Livret de Stages

Option MEC594

Aérodynamique et Hydrodynamique

Responsables

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28 novembre 2018

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DEMARCHE A SUIVRE

Une fois une liste de préférences établie, envoyez aux deux responsables d'option un e-mail indiquant une séquence de choix (par exemple : Angleterre-02 > Danemark-01 > Mexique-01) et votre classement. Celui-ci sera utilisé en cas de litige. Cette séquence de choix + classement doivent être envoyés aux adresses suivantes **avant le lundi 10 décembre 12h** :

clanet@ladhyx.polytechnique.fr
lesshafft@ladhyx.polytechnique.fr

Stages hors livret

Vous pouvez chercher des propositions de stage par vous-même. Pour cela vous pouvez consulter les sites des universités/organismes qui vous intéressent ; leurs offres de stage sont souvent en ligne. Il est cependant nécessaire de nous contacter par e-mail, en indiquant votre démarche afin que nous vous donnions notre avis sur le sujet et sur l'encadrement (si l'avis est négatif il est préférable de le savoir le plus tôt possible, et non pas au moment de la non-signature de la feuille de stage ...).

Chapitre 1

Angleterre

1.1 University of Oxford

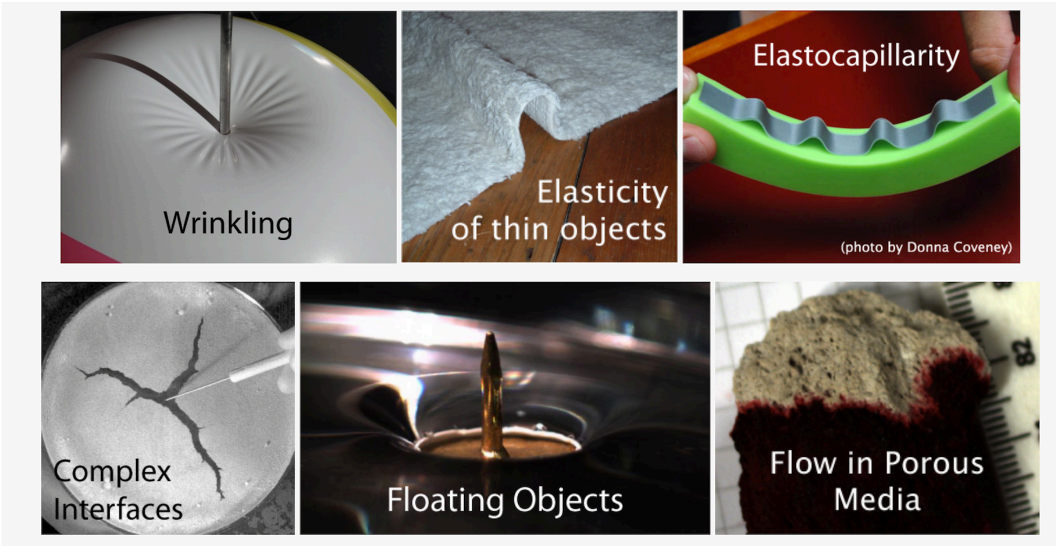
1.1.1 Elasto-capillarity and complex flows

Code : Angleterre-01
Responsable du stage : Dominic Vella

Please refer to the website of Dominic Vella and contact him to detail the subject if interested.

https ://people.maths.ox.ac.uk/vella/

dominic.vella@maths.ox.ac.uk



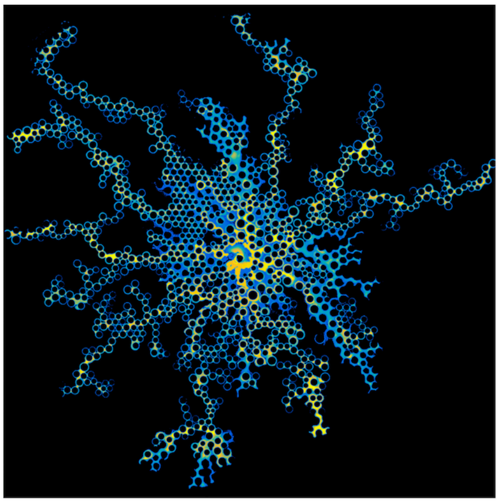
1.1.2 Poromechanics

Code : Angleterre-02
Responsable du stage : Chris MacMinn

Please refer to the website of Chris MacMinn and contact him to detail the subject if interested.

