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, which are fluid droplets enclosed in a thin elastic membrane, are current in nature (e.g. red blood cells), and in various industrial applications (biotechnology, pharmacology, cosmetics, food industry). Artificial microcapsules are used to protect and transport active principles, by isolating them from the external suspending fluid. One application with high potential is their use for **drug targeting**: once injected in the blood flow, the particles are subjected to complex flow conditions. A technique to increase the transfer properties of capsules is to make the particles non-spherical as it increases the surface-to-volume ratio.

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 project is to study the **behavior of ellipsoidal microcapsules or cells in suspension** and analyze the influence of their shape and membrane properties on their dynamics and wrinkle formation, which has never been done so far.

Original and novel enriched modeling strategies will be implemented to simulate the fluid-structure interactions accounting for the finite-thickness of the particle membrane. The numerical model will be based on codes that are available in the team (Walter *et al.* 2011, Hu *et al.* 2012, Dupont *et al.* 2015). It will consist in coupling a shell finite element code for the wall deformation to a boundary integrals code modeling the confined fluid flows (both internal and external to the cell).

The numerical results will be compared to state-of-the art experimental results, previously obtained for artificial capsules in a micro-rheometer. The experimental method consists of measuring the motion and deformation of artificial microcapsules with a membrane made of cross-linked proteins with a high-precision micro-cinematographic method. This comparison will help optimize capsule design and produce biomimetic models of cells.

The project will be conducted in close collaboration with:

- Prof. Dominique Barthès-Biesel from the Biomechanics & Bioengineering Laboratory (Université de Technologie de Compiègne, France),
- Prof. Xuqu Hu from the College of Mechanical and Vehicle Engineering (Hunan University, China),
- Prof. Patrick Le Tallec from the Solid Mechanics Laboratory (Ecole Polytechnique, Palaiseau, France),
- Dr Marina Vidrascu from J.-L. Lions Laboratory (Sorbonne University - INRIA-Paris Institute, France).

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. Dominique Barthès-Biesel, Emerit Professor, is internationally renowned for her pioneering work on the study of capsule dynamics. She is specialized in microhydrodynamics and complex fluids under low Reynolds number flows. She has conjointly held a Professorship at Ecole Polytechnique (Palaiseau, France) for 25 years. She was the Chair of the World Council for Biomechanics until 2018.

Material resources

All of the tools and equipment needed for the project are available in the Biological Fluid Structure Interaction team:

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

- College of Mechanical and Vehicle Engineering, Hunan University (China) – Prof. Hu
- Solid Mechanics Laboratory, Ecole Polytechnique (France) – Prof. Le Tallec
- J.-L. Lions Laboratory (Sorbonne University - INRIA-Paris Institute, France) – Dr Vidrascu
- Molecular Chemistry Institute of Reims, Université de Reims Champagne Ardennes – Dr Edwards-Lévy
- Roberval Laboratory, Université de Technologie de Compiègne – Prof. Villon

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Requirements

We are looking for **highly motivated, dynamic, conscientious and rigorous** candidates, who will be fully involved in the project and eager to integrate the interdisciplinary BFSI research team.
Technical skills: **strong knowledge in fluid and/or solid mechanics**, as well as in **numerical simulations**.
Interest in research topics at the interface between disciplines (in particular in **bioengineering**/biophysics).
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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