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Discrete multi-physics: a mesh-free approach for blood modelling in flexible biological valves including the formation of solid aggregates (thrombus, emboli, calcification).

Case study

Client Profile
Mostapha ARIANE
PhD student
School of Chemical Engineering
College of Engineering & Physical Sciences
University of Birmingham

Contact Details
mxa437@bham.ac.uk

Product Used
LAMMPS
OpenMPI v1.6.3
C++

Contributors
Dr. Alessio ALEXIADIS
Prof. Mostafa BARIGOU
(University of Birmingham)

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School of Chemical Engineering

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Challenges

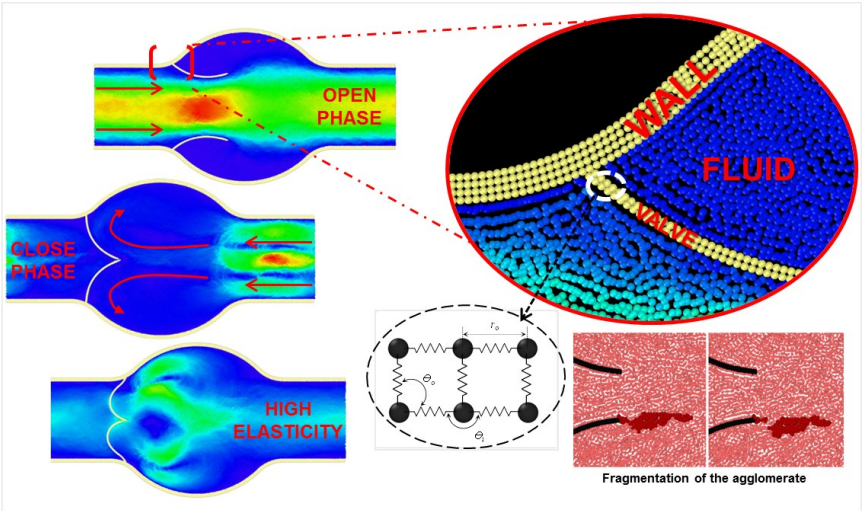
Modelling hydrodynamics, the membrane deformation and the formation of solid aggregates **in a single step** with the help of the High Performance Computing (HPC) Bear cluster.

Background

Computational fluid dynamic (CFD) simulations of biological valves have steadily improved over the years; however, procedures accounting for the formation of actual solid aggregates, such as calcification or clots, have not been implemented yet. At the same time, researchers have also devised mathematical models for clot formation and growth; however, these models have been developed independently and are not usually associated with the dynamics of the valve. We propose a particle-based method that, by taking advantage of its mesh-free nature, can compute the fluid dynamics, together with valve deformation and formation of solid aggregates.

Results

This original approach shows that, in certain circumstances, it is more than a mere alternative to traditional modelling. Discrete multi-physics can tackle, with relatively little effort, problems that are considered very challenging with mesh-based multi-physics. Elsewhere, [1] focused on solid-liquid flows where the dispersed phase is made of deformable, breakable, dissolving, melting or solidifying particles. Here, we apply the same approach to biological valves including the formation of solid aggregates in the flow and at the membrane surface. To the best of our knowledge, this is the first study to directly account for the hydrodynamics, the membrane deformation and the formation of solid aggregates at the same time and, as such, it has the potential to open a new prospective to the modelling of biological valves.



Hybrid SPH modelling of an aortic valve with flexible leaflets

[1] Alexiadis A. (2015a), The Discrete Multi-Hybrid System for the simulation of solid-liquid flows, PLoS ONE 10: e0124678.

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