PhD Proposal 2017

School: Ecole Centrale Marseille	
Laboratory: M2P2	**Web site: www.m2p2.fr**
Team: ITC	**Head of the team: E. Serre, J. Favier**
Supervisor: Julien Favier	**Email: Julien.Favier@univ-amu.fr**
Collaboration with other partner during this PhD: **In France:**	**In China:**

Title: Numerical simulation of the transport of mucus in human airways through the beating of epithelial cilia
Scientific field: Mechanical engineering
Key words: CFD, biofluids, Fluid structure interaction

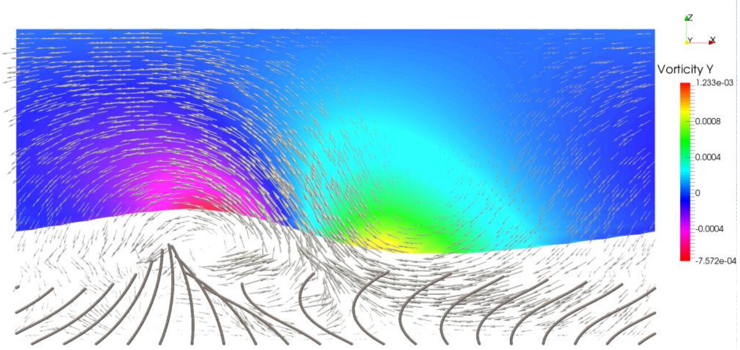
Details for the subject:

Background, Context:

The beating of cilia is ubiquitous in nature. Cilia are contractile hair-like structures, put into motion by biochemical energy, and protruding on the free surface cells, and many living organisms use ciliary and/or flagellar propulsion as a swimming mechanism, or to transport fluids, such as bronchial mucus in human airways, or cerebrospinal fluid in human brain.

Several respiratory diseases are concerned with the beating of cilia to transport mucus (‘mucociliary clearance’), such as chronic obstructive pulmonary disease (COPD), or severe asthma. To progress on the understanding of these diseases, the numerical simulation of the hydrodynamical interactions between cilia and mucus is of great interest nowadays. The project aims at analysing the coupled dynamics of the beating cilia using a unique code in literature, which can handle flexible structures in interaction with multiphase flows. The numerical code is a paralelised in-house Lattice Boltzmann solver coupled to immersed boundary method.

In particular, the coordination of the cilia is of primary importance. Instead of beating synchronisely, they can indeed generate waves which can enhance greatly the transport and mixing of mucus (metachronal waves). These waves are universal in nature and understanding the physical mechanisms at play in their beating is a key aspect of the understanding of the transport of bronchial mucus in human airways.

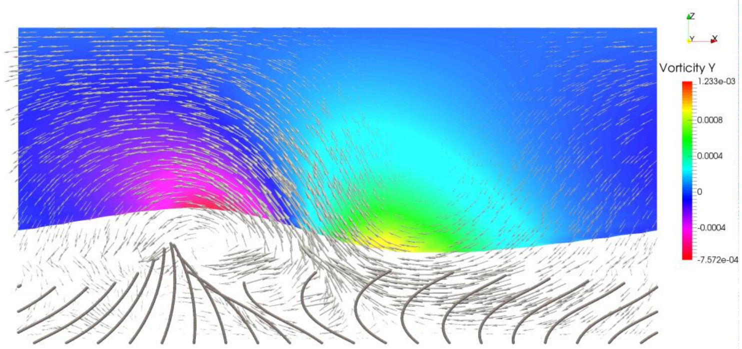


Research subject, work plan:

After a review of the state of the art, the phd will consists in using the numerical solver to study :

1. the emergence of the metachronal waves, based on a pure hydrodynamical feedback from the fluid,
2. characterisation the various kinds of synchronization (antiplectic, symplectic) and their effects on the macroscopic quantities such as mucus velocity or mixing.
3. link the microscopic parameters such as density of cilia, mucus viscosity with macroscopic quantities.

Interactions with biologist and medical doctors can be expected throughout the phd (INSERM-CINAM).



References on this topic:

Li, Z., Favier, J., D'Ortona, U. & Poncet, S. 2015 An improved explicit immersed boundary method to couple with lattice Boltzmann model for single- and multi-component fluid flows. J. Comput. Phys. 304, 424–440.

Dauptain, A., Favier, J. & Bottaro, A. 2008 Hydrodynamics of ciliary propulsion. J. Fluid. Struct. 24, 1156–1165.

Ding, Y., Nawroth, J. C., McFall-Ngai, M. J. & Kanso, E. 2014 Mixing and transport by ciliary carpets: a numerical study. J. Fluid Mech. 743, 124–140.

TRANSPORT EFFICIENCY OF METACHRONAL WAVES IN 3D CILIA ARRAYS IMMERSED IN A TWO-PHASE FLOW, S. Chateau, J. Favier, U. D'Ortona and S. Poncet . J. Fluid. Mech. (submitted)