http ://cwmacminn.com/

christopher.macminn@eng.ox.ac.uk



1.2 University of Manchester

1.2.1 Impact of lateral confinement on the cleaning of drops trapped in gaps and cracks

Code : Angleterre-03
Responsable du stage : Julien Landel

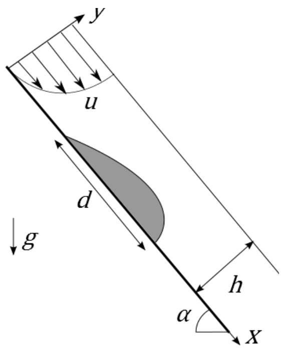


Figure 1: A liquid film flows over a viscous drop with the aim to dissolve it.

Brief description: this project is related to the cleaning or decontamination of narrow channels such as gaps and cracks. It has applications in cleaning for the food industry or chemical decontamination. In preliminary experiments, we have observed different regimes occurring when a viscous liquid drop lodged at the bottom of a U-shape channel is submerged by a liquid flow. At low Reynolds numbers, the cleaning of the drop occurs by establishing a convective mass transfer which dissolves the drop at the interface between the two phases. An advective–diffusive boundary layer develops and controls the mass transfer from the drop into the cleaning flow. At intermediate Reynolds numbers, we have observed a corner flow at the downstream end of the drop, which forms a large recirculation cell of drop material, whose effect on the mass transfer is still not clear and requires further investigation.
The first aim of this project is to conduct experimental observations, using a video camera, of the different regimes which seem to depend mainly on the Reynolds number. Second, the student will measure carefully the mass transfer by imaging analysis, in order to compare them with our theoretical predictions. The model identifies different power laws depending on the effect of lateral and/or vertical confinement for the variation of the convective mass transfer coefficient, also known as the Sherwood number, with the effective Péclet number. Currently, the model does not capture the effect of the corner flow mentioned above. From the experiments and observations made by the student, we will therefore investigate how the model can be adapted to take this effect into account.

Chapitre 2

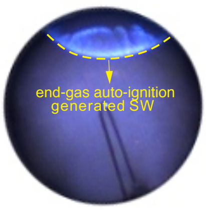
Chine

2.1 Center for Combustion Energy, Tsinghua University

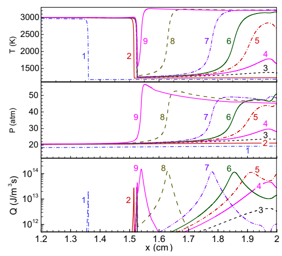
2.1.1 Effect of RON on End-gas Auto-ignition in the Context of Super-Knock

Code : Chine-01
Responsable du stage : Rémi Mevel

A promising approach to improve the efficiency and reduce pollutant emissions of spark-ignition internal combustion engines is to increase the energy density by high-boosting of downsized engine. The main limitation to the development of these new engines is the random occurrence of knock of very high intensity referred to as "super knock", which can significantly compromise the integrity of the engine. Super knock is a complex process which can be decomposed into three phases: (i) pre-ignition; (ii) end-gas auto-ignition; and (iii) detonation initiation.
A simple approach to study the second phase of super-knock, the end-gas auto-ignition, is to perform one-dimensional numerical simulations with realistic chemistry. While such an approach has been employed in many previous studies, the fuels considered were not representative of real gasoline auto-ignition behavior. In addition, the effect of the RON, Research Octane Number, on the auto-ignition process has not been investigated.



a) Experimental end-gas auto-ignition



b) 1-D simulation

The purpose of the study is to investigate the effect of the RON on the auto-ignition process using one-dimensional numerical simulation performed with the OpenFoam package. The RON of the fuel mixtures will be varied by considering n-heptane, iso-octane, and ethanol as the fuel components. First, a detailed reaction model will be assembled using reaction models from the literature. Then, a reduced reaction model will be obtained using state-of-the-art reduction methods. Finally, the end-gas auto-ignition will be studied using 1-D simulations under different engine-relevant conditions. The preferred period for the internship is from April 1^{st} to August 31^{st} 2018. Interests for numerical work and chemistry are required. A single bedroom apartment on campus and access to the university restaurants should be provided to non-Chinese student.

