given at the workshop are available at the workshop site https://dual.sphysics.org/5thusersworkshop/.

References

Domínguez JM, Fourtakas G, Altomare C, Canelas RB, Tafuni A, García-Feal O, Martínez-Estévez I, Mokos A, Vacondio R, Crespo AJC, Rogers BD, Stansby PK, Gómez-Gesteira M. 2021. DualSPHysics: from fluid dynamics to multiphysics problems. Computational Particle Mechanics, doi:10.1007/s40571-021-00404-2



SPHERIC Solids and Structures Interest Group (SSIG) created

Tom De Vuyst
t.de-vuyst@herts.ac.uk
University of Hertfordshire (UK) University of Manchester, UK

Members of the Interest Group

The Solids and Structure Interest Group currently has the following members:

Prof. Rade Vignjevic, Brunel University London, UK;
Dr. James Campbell, Brunel University London, UK;
Dr. Tom De Vuyst, University of Hertfordshire, UK (chair);
Prof. Peter Eberhard, Universität Stuttgart, Germany;
Dr. Paul Groenenboom, ESI Group, Netherlands;
Prof. Stefan Hiermaier, Freiburg University, Germany;
Prof. Xiangyu Hu, Technische Universität München, Germany;
Dr. Md Rushdie Ibne Islam, Birla Institute of Technology and Science Pilani, India;
Prof. Abbas Khayyer, Kyoto University, Japan;
Dr. Jerome Limido, Impetus, France;
Dr. Mike Owen, Lawrence Livermore National Laboratories, USA;
Dr. Martin Sauer, EMI Fraunhofer, Germany

Motivation for a Solids and Structures Interest Group

Although the SPH method was initially developed for astrophysics applications, the method was extended almost 30 years ago, in 1993, to deal with solid mechanics problems by Dr. Larry Libersky, and his co-authors A. Petschek, T. Carney, J. Hipp, F. Allahdadi [1]. The importance of this work is recognised in SPHERIC by the Libersky Prize which is awarded at every SPHERIC Workshop for the best work by a student.

Despite this, SPH research and applications related to solids and structures are not as well developed as astrophysics and fluid dynamics. This is reflected in SPHERIC, where activities in the area of SPH for solids and structures are currently underdeveloped compared to SPHERIC's CFD activities. The creation of a SPHERIC Solids & Structures Interest Group aims to address this by organising and invigorating a network of researchers working in this field. The SPHERIC Solids and Structures Interest Group is an initiative that originated from Prof. Rade Vignjevic Brunel University London, UK as part of his involvement in the SPHERIC Steering Committee.

Activities

The Solids and Structure Interest Group members have held initial meetings (virtually due to the covid pandemic) at which the following immediate areas of activity have been agreed:

- The publishing benchmark cases focussed on solid mechanics problems on the SPHERIC website.
- Mapping of aspects of grand challenges relevant to solids (tensile instability, consistency, diffuse boundaries)
- Highlighting industry relevance and industrial applications
- Organise informal discussions on relevant topics identified by Solids and Structures Interest Group members

Examples of solids and structures benchmark cases that are being developed for the SPHERIC Benchmark page (https://www.spheric-sph.org/validation-tests) can be seen in Figures 1 and 2. Figure 1 shows an elastic impact of 2 cylinders, and Figure 2 an impact of a rigid projectile on an elasto plastic beam. These problems test the basic capabilities in terms of modelling elastic and elasto-plastic materials but also several topics identified as SPH Grand Challenges (https://www.spheric-sph.org/grand-challenges): tensile instability, zero-energy modes, boundary conditions, and contact.

Get Involved

If you are interested in the activities of the SPH for Solids and Structures Interest Group and would like to get involved in this initiative, please contact Dr Tom De Vuyst (t.de-vuyst@herts.ac.uk). We would particularly welcome any contributions on the SPH Grand Challenges, benchmark cases, industrial applications, and discussion topics.

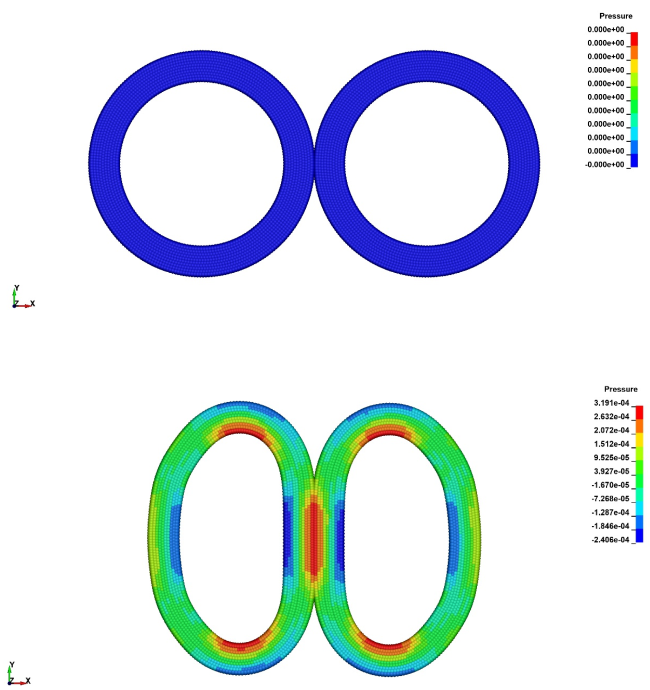


Figure 1 - Impact of two elastic cylinders, pressure before and during impact, from Campbell [2]. Problem adapted from Swegle [3]

