Topic: Development of a monolithic first-order conservation law framework for fluid structure interaction

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Funding: EPSRC DTP Scholarship (3.5 years)

Project Description

The computational analysis of fluid structure interaction phenomena is widely used these days for a wealth of industrial and physical applications. In particular, the field of renewable wave energy (see Figure 1) has observed a surge in Scotland (and the UK) over the last few years in the application of these computational techniques for the modelling of flexible elastomer-based structure interacting with fluids under harsh environment. Some of these problems are highly challenging, requiring the modelling of highly deformable (and nearly incompressible) solids immersed with a surrounding incompressible Newtonian fluid. In this case, a fast and robust computational framework becomes essential for a successful simulation.

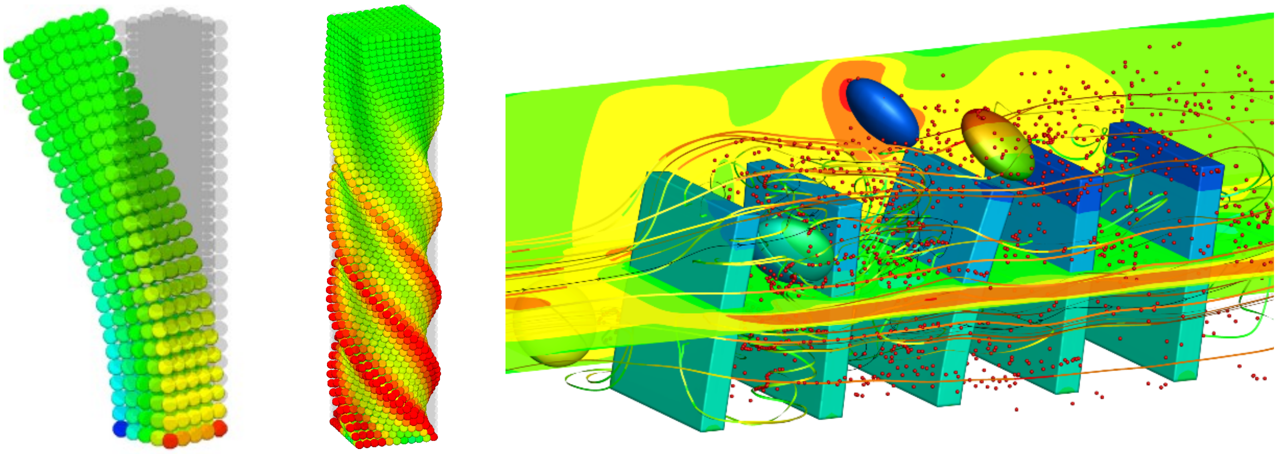

Figure 1: Wave energy converter applications. (Left to right) Bending mode, torsional mode and FSI membrane.

Building upon recent discoveries (i.e. first order conservation law for solid dynamics) made by the supervisory team, the objective of this PhD is the further development of a novel 3D Smoothed Particle Hydrodynamics (SPH) framework with significantly improved properties with respect to the current state of the art. Initial implementation has been carried out in Matlab platform, with very promising results in some extremely challenging solid dynamics problems. Interestingly, the methodology will borrow concepts from Computational Fluid Dynamics and apply them to Computational Solid Dynamics in a way that will greatly enhance the robustness and accuracy of the simulations, with the final aim to handle fluid-structure interaction.

The recruited PhD candidate will become a member of an active research group working on the development and application of cutting-edge computational techniques for large strain solid dynamics, fluid structure interaction and computational multi-physics.

Project Summary

Traditional low-order finite element/finite volume formulations are typically employed in Industry when simulating complex engineering large strain fluid structure interaction problems. However, this approach presents a number of challenging shortcomings, namely: (1)

unable to accurately and reliably capture the initiation and propagation of strong discontinuities in solids/fluids, (2) poor resolution for strains and stresses, (3) poor performance in nearly incompressible solids (with path-dependent solid model such as large strain visco-elasticity), (4) numerical artefacts in the form of shear/bending locking, volumetric locking and spurious pressure modes and (5) inefficient in massive deformation problems involving topological change such as breaking waves and/or material separation.

The objective of this PhD is the development, implementation and benchmarking of a new monolithic computational framework for the numerical analysis of fluid structure interaction problems, with special emphasis on highly deformable structure interacting with violent fluid impact. The recruited PhD candidate will extend the new SPH algorithm, recently developed by the supervisory team, to include the ability of (1) modelling large strain viscoelastic solids, (2) incorporating particle shifting technology inspired by the new Arbitrary Lagrangian Eulerian formalism recently proposed by the supervisory team and (3) coupling with incompressible fluid solver (i.e. implicit incompressible SPH) already well established in the SPH community. In this algorithm, the solid-fluid coupling conditions on the interface will be solved via a physically based Riemann solver. In addition, for problems involving extremely massive deformations, it may be necessary to shift the particles to maintain both regular particle distributions and the solution accuracy. New boundary corrections will also be explored to allow for the direct enforcement of traction and velocity at the interface conditions whilst still ensuring the discrete satisfaction of the second law of thermodynamics.

To guarantee the impact and the legacy of the project, the numerical developments throughout the project duration will be implemented in the SPH open-source codes such as DualSPHyics. Interestingly, the new framework will pave the foundation for the unified modelling of multi-material and multi-phase engineering problems of interest to industry.

This PhD project, together with the support of Glasgow Computational Engineering Centre (GCEC), will further strengthen the depth and breadth of the expertise in building University of Glasgow (UofG) to become the UK's leading institution in the area of Computational Engineering. This indeed aligns with the UofG's Research Strategy 2020-25, by working in teams to tackle urgent problems (i.e. commitment to net-zero via renewable ocean energy wave) in our society, building on each other's idea, and making UofG the best place to develop a career, our research transforms lives and changes the world.

How to Apply

All interested candidates are invited to apply. The application process includes three steps:

1. Get in contact with us by sending email with a CV attached to chunhean.lee@glasgow.ac.uk. After an informal interview, we will support most suitable candidates towards the scholarship application.
2. Complete the academic application on the Infrastructure and Environment Division page, submitting relevant documents such as CV, transcripts, references and a research proposal. The deadline for the academic application is **29 May 2023**.
3. Complete the EPSRC scholarship application via online portal gla.ac.uk/ScholarshipApp/ including the candidates's statement of motivation. The deadline for the scholarship application is also **29 May 2023**.