Chapitre 3

Danemark

3.1 Technical University of Denmark

3.1.1 Hydrodynamics of feeding and swimming flagellates

Code : Danemark-01
Responsable du stage : Anders Andersen

Flagellates are unicellular organisms that use long, slender appendages (flagella) to create flows that propel them, support their nutrient and prey uptake, but also expose them to flow-sensing predators. It is largely unknown what the flagellar characteristics are optimized for and which strategies and functions they reflect. To address these questions we are working on an analytical model in which we represent the cell as a solid sphere and the flagellar beat as a number of steady or time-varying point forces (figure 1). We have recently used the model and observations on freely swimming individual flagellates to study the flagellar arrangement and beat pattern as a key trait in flagellates with two symmetrically arranged flagella [3, 4]. In the project you will use the model framework to describe near-cell flows and trajectories of other biologically important marine flagellates that swim with different numbers, arrangements, and beat patterns of their flagellar appendages.

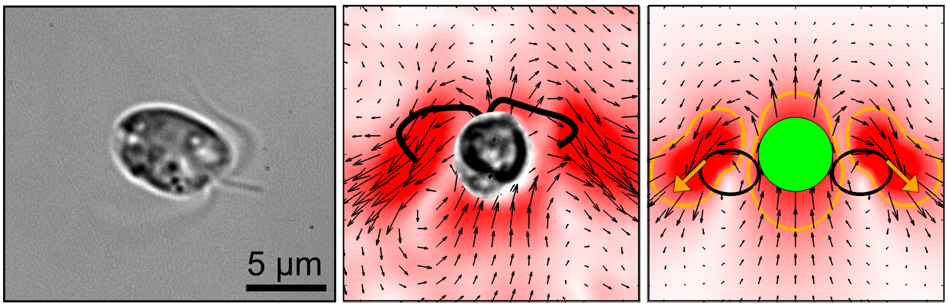


Figure 1: Individual of the flagellated microswimmer *Prymnesium parvum* (left), measured velocity field around *P. parvum* (middle), and velocity field for the theoretical model of *P. parvum* (right). Adapted from reference [4].

[1] http://www.fysik.dtu.dk/english/Research/FLUIDS/Research-Groups/Complex-Motion-in-Fluids
[2] http://www.oceanlifecentre.dk/
[3] J. Dölger, T. Bohr, and A. Andersen, An analytical model of flagellate hydrodynamics, Physica Scripta **92**, 044003, 9 pages (2017).
[4] J. Dölger, L. T. Nielsen, T. Kiørboe, and A. Andersen, Swimming and feeding of mixotrophic biflagellates, Scientific Reports **7**, 39892, 10 pages (2017).

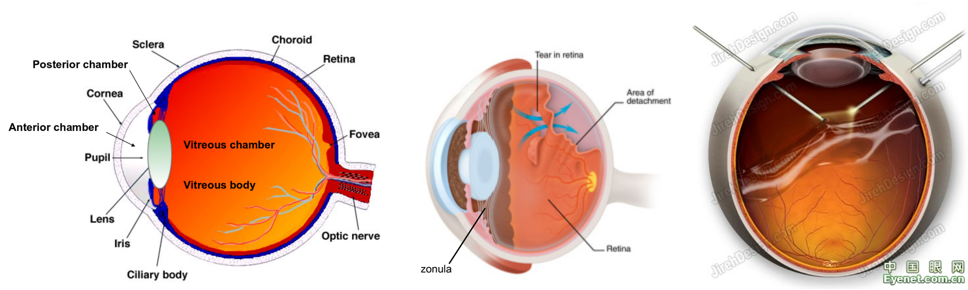
Chapitre 4

Italie

4.1 Università di Genova

4.1.1 Understanding the occurrence of emulsion in vitrectomised eyes

Code : Italie-01
Responsable du stage : Jan Pralits & Rodolfo Repetto



a) b) c)

Figure 1: Sketch of eye (a), retinal detachment (b), vitrectomy using silicone oil (c).