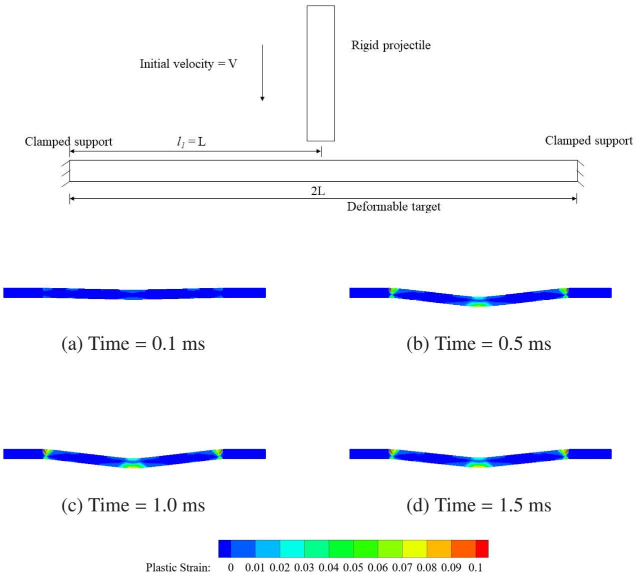


Figure 2 - Impact of rigid impactor on an elastoplastic beam, problem setup and deformed shape at different instances of time, from Islam [4]. Problem adapted from Jones [5].

References

1. L.D. Libersky, A.G. Petschek, T.C. Carney, J.R. Hipp, F.A. Allahdadi, High Strain Lagrangian Hydrodynamics: A Three-Dimensional SPH Code for Dynamic Material Response, Journal of Computational Physics 109(1) (1993): 67-75, https://doi.org/10.1006/jcph.1993.1199.

2. R. Vignjevic, J. Campbell, L. Libersky, A treatment of zero-energy modes in the smoothed particle hydrodynamics method, Computer Methods in Applied Mechanics and Engineering 184(1) (2000): 67-85.

3. J.W. Swegle, S.W. Attaway, M.W. Heinstein, F.J. Mello, D.L. Hicks, An analysis of smoothed particle hydrodynamics, Sandia
Report, SAND93-2513, March 1994.

4. M.R.I Islam, and P. Chong. "A Total Lagrangian SPH method for modelling damage and failure in solids." International Journal of Mechanical Sciences 157 (2019): 498-511.

5. J. Liu, N. Jones, Experimental investigation of clamped beams struck transversely by a mass, International. Journal of Impact Engineering 6 (4) (1987): 303–335

Articles nominated for the 3rd Joe Monaghan Prize

Salvatore Marrone
salvatore.marrone@cnr.it
CNR-INM, Institute of Marine Engineering, Rome, Italy

Prof. Joe Monaghan during the prize ceremony in 2015.

The 16th SPHERIC Workshop in Catania will be an exciting event for exchanging experiences and new findings within the SPH community but it will also determine the winner of 3rd Joe Monaghan Prize. A shortlist of candidate papers is ready and a secret ballot by the workshop attendees will assign the prize. The authors of the winning publication will give an invited lecture at the following SPHERIC Workshop.

After the call for nominations, which closed on the last 30th November, six articles were selected for the third edition of the "Joe Monaghan Prize". A specific commission of the SPHERIC Steering Committee checked the eligibility of each nominee. Only peer-reviewed journal articles published in the years 2013-2018 have been considered for this 2022 edition of the prize.

The selected articles are listed in the table below in alphabetical order and motivations given by each nominating institute (whose identity was kept anonymous) are provided.

PAPER #1

TITLE: Extending DualSPHysics with a Differential Variational Inequality: modeling fluid-mechanism interaction

Summary of the articles nominated for the 3rd Joe Monaghan Prize

	Author	Title	Journal	Year	Grand Challenge
1	Canelas R.B., Brito M., Feal O.G., Domínguez J.M., Crespo A.J.C.	Extending DualSPHysics with a Differential Variational Inequality: modeling fluid-mechanism interaction	Applied Ocean Research	2018	4-5
2	Ferrand, M., Laurence, D. R., Rogers, B. D., Violeau, D., & Kassiotis, C.	Unified semi-analytical wall boundary conditions for inviscid, laminar or turbulent flows in the meshless SPH method	International Journal for Numerical Methods in Fluids	2013	2
3	Franz, T., Wendland, H.	Convergence of the Smoothed Particle Hydrodynamics. Method for a Specific Barotropic Fluid Flow: Constructive Kernel Theory	SIAM Journal of Mathematical Analysis	2018	1
4	Alex Skillen, Steven Lind, Peter K. Stansby, Benedict D. Rogers	Incompressible smoothed particle hydrodynamics (SPH) with reduced temporal noise and generalised Fickian smoothing applied to body–water slam and efficient wave–body interaction	Computer Methods in Applied Mechanics and Engineering	2013	1
5	Vacondio, R., Rogers, B. D., Stansby, P. K., Mignosa, P., & Feldman, J.	Variable resolution for SPH: a dynamic particle coalescing and splitting scheme	Computer Methods in Applied Mechanics and Engineering	2013	3
6	Violeau D., Leroy A.	On the maximum time step in weakly compressible SPH	Journal of Computational Physics	2014	1

AUTHORS: Canelas R.B., Brito M., Feal O.G., Domínguez J.M., Crespo A.J.C.

BIBLIOGRAPHIC DETAILS: Applied Ocean Research, Volume 76, July 2018, Pages 88-97, (2018).

GRAND CHALLENGE(S) ADDRESSED:

GC#4: Coupling to other models

GC#5: Applicability to industry

MOTIVATION:

This paper has completely revolutionised what most users and engineers can realistically simulate with SPH hitting both SPHERIC Grand Challenges GC#4 and GC#5 as a general-purpose simulation framework for multi-body problems with support for very large systems. As far as we are aware Canelas et al. (2018) were the first to achieve this for an open-source code. The paper hits multiple targets of (i) coupling two very different methods together (SPH + FEM) by introducing the Project Chrono library, (ii) coupling without introducing numerical instability, (iii) massively extending the applicability of the SPH method to applications that involve complex fluid-structure interaction.

