# Can SPH be competitive with conventional engineering simulation? Towards Higher-order SPH simulations

**Benedict D. Rogers**

* Modelling and Simulation Centre (MaSC), School of Mechanical, Aerospace and Civil Engineering (MACE), University of Manchester, Manchester, United Kingdom
e-mail: benedict.rogers@manchester.ac.uk, web page: https://www.mace.manchester.ac.uk/

## ABSTRACT

As a meshless method, smoothed particle hydrodynamics (SPH) has long been promoted as being able to simulate cases and applications that are beyond existing commercial engineering software packages. Applications range from free-surface hydrodynamics, breaking waves and maritime engineering, to multi-phase and multi-component mixing in process industries to highly-explosive material deformation. However, in engineering practice, users remain loyal to existing software and methods for a variety of reasons. One of the most limiting features of SPH has been the lack of higher-order convergence. While the theoretical basis for its behaviour is gradually improving ([1], [3]), engineers in industry continue to identify the lack of higher-order convergence behaviour as being inferior to existing mesh-based solvers such as spectral-based methods. In industries that are highly regulated for public safety, such as the nuclear and aerospace industries, this limitation prevents engineers even contemplating using SPH for a specific application. This presentation will examine the causes and present the new research ideas in this area.

The presentation will cover how the issues are being addressed. Specifically, the talk will discuss the elements of the SPH formulation and particle interpolation process which have traditionally limited a simple extension of SPH to higher-order and then how new developments are tackling these issues. Stabilisation techniques whose theoretical foundation are being developed and secured, such as particle shifting and density diffusion, will be examined to indicate how we can exploit the drawbacks of SPH to include high-order ($4^{th}$, $6^{th}$, $8^{th}$ order) numerical convergence [3] and address one of the Grand Challenges of SPH [4], extending boundary conditions to high order. Finally, some ideas on how to extend higher-order behaviour in the context of variable resolution will be presented.

Some initial applications of these developments will be shown including incompressible flows in confined geometries where the complication of a free surface is avoided. The implications for implementation within popular current SPH solvers such as DualSPHysics [5] will be also be discussed where the hardware acceleration can pose obstacles to the development.

## REFERENCES

[1] Franz, T., Wendland, H., 2018, Convergence of the Smoothed Particle Hydrodynamics method for a specific barotropic fluid flow: Constructive Kernel Theory, *SIAM J. Math. Anal*., 50(5), 4752-4784.

[2] Evers, J.H.M., Zisis, I., van der Linden B.J., Duong, M.H., 2018, From continuum mechanics to SPH particle systems and back, ZAMM *Z. Angew. Math. Mech*. 98(1), 106-133.

[3] Lind, S., Stansby, P.K. 2016. High-Order Eulerian Incompressible Smoothed Particle Hydrodynamics with Transition to Lagrangian Free-Surface Motion. *Journal of Computational Physics*, 326.

[4] SPHERIC Grand Challenges #1 and #2: http://spheric-sph.org/grand-challenges

[5] Crespo AJC, Domínguez JM, Rogers BD, Gómez-Gesteira M, Longshaw S, Canelas R, Vacondio R, Barreiro A, García-Feal O. 2015. DualSPHysics: open-source parallel CFD solver on Smoothed Particle Hydrodynamics (SPH). Computer Physics Communications, 187: 204-216.