A common treatment for retinal detachment consists in performing vitrectomy, i.e. replacing the vitreous humour in the eye with a tamponade fluid. The role of such fluid is to push back the retina in contact with the pigment epithelium, in order to facilitate the reattachment of the two layers. Silicon oils are commonly used as tamponades, since they have desirable properties. However, a common complication, which does not allow the oil to be left permanently in the eye, is the tendency of the oil to emulsify. The causes of emulsification are poorly understood and this hampers our chances to develop effective strategies to avoid it. We propose to study this problem either with a theoretical approach or through experiments on eye models.

Chapitre 5

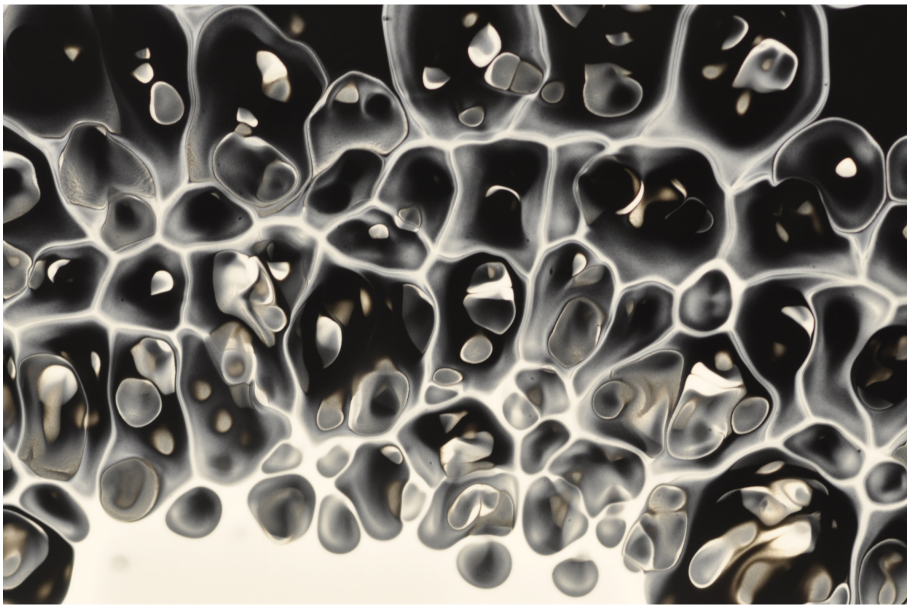
Mexique

5.1 Universidad Nacional Autonoma de Mexico

5.1.1 Rheology of Art

Code : Mexique-01
Responsables du stage : Roberto Zenit

An artistic painting results from the interactions between an applying tool (brush), a fluid (paint, lacquer, etc.), a substrate (canvas), all orchestrated by the artist mind. While the composition arises from the non-quantifiable desires of the artist, the action of painting is essentially a mechanical processes. Painting consists in spreading a layer of a liquid on a surface; in contrast to ordinary painting, artistic painting does not always aim to cover the surfaces uniformly. Many artists have empirically learned to manipulate the process to produce textures with aesthetic value. Interestingly, many of the produces textures and patterns arise from hydrodynamic instabilities. Our goal in this project is to investigate the mechanical processes at stake in painting in order to understand how painters produce the desired image. We are currently working on the analysis and reproduction of techniques such as accidental painting (D.A. Siqueiros), decalcomania (M. Ernst), dripping (J. Pollock), suminagashi (ancient Japanese water-surface-painting technique), encaustic (D. Rivera), among others. The project involves designing and conducting experiments, rheological characterization of paints, mathematical modeling and interpretation.



This image shows an example of the pattern created by D.A. Siqueiros accidental painting technique (Zetina, S. Godinez, F.A. and Zenit, R. A hydrodynamic instability is used to create aesthetically appealing patterns in painting. PLOS ONE, 10, e0126135, 2015)

Subject: Fluid Mechanics, Art History, Conservation.