Extending the applicability of the SPH method is absolutely crucial to making SPH acceptable for widespread use. Very few works have made much progress in pushing the applicability of SPH at the same time as extending the accessibility as part of an open-source SPH code free for all to use. This article stands out as being unique and ambitious. The article focuses on developing a rigorous theoretical framework and includes frictional constraints, non-smooth multi-body dynamics based on the differential variational inequality.

The paper demonstrates the typically high-standard of academic rigor with validation tests with convergence tests for FSI including a platform washout by a dam break, a swinging pendulum in viscous fluids, before showing a range of demonstration cases including the WaveStar Wave Energy Converter (WEC) with multiple floats, tidal turbine and a human-like multi-element object being carried by a flood wave through a complex geometry. Thanks to the novel developments in this paper, users have been able to apply DualSPHysics to an extraordinary range of new applications as evidenced by the presentations at the Users Workshops and journal papers published.

I have seen very few publications on SPH where the academic rigour of the article is world class directly addresses multiple SPHERIC Grand Challenges. It is a worthy candidate for the JJM prize and directly addresses two of the SPHERIC Grand Challenges so crucial for our field.

PAPER #2

TITLE: Unified semi-analytical wall boundary conditions for inviscid, laminar or turbulent flows in the meshless SPH method.

AUTHORS: Ferrand, M., Laurence, D. R., Rogers, B. D., Violeau, D., & Kassiotis, C.

BIBLIOGRAPHIC DETAILS: International Journal for Numerical Methods in Fluids, 71(4), 446-472 (2013).

GRAND CHALLENGE(S) ADDRESSED:

- GC#2: Boundary conditions

MOTIVATION:

In the SPH method, two families are used in the literature to deal with solid boundaries: (i) volume-based methods such as the moving-ghost-particle method, and (ii) surface-based methods such as the one developed in the present paper, which are necessary to deal with complex geometries. This paper addresses precisely the surface-based method, particularly by proposing a semi-analytical manner to compute the renormalization factor which is crucial to compute accurately the boundary integral of the SPH operators. It is important to note that the proposed development is derived for inviscid, laminar and turbulent flows. The validation is performed and compared to other solid boundary treatment methods, on challenging test cases involving both complex geometries and free-surface. The authors have shown that using their surface-based method allows for (i) increasing the accuracy of the results on a Poiseuille flow at Re = 10 in comparison to other existing solid boundary treatments [GC#2], (ii) recovering the hydrostatic solution even with complex geometries, both in terms of pressure and velocity, and providing better results than the other methods tested, (iii) a more regular pressure field when complex geometries are involved, with respect to other solid boundary treatments available in the SPH literature [linked to

GC#1], and (iv) obtaining results that are similar to the ones obtained with a Finite Volume solver for a turbulent flow. To summary, the results are extended and convincing.

Furthermore, from our point of view, this paper is very important for the SPH community since it constitutes a solid base for several papers refering to the same topic. For example, (i) the study has been extended to 2D-incompressible SPH in "Unified semi-analytical wall boundary conditions applied to 2-D incompressible SPH, Leroy et al., JCP 2014", (ii) the extension of the present paper for 3D applications is given in "Unified semi-analytical wall boundary conditions in SPH: analytical extension to 3-D, Mayrhofer et al., Numerical algorithm, 2015", (iii) it is related to other papers from other research teams such as "Fast and accurate SPH modelling of 3D complex wall boundaries in viscous and non viscous flows, Chiron et al., JCP 2019", allowing to investigate problems involving complex flows in presence of complex geometries, such as the hydroplaning phenomenon (Chiron et al., JCP 2019), the helicopter ditching (Oger et al. Journal of Hydrodynamics, 2020), the landslide phenomenon (Ghaïtanellis et al., Journal of Hydraulic Research, 2021).

For these reasons, we think that this paper deserves to be nominated for the Monaghan Prize.

PAPER #3

TITLE: Convergence of the Smoothed Particle Hydrodynamics. Method for a Specific Barotropic Fluid Flow: Constructive Kernel Theory.

AUTHORS: Franz, T., Wendland, H.

BIBLIOGRAPHIC DETAILS: SIAM Journal of Mathematical Analysis, 50(5), 4752-4784 (2018).

GRAND CHALLENGE(S) ADDRESSED:

- GC#1: Convergence, consistency and stability

MOTIVATION:

There are many papers in the considered period which have contributed to the progress of the Smoothed Particle Hydrodynamics (SPH) method. Turbulence models or particle shifting techniques, among other topics, have been investigated leading to cited and influential papers, known by all the SPH community. However, we dare to nominate one paper which may not be so well known but is, in our opinion, as relevant as those in regards to the progress, prestige and rigor of the method. In particular, it implied significant increase of knowledge regarding the Grand Challenge: Convergence, consistency and stability. The paper chosen,

