

Université de technologie de Compiègne – Thesis proposal

Part 1: Scientific sheet	
Thesis proposal title	Modeling of microcapsules in flow using advanced computational methods to speed up the simulations
PhD grant	Ministry of Research Fellowship
Research laboratory	<i>Laboratory in which the candidate will be recruited:</i> Biomechanics & Bioengineering Laboratory (UMR CNRS-UTC 7338), UTC Compiègne <i>research team:</i> Biological Fluid Structure Interactions <i>web site:</i> http://www.utc.fr/~salsacan/
Thesis supervisor(s)	Dr Anne-Virginie Salsac, CR CNRS (HDR), BMBI, UTC Dr Florian de Vuyst, Prof, LMAC Laboratory, UTC
Scientific domain(s)	Computational Mathematics, Science and technology, Biomedical and health science engineering <i>EURAXESS fields:</i> Biomedical Engineering, Mechanical Engineering, Simulation Engineering, 3D Modelling, Modelling Tools, Computational Mathematics
Research work	<p>Micro-capsules, which are fluid droplets enclosed in a thin elastic membrane, are current in nature (red blood cells, phospholipidic vesicles) and in various industrial applications (biotechnology, pharmacology, cosmetics, food industry). They are used to protect and transport active principles, by isolating them from the external suspending fluid. One application with high potential is the use of microcapsules for active substance targeting, but scientific challenges remain to be met, such as finding the optimal compromise between payload and membrane thickness, characterizing the membrane resistance and controlling the moment of rupture. Once injected in an external flow, the particles are indeed subjected to dynamical loading conditions, which result from the complex 3D capsule-flow interactions. To model them numerically, one needs to account for the non-linear large deformations, which results in large systems of equations and thus in long computational times.</p> <p>The objective of the PhD project is to explore the use of advanced numerical methods to speed up the simulations when solving the interactions between the Stokes flows (internal and external to the capsule) and the deformation of the hyperelastic membrane. Innovative sophisticated numerical methods will be conceived: integration of learning approaches to accelerate the calculation of integrals, addition of innovative pre-conditioners in the resolution of systems of equations.</p> <p>We will then use reduced-order approaches and apply them on the databases of high-fidelity simulations previously obtained. We will use reduction techniques coupling decomposition into eigenmodes (POD) and decomposition by dynamic modes (DMD, EDMD, kernel-DMD). The models will allow a very strong acceleration in computational time, while allowing a detailed analysis of the physics of the problem.</p>
Key words	Microcapsules, fluid-structure interaction, reduced order models, pre-conditioners, numerical complexity
Requirements	<p>Skills:</p> <ul style="list-style-type: none"> - Strong scientific background in scientific computing for fluid-solid mechanics - Notions of biomechanics and bioengineering will be a plus - High skills in English and French - Excellent interpersonal and communication (written and verbal) skills <p>Personal Qualities:</p> <ul style="list-style-type: none"> - Ability to work collaboratively as part of a team in an interdisciplinary context - Flexibility, motivation, pro-activity, commitment to high quality - Work organization - Commitment to continuous educational and professional development - Commitment to UTC's and CNRS' policy of Equal Opportunity, ability to work harmoniously with colleagues and students of all cultures and backgrounds <p>Qualification: MS degree or equivalent qualification.</p>
Starting time	Fall 2022
Location	BMBI Laboratory, UTC, Compiègne, France

Part 2: Job description

Duration	36 months
Additional missions available	
Research laboratory	<p>The project will take place within the 'Biological Fluid-Structure Interactions' Group, directed by A.V. Salsac, which is one of the 3 research teams of the UTC Biomechanics & Bioengineering Laboratory (http://www.utc.fr/bmbi/). The group is specialized in the fields of biofluids and hemodynamics at both the microscopic and macroscopic scales. It focuses on the study of the fluid-structure interactions that occur between fluid flows and various flexible structures (vessel wall, capsule and cell membrane, biomedical devices, etc.).</p> <p>The strength of the group is the long expertise in numerical modeling of artificial capsules with the boundary integral method. The group has the unique characteristic of combining numerical and experimental expertise, which enables to translate theoretical results into practical applications. They have developed microfluidic techniques to produce and characterize microcapsules, as well as study their deformation when they flow in microtubes and networks.</p> <p>http://www.utc.fr/~salsacan/</p> <p>The project will be conducted in collaboration with LMAC from UTC.</p> <p>Florian de Vuyst, who will co-supervise the PhD, is an expert in numerical modeling in Fluid Mechanics and engineering, with special focus on models and methods in 2-phase flows as well as model-order reduction. He is specialized in the development of numerical tools to model complex multiphysics problem in mechanical engineering, correlate experiments and numerical simulation and optimize large-scale problems using reduced-order approaches. He has supervised about 20 PhD theses.</p> <p>https://fdevuyst.jimdo.com/</p>
Material resources	<p>All of the tools and equipment needed for the project are available in the 'Biological Fluid Structure Interactions' team of BMBI and the LMAC Laboratory:</p> <p>For the numerical simulations:</p> <ul style="list-style-type: none"> - 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, High Performance Computing facilities
Human resources	<p>The BMBI laboratory is composed of about:</p> <ul style="list-style-type: none"> - 40 permanent staff members (27 academic staff, 13 technical and administrative staff) - 31 PhD students - 8 Postdocs - 7 associated researchers - 15 Master students
Financial resources	MultiphysMicroCaps, financed by ERC
Working conditions	<p>What is expected from the candidate is to have a sense of autonomy and to be capable to work in group. His/her mission will be to conduct the research project, present his/her results during the research meetings (meetings with the advisors, lab meetings, etc) and to the rest of the scientific community via publications in international journals and conferences.</p>
National collaborations	<ul style="list-style-type: none"> - Roberval, GEC, TIMR, LMAC Laboratories, UTC - Solid Mechanics Laboratory, Ecole Polytechnique - INRIA Paris Institute
International collaborations	<ul style="list-style-type: none"> - Applied Mechanics and Bioengineering, Zaragoza (Spain) - School of Engineering and Materials Science, Queen Mary University of London (UK)
International cosupervision	

Contact	<p>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:</p> <p>Dr Anne-Virginie Salsac (a.salsac@utc.fr) BMBI Laboratory (UMR CNRS-UTC 7338) UTC CS60319 60203 COMPIEGNE cedex, France</p> <p>Prof Florian de Vuyst (florian.de-vuyst@utc.fr) LMAC Laboratory UTC CS60319 60203 COMPIEGNE cedex, France</p> <p>Please note that only candidates who have been shortlisted will be contacted</p>
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Please contact first the thesis supervisor before applying online
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