Chapitre 6

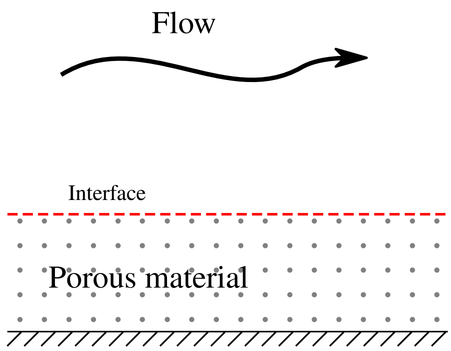
Suède

6.1 KTH Stockholm

6.1.1 Numerical modelling of flow over and through porous materials

Code : Suède-01
Responsable du stage : Shervin Bagheri & Ugis Lacis

Numerical modelling of flow over and through porous materials
KTH Mechanics, Stockholm, Sweden
Shervin Bagheri and Ugis Lacis



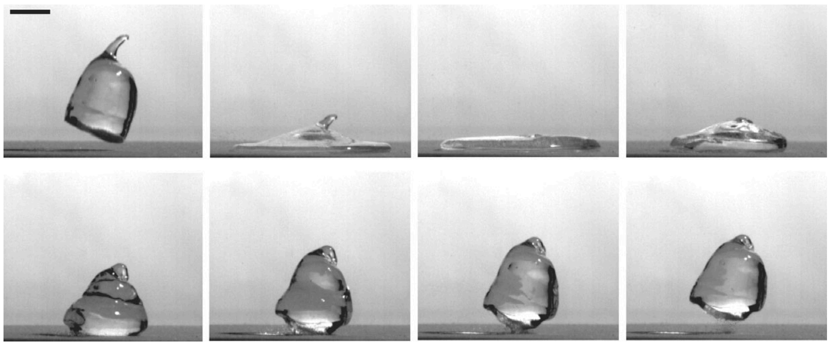
Porous materials are ubiquitous both in engineering (appearing, for example, in kitchen sponge, fuel cell, filtration device) and nature (such as soil, wood, animal fur). Appropriately designed porous materials have the potential to reduce friction, modify separation, influence mixing efficiency and modify heat transfer properties. Yet, our ability to create such effective materials for mentioned applications is limited. Experimental approaches lack precision, comprehensive measurement techniques are highly non-trivtil, and direct numerical approaches are generally too expensive for complex materials. Moreover, the modelling of the interior of the porous material as well as its interface with overlying fluid is challenging with many open questions remaining to be answered.
In the proposed internship, the student will use direct numerical simulations as well as effective modelling of porous material in order to advance the cutting-edge understanding of flows over and through porous materials. The student will contribute to the development of effective models capable of accurately predicting mass and momentum exchange between free flow and porous material, as well as fluid flow within the material itself. This work is a vital step towards enabling efficient design of porous materials suitable for various applications such as filters, fuel cells, surface coatings, etc.

6.1.2 Experiments in wetting of complex fluids

Code : Suède-02

Responsable du stage : Outi Tammisola & Shervin Bagheri

Experiments in wetting of complex fluids
KTH Mechanics, Stockholm, Sweden
O. Tammisola and S. Bagheri



Bouncing of a 2% Carbopol droplet from a surface[1]

This research project will examine the wetting behaviour of non-Newtonian fluids on solid surfaces. Wetting and spreading of non-Newtonian fluids is important to enable modern technologies (for example 3D printing) as well as to understand and predict natural phenomena (geohazards, biological flows). It is known that the complex fluid flow over surfaces is different from Newtonian fluids such as water, but the details are not well understood, especially when the process is fast (inertial). The interaction of complex fluids with surface hills and grooves, and wettability patterns, will then depend on the non-Newtonian properties in a way that cannot yet be modelled. Examples of complex fluid properties that will affect droplet impact and wetting is elasticity (polymers) and the yield stress.

This internship holder will experiment with droplet impact and spreading in the facilities in KTH Fluid Physics Lab, with different surface structures and wettabilities, using polymeric liquids and Carbopol (a yield-stress fluid). These experiments will be important to explore the physics, and for validation of new computational models for interfacial flows of complex fluids that are being developed at KTH [2].

References

[1] L.-H. Luu and Y. Forterre Drop impact of yield-stress fluids *J. Fluid Mech.*, 632, 301-327, 2009.

[2] D. Izbassarov, M. E. Rosti, M. Niazi, M. Sarabian, S. Hormozi, L. Brandt and O. Tammisola Computational modeling of multiphase viscoelastic and elastoviscoplastic flows *Int. J. Num. Meth. Fluids*, 88(10), 2018.