Franz, T., Wendland, H. (2018). Convergence of the Smoothed Particle Hydrodynamics Method for a Specific Barotropic Fluid Flow: Constructive Kernel Theory. SIAM Journal of Mathematical Analysis, 50(5), 4752-4784. https://doi.org/10.1137/17M1157696

is the product of the work of Dr. Tino Franz and Dr. Holger Wendland, members of the "Applied and Numerical Analysis" group at the University of Bayreuth. It addresses the important topic of the convergence of the SPH method. In particular, the Euler equations, using a barotropic equation of state to link pressure and density, are studied. The convergence of a semi-discrete SPH scheme is established provided that the kernel function satisfies several requirements. The scheme is semi-discrete in the sense that the time appears as a continuous variable. Finally, examples of kernels satisfying the aforementioned requirements are provided. Regarding its influence in the work of our research group, this paper has motivated posterior publications looking at the convergence of the method in different specific cases. In particular, the Hydrostatic problem at the continuous level was addressed in [1]. As a continuation of that research, the discrete version of the hydrostatic problem was treated in [2]. That work, presented in the SPHERIC HARBIN 2020, was awarded with the "Outstanding Student Paper Prize". Along that line, further research has been conducted by studying the Laplacian operator at the continuous level, leading to the obtention of a proof of convergence for the heat equation, presented in the 2021 SPHERIC congress. During the last months, those results have been extended to more complex cases involving the advection-diffusion equation with non constant velocity fields and will be published soon. We found in the nominated paper, as a relevant achievement in the establishment of the convergence of the SPH method, the motivation to develop these works. As a final remark, we think the paper is influential because it presents a complete proof of convergence of a semi-discrete SPH system. These studies are very rare in literature. While other works have addressed the topic of convergence in the context of particle methods, this is one of the few referring to SPH specifically. We believe this is a very relevant achievement for the SPH community and hope that awarding the Joe Monaghan Prize to this work will inspire other researchers to deepen into the topic of convergence.

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PAPER #4

TITLE: Incompressible smoothed particle hydrodynamics (SPH) with reduced temporal noise and generalised Fickian smoothing applied to body–water slam and efficient wave–body interaction

AUTHORS: Alex Skillen, Steven Lind, Peter K. Stansby, Benedict D. Rogers,

BIBLIOGRAPHIC DETAILS: Computer Methods in Applied Mechanics and Engineering, Volume 265, Pages 163-173, (2013).

GRAND CHALLENGE(S) ADDRESSED:

- GC#1: Convergence, consistency and stability

MOTIVATION:

The paper presents the application of ISPH models to a class of very challenging free-surface flows which are difficult to model with conventional Eulerian schemes. In particular, the paper demonstrate the importance of adopting a partice correction algorithm to improve the accuracy of SPH spatial interpolation.

This work has inspired many other authors which have introduced the particle shifting in several different variants of SPH including ALE-SPH, delta-SPH etc. In my opinion particle shifting represents one of the most significant improvements introduced in SPH schemes in the period 2013 - 2018 not just in the ISPH scheme, but in all variants of SPH that are proposed in literature.

Many very complex engineering problems which where considered too complex 10 year ago, can be now successfully simulated with SPH mainly thanks to the introduction of particle shifting.

PAPER #5

TITLE: Variable resolution for SPH: a dynamic particle coalescing and splitting scheme

AUTHORS: Vacondio, R., Rogers, B. D., Stansby, P. K., Mignosa, P., & Feldman, J.

BIBLIOGRAPHIC DETAILS: Computer Methods in Applied Mechanics and Engineering, 256, 132-148 (2013).

GRAND CHALLENGE(S) ADDRESSED:

- GC#3: Adaptivity

MOTIVATION:

In this work a novel SPH variable resolution method is presented. It is based on the use of particle splitting and coalescing techniques which dynamically modify the particle sizes, providing high resolution only where it is needed. The proposed method guarantees the mass and momentum conservation for particles with different smoothing lengths. The algorithm is tested against analytical solutions for Poiseuille and Taylor–Green flows and also on other benchmark test-cases of increasing difficulty. This paper has a fundamental importance in GC#3, being a pioneering work for particle splitting and merging techniques and paving the way to more advanced adaptive schemes.

PAPER #6

TITLE: On the maximum time step in weakly compressible SPH

AUTHORS: Violeau D., Leroy A.

BIBLIOGRAPHIC DETAILS: Journal of Computational Physics, Volume 256, Pages 388-415 (2014). https://doi.org/10.1016/j.jcp.2013.09.001

GRAND CHALLENGE(S) ADDRESSED:

- GC#1: Convergence, consistency and stability

MOTIVATION:

The paper presents a rigorous study on stability of weakly compressible SPH. The authors present a theoretical stability criterion for the time step, depending on the kernel standard deviation, the speed of sound and the viscosity. The stability domain appears to be almost independent of the kernel choice for a given space discretisation. Numerical tests show that the theory is very accurate, despite the approximations made. The authors then extend the theory in order to study the influence of the method used to compute the density, of the gradient and divergence SPH operators, of background pressure, of the model used for viscous forces and of a constant velocity gradient. The influence of time integration scheme is also studied, and proved to be prominent. All of the above theoretical developments give excellent agreement against numerical results. It is found that velocity gradients almost do not affect stability, provided some background pressure is used. Finally, the case of bounded flows is briefly addressed from numerical tests in three cases: a laminar Poiseuille flow in a pipe , a lid-driven cavity and the collapse of a water column on a wedge.

On Using SPH to Study Nuclear Severe Accidents

Young Beom Jo[1], Hee Sang Yoo[1], Tae Soo Choi[1], Tae Hoon Lee[1], Jin Woo Kim[1], Su-Jong Yoon[2], Tae-Sic Yoo[2], and Eung Soo Kim[1]*

*kes7741@snu.ac.kr

[1]Department of Nuclear Engineering, Seoul National University, South Korea

[2]Idaho National Laboratory, USA

After the TMI, Chernobyl and Fukushima accidents, extensive research has been conducted on the nuclear severe accidents around the world, which may result in catastrophic core melt-down and large radioactive release. Based on those efforts, much knowledge had been accumulated on understanding various key safety phenomena and analyzing their progress & consequences. However, there are still lots of uncertainties to be understood or clarified due to the complexity in phenomena, difficulty in experiment, and empiricism in modeling [1,2].

