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	*Laboratory in which the candidate will be recruited*: Biomechanics & Bioengineering Laboratory (UMR CNRS-UTC 7338), UTC Compiègne *research team*: Biological Fluid Structure Interactions *web site*: 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 *EURAXESS fields*: Biomedical Engineering, Mechanical Engineering, Simulation Engineering, 3D Modelling, Modelling Tools, Computational Mathematics
Research work	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 and wrinkling of the capsule membrane and potential damage, which results in large systems of equations and thus in long computational times. 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 using approaches such as the Fast Multipole Method (FMM) that can be used to speed up the Boundary Integral Method (BIM) and solve for Stokes flows, or reduced order models. We will use the fast-simulation tools to study the motion and deformation of microcapsule suspensions and identify the mechanical properties from experimental results of capsule deformation. The properties will be determined by fitting the deformed capsule shape predicted by the reduced order models to the experimental one using diffuse approximation techniques. They will thus help design deformable liquid-core capsules of micrometric size for health-related applications to protect and deliver active substances. It will enable optimize their properties for specific industrial and biomedical applications, and predict membrane damage to control the delivery.
Key words	Microcapsules, reduced order models, fluid-structure interaction, active substance targeting, numerical complexity, fast multipole method
Requirements	*Skills*: - Strong scientific background in scientific computing for fluid-solid mechanics

	- Notions of biomechanics and bioengineering will be a plus - Good English skills - Excellent interpersonal and communication (written and verbal) skills *Personal Qualities*: - 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 *Qualification*: MS degree or equivalent qualification.
Starting time	Between October and December 2021
Location	BMBI Laboratory, UTC

Part 2: Job description	
Duration	36 months
Additional missions available	
Research laboratory	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.). 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 combing 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 micro-tubes and networks. http://www.utc.fr/~salsacan/ The project will be conducted in collaboration with LMAC from UTC. 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. https://fdevuyst.jimdo.com/
Material resources	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: 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, High Performance Computing facilities

Human resources	The BMBI laboratory is composed of about: - 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	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.
National collaborations	- Roberval, GEC, TIMR, LMAC Laboratories, UTC - Solid Mechanics Laboratory, Ecole Polytechnique - INRIA Paris Institute
International collaborations	- Applied Mechanics and Bioengineering, Zaragoza (Spain) - School of Engineering and Materials Science, Queen Mary University of London (UK)
International cosupervision	
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: Dr Anne-Virginie Salsac (a.salsac@utc.fr) BMBI Laboratory (UMR CNRS-UTC 7338) UTC CS60319 60203 COMPIEGNE cedex, France Prof Florian de Vuyst (florian.de-vuyst@utc.fr) LMAC Laboratory UTC CS60319 60203 COMPIEGNE cedex, France Please note that only candidates who have been shortlisted will be contacted

Please contact first the thesis supervisor before applying online on https://webapplis.utc.fr/admissions/doctorants/accueil.jsf