Université de technologie de Compiègne – PhD proposal

Part 1: Scientific project	
Thesis proposal title	**Modeling the rupture of microcapsules in flow**
Research laboratory	*Laboratory*: 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 Delphine Brancherie, Assistant Professor (HDR), Roberval Laboratory, UTC
Scientific domain(s)	Science and technology Biology, biomedical and health sciences
Research work	Encapsulation consists in protecting a substance inside a solid envelope. It avoids its dispersion in the ambient environment or its degradation in contact with it. It is also used to control the substance release. The use of capsules is common in nature (red blood cells, phospholipid vesicles) and in different industrial applications (biotechnology, pharmacology, cosmetics, food industry) [1]. A promising biomedical application is drug targeting that consists in optimizing drug delivery using a vector that carries the active ingredient and delivers it preferentially to the targeted location. The project will explore the use of liquid-core micrometric capsules made of an elastic membrane to efficiently transport active material. In all the applications, the capsules are suspended in a carrying fluid flow, which constitutes a formidable problem of complex fluid-structure interactions. In vivo tests have shown that artificial blood cells could be easily damaged in circulation depending on the particle shape and deformability [2]. It illustrates the key role played by the particle mechanical properties and the importance to control the occurrence of rupture. The project is dedicated to the modeling of the rupture of deformable microcapsules subjected to an external flow. The burst of a capsule under shear was first observed by Chang & Olbricht [3-4], but no systematic study was performed ever since. There is only sparse experimental data and hardly any numerical model. The goal of the project will be to understand the phenomena governing the initiation of rupture and the propagation of a crack, which will help us trigger or prevent rupture depending on the applications. To reach this goal and determine the parameters governing the rupture, there is the need to conduct experimental studies of microcapsule breakup. Different characterization strategies will be developed based on existing experimental setups. To identify the parameters of the capsule wall on the basis of the experimental results, dedicated numerical models will need to be created. To model the fluid-structure interactions, we propose to use the coupling strategy that the BMBI team has developed and that is based on the Boundary Integral (BI) method to solve for the fluids and the Finite Element (FE) method for the membrane [5-9]. In order to properly model failure and simulate the crack propagation, the embedded discontinuity approach developed by the Roberval team [10] will be implemented within the solid solver of the BI-FE code. The innovation will be to create a fluid-structure interaction code capable of modelling rupture. A sensitivity analysis will be conducted to identify the influence of the different model parameters on the rupture modes. Depending on the expertise and interest of the candidate, the PhD may have a stronger focus on either the experimental or the numerical aspects. *References:* [1] Patwardhan S.A., Das K.G. 1983 Microencapsulation. In Das K.G. editor, Controlled release technology - bioengineering aspects, 121–141, Wiley, New York. [2] Cerdá B., Espín J.C., Parra S., Martínez P., Tomás-Barberán F.A. 2004 The potent in vitro antioxidant ellagitannins from pomegranate juice are metabolised into

	bioavailable but poor antioxidant hydroxy–6H–dibenzopyran–6– one derivatives by the colonic microflora of healthy humans. Eur. J. Nutrition 43, 205–220. [3] Chang K.S., Olbricht W.L. 1993 Experimental studies of the deformation and breakup of a synthetic capsule in steady and unsteady simple shear-flow. J. Fluid Mech. 250, 587–608. [4] Chang K.S., Olbricht W.L. 1993 Experimental studies of the deformation of a synthetic capsule in extensional flow. J. Fluid Mech. 250, 609–633. [5] Walter J., Salsac A.-V., Barthès-Biesel D., Le Tallec, P. 2010 Coupling of finite element and boundary integral methods for a capsule in a Stokes flow. Int. J. Num. Meth. Eng. 83, 829-850. [6] Walter J., Salsac A.-V., Barthès-Biesel D. 2011 Ellipsoidal capsules in simple shear flow: prolate versus oblate initial shapes. J. Fluid Mech. 676, 318-347. [7] Foessel É., Walter J., Salsac A.-V., Barthès-Biesel D. 2011 Influence of internal viscosity on the large deformation and buckling of a spherical capsule in a simple shear flow. J. Fluid Mech. 672, 477-486. [8] Hu X., Salsac A.-V., Barthès-Biesel D. 2012 Flow of a spherical capsule in a pore with circular or square cross-section, J. Fluid Mech. 705, 176-194. [9] Dupont C., Salsac A.-V., Barthès-Biesel D., Vidrascu M., Le Tallec P. 2015 Influence of bending resistance on the dynamics of a capsule in shear flow. Physics of Fluids. 27, 051902. [10] Dujc B., Brank J., Ibrahimbegovic A., Brancherie D. 2010 An embedded crack model for failure analysis of concrete solids. Computers and Concrete. 7, 331-346.
Keywords	Capsule suspension, membrane rupture, fluid-structure interaction, drug targeting
Requirements	- Knowledge in fluid-solid mechanics and/or numerical methods - Notions of biomechanics and bioengineering will be a plus - Ability to work in team in an interdisciplinary context - Rigor, motivation, dynamism - Good English skills
Starting time	September 2017

Part 2: Job description	
Duration	36 months
Research laboratory	The project will take place within the 'Biological Fluid-Structure Interactions' Group, directed by A.V. Salsac, which is one of the 4 research teams of the UTC Biomechanics & Bioengineering Laboratory (rated A+ by AERES). 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. The project will be conducted in collaboration with Roberval Laboratory from UTC. The team "Computational mechanics" 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 with multi-scale approaches.
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 'Computational Mechanics' team

	from Roberval 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 - Embedded-discontinuity FE numerical code - Workstations, server, software For the microfluidic experiments: - Microsystem fabrication room - Microfluidic platform equipped with microscopes, pressure flow controllers, flowmeters, high-speed cameras), …
Working conditions	What is expected from the candidate is to have a sense of autonomy and to be capable to work in group. His mission will be to conduct the research project, present his 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	- Solid Mechanics Laboratory, Ecole Polytechnique – Prof. Le Tallec - INRIA Paris Institute – Dr Vidrascu
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 (+33 (0)3 44 23 73 38, a.salsac@utc.fr) BMBI Laboratory (UMR CNRS-UTC 7338) UTC CS60203 60203 COMPIEGNE cedex, France Dr Delphine Brancherie (+33 (0)3 44 23 52 71, delphine.brancherie@utc.fr) Roberval Laboratory (UMR CNRS-UTC 7337 UTC CS60203 60203 COMPIEGNE cedex, France