Traditionally, the analysis for nuclear severe accident have been based on empirical-based simple lumped-parameter (LP) models. However, recent advancement in computational fluid dynamics (CFD) and high-performance computing (HPC) is opening up new possibility to fill the gap between the empirical models and the reality by enabling realistic visualization and numerical reproduction of key safety-related phenomena. Especially, the use of particle-based methods such as smoothed particle hydrodynamics (SPH) and discrete element method (DEM) can contribute to understanding severe nuclear accident not only by diversifying the computational tools but also by providing physical insights into the mitigating measures due to their multi-physics capability & geometrical flexibilities.

In this respect, Seoul National University (SNU) is developing a particle-based simulation framework (named as SOPHIA) for nuclear engineering and safety purpose [3,4]. This in-house code is written in C++ and fully parallelized with MPI (multi-nodes & multi-GPUs). In terms of physical models, the current code has the capability to handle various combined physical/chemical phenomena: (1) fluid flow, (2) heat transfer, (3) turbulence, (4) multi-phase, (5) melting & solidification, (6)diffusion, (7) fluid structure interaction, (8) chemical reactions, (9) solid body interactions, (10) shockwaves, and etc. This code incorporates SPH, DEM and Lagrangian stochastic method (LSM) with a coupling platform with a conventional nuclear system analysis code for multi-scale nuclear applications. Several feasibility studies of the SPH for the nuclear severe

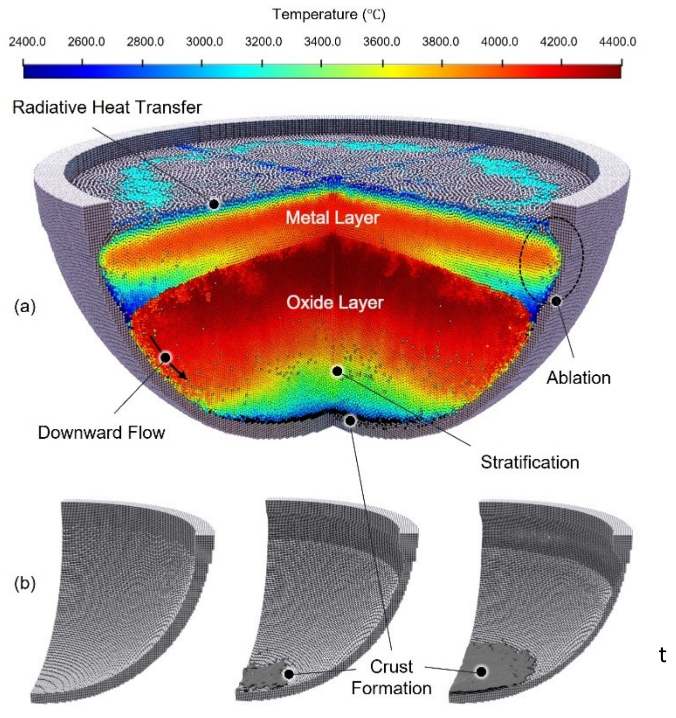

Figure 1 - . Example of IVR-ERVC Simulation: Considering the reactor vessel external wall ablation under the APR-1400 reactor conditions, the temperature distribution of the core melt (a) and crust formation (b) at t=0s, 200s, 1000s are illustrated.

accident applications have been being conducted in recent years and some of them are introduced below.

In-Vessel Retention through External Reactor Vessel Cooling (IVR-ERVC) is a major severe accident early termination strategy for conventional light water reactors (LWRs), which confines the core-melt inside the lower head of the reactor vessel [5]. The main safety issues on the IVR-ERVC strategy are related to the coolability of the core-melt releasing decay heat and the structural integrity of the vessel walls with ablation thickness. To simulate the IVR phenomena, the stratified core-melt behaviors were modeled using SPH (natural convection, stratification, thermal ablation, crust-formation, turbulence, etc), and the external water pool was modeled by a nuclear system analysis code. The two numerical methods were integrated via socket networking. Figure 1 shows that the proposed SPH-system-code model can capture the key safety phenomena regarding IVR-ERVC.

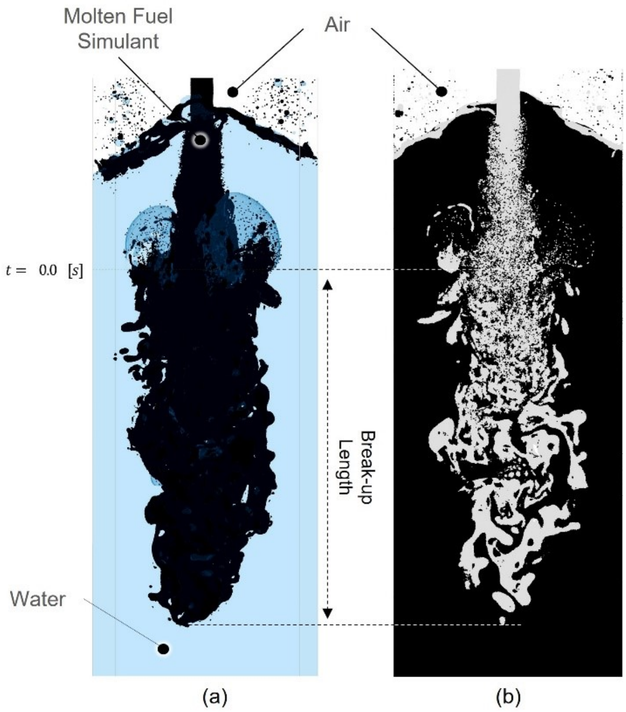

Figure 2 - SPH Simulation on fuel-coolant interaction (FCI) : A jet column (10mm diameter) was injected into water a water pool (0.1m*0.02m*0.4m) with 3.8 m/s speed. 3D particle image (a) and 2D cross-sectional snapshot (b) at t=0.265s are shown.

