Refined modeling of suspensions of red blood cells and ellipsoidal micro-capsules

Research laboratory Université de Technologie de Compiègne
Biomechanics & Bioengineering Laboratory (BMBI), UMR CNRS 7338
"Biological Fluid Structure Interactions" Team (http://www.utc.fr/bmbi/spip.php?article378)

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Scientific domains **Biomedical and health science engineering**, Science and technology

Research work

Micro-capsules are small liquid droplets enclosed by a thin deformable membrane, which separates and protects the internal fluid from the environment and controls the exchanges. Examples of natural capsules are the red blood cells, which are essential for oxygen and carbon dioxide transport. Artificial capsules have many applications in various industrial applications (biotechnology, pharmacology, cosmetics, food industry). One application with high potential is their use for **drug targeting**. When flowing in microvessels, capsules and cells are subjected to complex flow conditions due to changes in cross-sections and the presence of bifurcations.

Like red blood cells, artificial capsules take complex deformed shapes under flow, with potential membrane wrinkling and fatigue breakup. It is important to predict those phenomena in order to avoid/provoke membrane rupture.

The objective of the thesis is to study the dynamic motion, deformation and path selection of a micro-capsule inside a **complex network** as a function of the **capsule properties** and **concentration of the capsule suspension**. The numerical model will be run using an open-source fluid-structure interaction solver. The results will be compared to those provided by the boundary integral-finite element codes available in the team (Hu et al. 2012, Dupont et al. 2015 available at http://www.utc.fr/~salsacan/).

This topic represents a key challenging problem to understand cell mechanics and path selection in a network.

Keywords Cell biomimetic models, microencapsulation, fluid-structure interactions, numerical simulations

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Research team

The project will take place within the Biological Fluid-Structure Interaction Group (~20 persons), directed by A.V. Salsac, which is one of the 3 research teams of the UTC Biomechanics & Bioengineering Laboratory (BMBI). The team is one of the leading groups specialized in the fields of biofluids and hemodynamics at both the microscopic and macroscopic scales. The strength of the group is the long-standing expertise in numerical and experimental modeling of the fluid-structure interactions associated with blood flows and of innovative endovascular techniques.

Scientific context

The project will be inserted within the context of the **MultiphysMicroCaps ERC Consolidator Grant (PI: Dr Salsac)**, that explores the use of deformable liquid-core capsules of micrometric size to efficiently transport active material, with a primary focus on health-related applications. The project is focused on the design of innovative sophisticated numerical models and high-tech experiments, needed to determine the potential of such vectors for the protection of active substances, predict membrane breakup to control the delivery, and optimize their properties for specific industrial and biomedical applications.

Supervisors

After having graduated from UCSD & Ecole Polytechnique with a PhD in Biofluids, **Dr Anne-Virginie Salsac** spent two years at University College London as a Lecturer and was recruited by the CNRS in 2007. She is CNRS Director of Research (equivalent to Professor at university) at BMBI and Visiting Professor at Queen Mary University of London. She has been awarded various prices, including the CNRS bronze medal in 2015 and National Order of Merit in 2016, for her research on vascular mechanics, the microcirculation and biomedical engineering applications. She has authored over 200 papers and conferences and is co-inventor of one patent. She is strongly involved in dissemination of scientific activities (Femmes en Or, Three Minute Thesis …) and has a strong involvement in institutional activities (member of the interdisciplinary section 54 of CoCNRS, elected member of the Scientific Council at UTC).

Prof. Florian de Vuyst is specialized in the development of new tools for numerical modeling in fluid mechanics, with a particular focus on reduced-order modeling. He is specialized in the development of numerical techniques to model multiphysics engineering problems and to optimize large-scale problems by model reduction approaches. He has also worked on GPU-accelerated CFD algorithms.

Material resources

The Biological Fluid Structure Interaction team has all of the tools and equipment to run cutting edge numerical simulations and experiments on microcapsules suspensions

For the numerical simulations:

- Fluid-structure simulation codes based on the coupling between the Boundary Integral Method to solve for the fluid flow and the Finite Element Method for the capsule wall deformation
- Workstations, server, software

For the microfluidic experiments:

- Microsystem fabrication room
- Microfluidic platform equipped with microscopes, pressure flow controllers, flowmeters, high-speed cameras)
- Counter-rotating plate rheometer

Human resources

The Biomechanics & Bioengineering laboratory is composed of:

- 40 permanent staff members (27 academic staff, 13 technical and administrative staff)
- 31 PhD students
- 8 Postdocs
- 7 associated researchers
- 15 Master students

Related collaborations

- Prof de Vuyst, Compiègne Applied Mathematics Laboratory (Université de Technologie de Compiègne, France)
- Prof. Barthès-Biesel, Biomechanics & Bioengineering Laboratory (Université de Technologie de Compiègne, France),
- Prof. Villon, Roberval Laboratory, Université de Technologie de Compiègne
- Prof. Hu, College of Mechanical and Vehicle Engineering (Hunan University, China),
- Prof. Le Tallec, Solid Mechanics Laboratory (Ecole Polytechnique, Palaiseau, France).

Requirements

We are looking for highly motivated, dynamic, conscientious and rigorous candidates, who will be fully involved in the project and eager to integrate our research team.

Technical skills: Strong knowledge in fluid/solid mechanics and in numerical simulations/numerical methods. Interest in bioengineering/biophysics. Knowledge in artificial intelligence algorithms or order reduction methods will be a plus.

Other skills: proficiency in English, ability to adapt and anticipate, team spirit

Contact

To apply please send a complete CV, a letter of motivation, 2 letters of recommendation or the contact details of 2 referring persons, as well as the result transcripts for all the courses followed at university to:

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