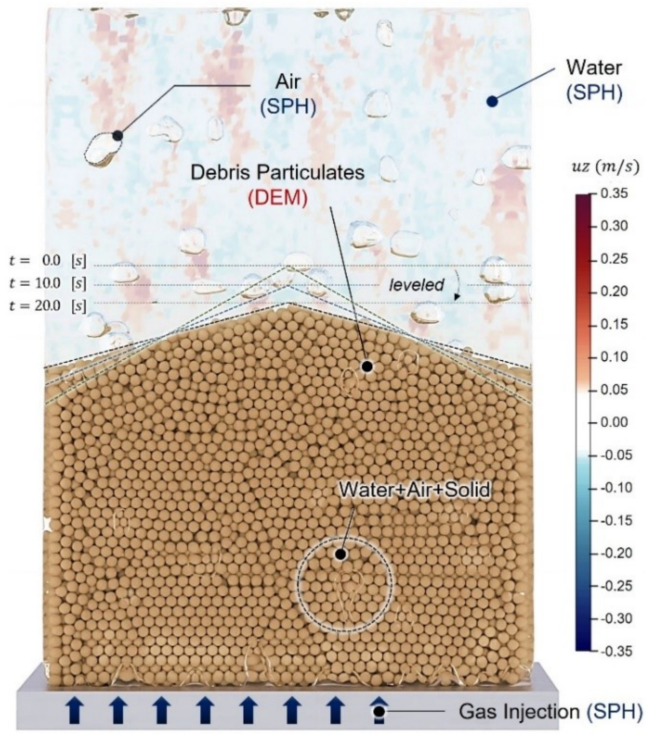

Figure 3 - SPH-DEM Simulation on Debris Self-leveling Effect: The surface shape of the debris particles (DEM, D=6mm) is leveled by the gas flow (SPH, 5.04 mm/s) injected from the bottom of the water tank (SPH, 0.5m*0.055m*0.25m). The configuration of debris particles at t=0.0s, 10.0s, 20.0s are highlighted with dashed lines.

Energetic fuel-coolant-interaction (FCI), which occurs when high temperature molten-fuel-jet penetrates the coolant, can threaten the reactor cavity integrity sometime by triggering steam explosion [6]. Figure 2 shows the SPH simulation conducted for the FCI isothermal benchmark experiment. Overall, the simulation reproduces well the jet break-up and hydraulic fragmentation compared to the experimental observations, for which the conventional CFD software have difficulties in modeling.

In the late phase of the LWR severe accident, particulate fuel debris may sediment on the concrete basement with a conical shape. In this case, the cooling of the debris bed is a critical safety issue since it generates decay heat continuously. In

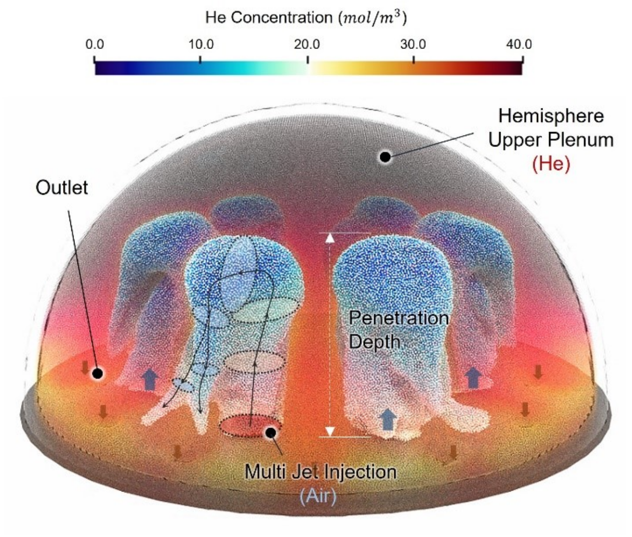

Figure 4 - Snapshot of Turbulent Multi-jet Gas Mixing Simulation in Reactor Upper Plenum: Air flow with Re=4,000 is jetted into the plenum (He) through 6 inlets, while He-Air mixture exits through 12 outlets. As the inflow multi-jet develops into plumes, the penetration depth is shorter than the plenum radius. Since the inflow gas proceeds in the form of plumes, gas mixing by inertia is more dominant than diffusion by turbulent eddies.

the traditional severe accident analysis, the shape of the debris bed is typically assumed as a user input. However, this conical-shaped bed can be levelized due to the two-phase natural convection flow. This so-called self-leveling phenomenon is an important issue in terms of mitigation of severe accident [7]. To simulate this self-leveling phenomenon, SPH and DEM are integrated under the GPU-parallelized framework, where gas and liquid phases are simulated using SPH while the solid phase is simulated using DEM. Figure 3 shows that the 2-way SPH-DEM coupling is capable of reproducing the self-leveling phenomena in both a qualitative and quantitative manner.

During a severe accident, flammable gases such as hydrogen and carbon monoxide are produced, and it can be the serious threat to the containment integrity [8]. In order to evaluate the potential risk of explosive reaction properly, mixing of gaseous species should be well predicted. To simulate this phenomenon using SPH, multi-component gas mixture model was applied with conventional turbulence models. Figure 4 shows the simulation results of the turbulent multi-jet with simplified reactor upper plenum structure.

In addition to severe nuclear accidents, the SPH can be a great numerical tool for nuclear fuel cycle and waste management. In the pyro-processing, oxide reduction process which converts uranium oxides to metals is essential to feed the metallic product in subsequent processes [9]. To model its reduction kinetics, the phase interface between molten salt and oxide materials should be located effectively. Armed with the interface tracking capability, the SPH simulation reproduced the experimental observations successfully and estimated effects of basket thickness, feed material shapes and molten salt flow on the reduction process in complex and realistic reduction geometries as shown in Figure 5.

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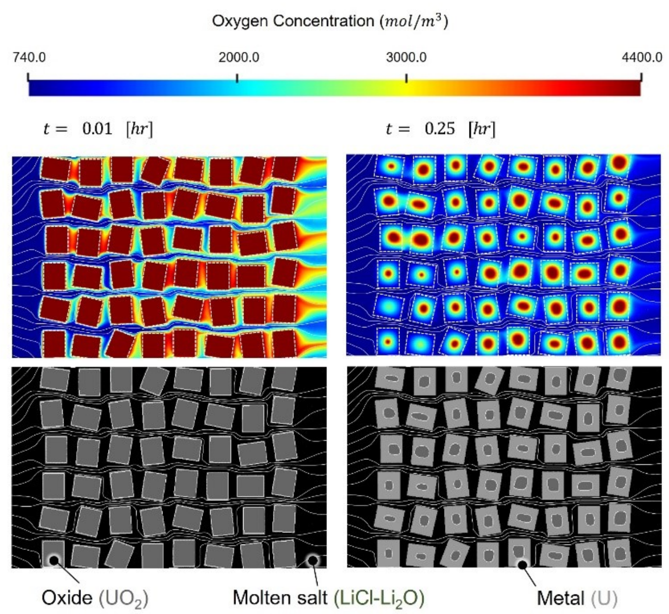

Figure 5 - Simulation of Oxide Reduction of a Pelletized Oxide Fuel for Pyro-processing: Oxygen is actively transported from the oxide fuels to the bulk molten salt by convective diffusion, and fast material conversion of UO2 to U is achieved. The Peclet number of the system was set to be 562, and the fuel pellets (2mm*2.5mm) were uniformly distributed with porosity of 0.48.

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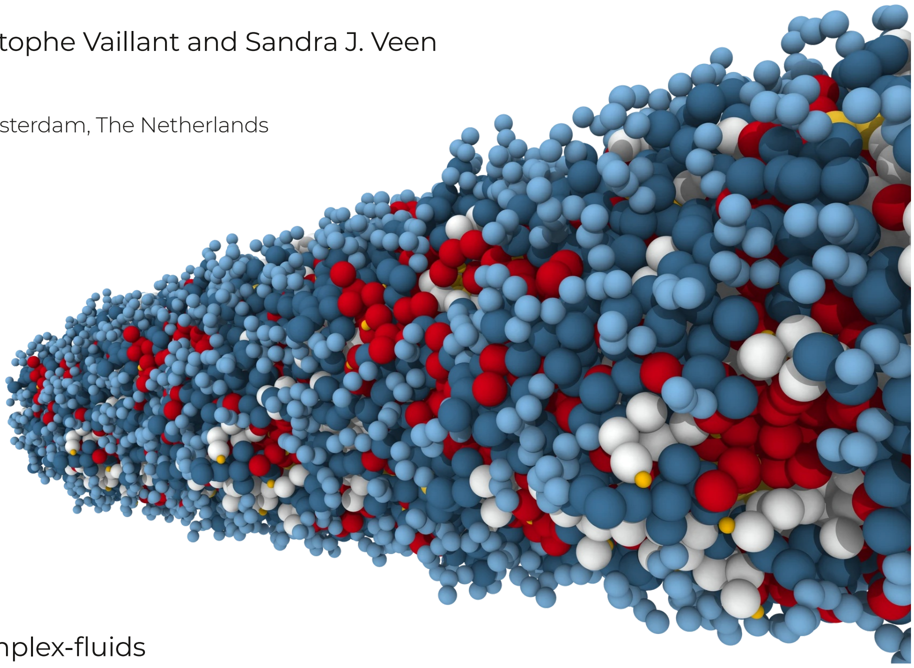
RheoCube: a cloud based simulation software for experimental scientists

Qingguang Xie, Merit van der Lee, Christophe Vaillant and Sandra J. Veen

q.xie@electricant.com

Electric Ant Lab B.V., Science Park 106, 1098 XG Amsterdam, The Netherlands



Smarter, faster R&D cycles

RheoCube is a user-friendly complex-fluids simulation tool designed for experimental R&D scientists. It allows the user to create a digital version of their ingredients, and thus, from these, a formulation. Users can run virtual experiments on their formulations with RheoCube's simulation engine and cloud-based high performance computing platform thus giving the user insights into the microstructure of their products. This allows a user to study the static and dynamic properties (e.g. stability, rheology) of their system and how changes in ingredients or environmental parameters will affect these properties. All this leads to increased understanding of formulations, thereby shortening R&D cycles. Typical systems that can be studied with RheoCube are suspensions and emulsions, or more generally, systems that have structures resolved at the micrometer scale. Performing such virtual experiments allows the user to create ingredients before they are made in the lab, which can be a very time consuming process. For example, particle ingredients (food ingredients, coatings, adhesives) can be designed in such a way that they have the desired rheological behavior and stability in their final formulations. A formulator then only needs to make or buy the particles that give the most promising results in RheoCube for their final physical product testing.

In a similar way, RheoCube can help troubleshoot deviations in the product behavior. By having the flexibility of changing the particle shape/size/chemistry, scientists can pinpoint the cause of their problems in a much faster and systematic manner. This will also lead to long term benefits due to enhanced understanding of their formulations and its ingredients. The simulations are not limited to particle systems, but also allow fluid interactions, and even more complex systems like surfactant and polymer solutions, to be studied with RheoCube's microscale extension. Overall, RheoCube is a powerful R&D tool that leads to smarter research and removes tedious trial-and-error work that is still too often the standard in the chemical industry.

Meso- and micro-scale models

Our technique of choice for complex fluid simulations on the meso-scale is Smoothed Particle Hydrodynamics (SPH). We have chosen this method for various reasons, ranging from the ability to introduce molecular interactions to solving transport and flow fields with clear separation of advection and diffusion. Since its invention a few decades ago, the SPH method has been improved and extended to a vast range of problems in both fluid and solid mechanics because of its superior ability to incorporate all relevant physics within one consistent theoretical framework. SPH is also well-parallelizable, which is a crucial prerequisite for solving complex computational problems of application-relevant size within acceptable time frames.

In order for mesoscale simulations to capture the correct physics, it is important for models to contain information from the microscopic scale. One way to obtain detailed information on the physics of the microscale is to perform "molecular dynamics" (MD) simulations. MD simulations are a general way of simulating atoms and molecules on the microscale, by solving the equations of classical mechanics. The forces between individual atoms and molecules are derived from the electrostatic interactions between them. If we were to include every atom in the simulation, the typical simulation time would be on the order of weeks. One solution is to perform what is known as "coarse-grained molecular dynamics" (CGMD). In CGMD, one collects together several atoms into a single "bead", and matches the corresponding interactions.

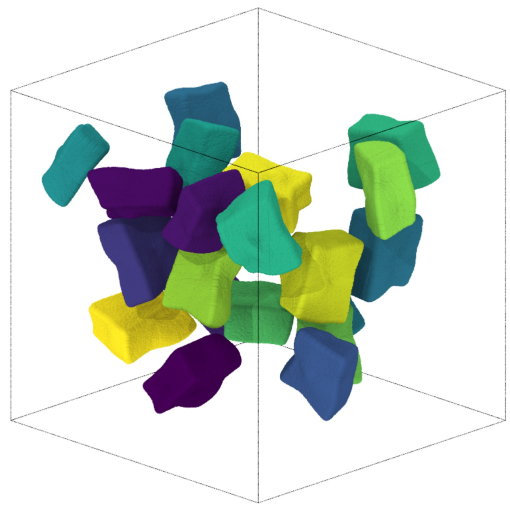


Figure 1 - Snapshot of a smoothed particle hydrodynamics simulation of particle suspensions

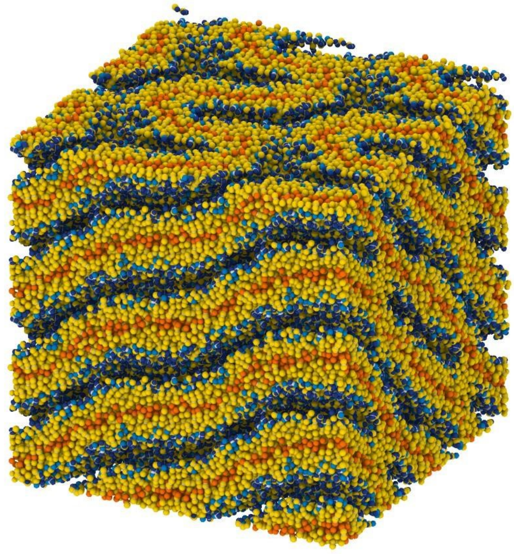


Figure 2 - Snapshot of a coarse-grained molecular dynamics simulation of monoolein, a common lipid, forming a liquid crystal structure when mixed in water (not shown)

Instead of "hundreds of thousands of atoms", we now have a more manageable "thousands of beads". With RheoCube, the CGMD models and the interactions are automatically generated based on the input that the users set.

Pre/post-processing and cloud resources

As a cloud solution, RheoCube does not require any software installation. Users can easily set up the simulation system on their own secure RheoCube webpage. Afterwards, the simulations are pre-processed and executed on cloud resources. The generated data is stored in the cloud and accessible through user's own RheoCube environment from any computer with internet access. Rheocube has its own data analysis and visualization tools, which are managed through the RheoCube webpage. The data and results can be downloaded and used in other media, e.g. presentation, reports, or manuscripts.

Information on Two Recent SPH Special Issues

Abbas Khayyer

khayyer@particle.kuciv.kyoto-u.ac.jp

Kyoto University, Japan

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This article presents a brief report on two recent Special Issues dedicated to SPH, published in Applied Ocean Research and European Journal of Mechanics B/Fluids.

The SPH Special Issue published in Applied Ocean Research has already been finalised with a total number of 18 high quality papers:

https://www.sciencedirect.com/journal/applied-ocean-research/special-issue/10J5G0NGSKW

corresponding to advanced coupled particle methods, comprehensive review articles, applications of SPH in ocean engineering and new developments for SPH or MPS, as briefly described in the special issue's Preface. As the managing guest editor, the author of this article sincerely appreciates the great support and professional collaborations by **Professor Benedict Rogers and Professor A-Man Zhang**, as other guest editors of this special issue. We are also grateful to all reviewers of this special issue for their thorough and timely reviews as well as all contributing authors, as also highlighted in the special issue's preface.

The SPH Special Issue of European Journal of Mechanics B/Fluids is in progress:

https://www.sciencedirect.com/journal/european-journal-of-mechanics-b-fluids/special-issue/10L644QW8D6

We received 28 manuscripts and 4 have already been accepted and published. The author of this article would like to express his sincere gratitude to other guest editors of this special issue including **Professor Damien Violeau, Professor Songdong Shao** and **Dr Danilo Durante**, as well as all respected reviewers and all contributing authors.

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Contact: renato.vacondio@unipr.it