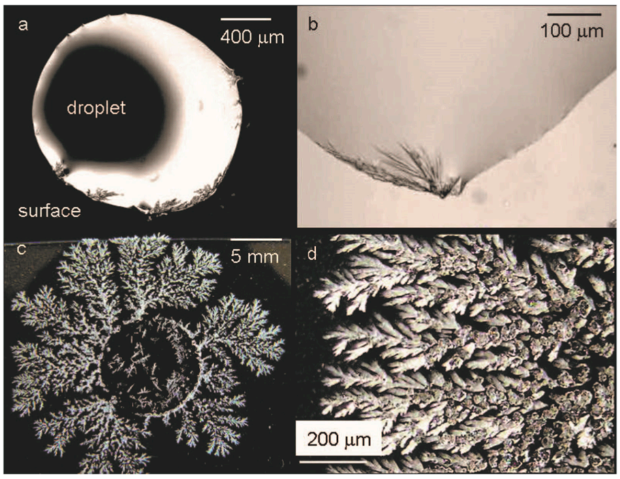
Chapitre 7

Suisse

7.1 EPFL

7.1.1 Salt invasion : Enhanced wetting by soluble substrate deposition and evaporately-driven instabilities

Code : Suisse-01
Responsable du stage : H. Elettro and F. Gallaire



Dendrites form during the evaporation of aqueous droplets loaded with sodium sulfate. Reproduced from Noushine Shahidzadeh-Bonn, et al. "Salt crystallization during evaporation: impact of interfacial properties." *Langmuir* 24.16 (2008)

Salt deposition leads to a variety of pattern formation in natural landscapes such as salt trees or structures on limestone stalactites. Salt crystallization in porous rocks have been recorded to induce mechanical stresses in excess of 200MPa, leading to irreversible damage and fracture. While we know that ions increase the surface tension of liquids, their influence on the wetting properties are little studied. We will study theoretically and experimentally the coupled dynamics of evaporative wetting, where a drop may spread and deposit its own (soluble) substrate on different time scales. This leads to instabilities and the formation of patterns, due to enhanced evaporation in highly curved interfaces.

Classical wetting experiments (equilibrium drop diameter on a given substrate, Jurin's tube, capillary meniscus,..) will be revisited in this new bicomponent system.

7.1.2 Mesure de la déformation élastique de la glace et de l'épaisseur de lubrification dans le patinage sur glace

Code : Suisse-02
Responsable du stage : G. Lerisson and F. Gallaire

Le calcul de la friction d'une lame de patin à glace dans son sens de marche mène à des rsultats surprenants. La faible friction générale de la glace n'est pas élucidée et reste très actif (**https://physicstoday.scitation.org/doi/pdf/10.1063/1.2169444**). Le problème présent se concentre sur le cas particulier d'une lame de patin. Le modèle actuel décrit la formation d'une couche d'eau macroscopique maintenue liquide sous la patin gâce à l'énergie de friction, venant alors lubrifier le contact. La question concerne la dimension du film d'eau liquide sur laquelle s'applique la pression du patineur, qui selon les résultats du modèle, est étonnamment petite.

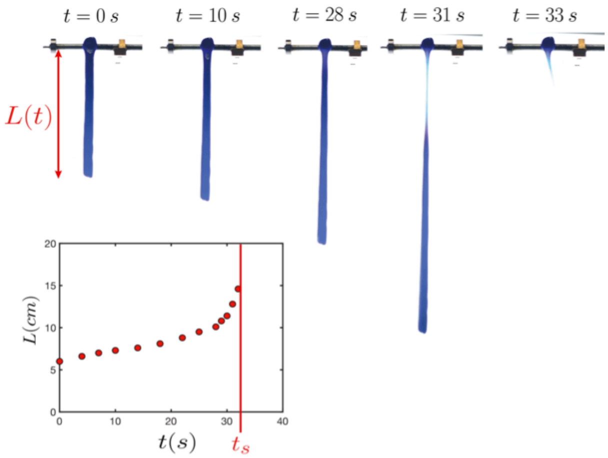
En poussant la théorie (Le Berre & Pomeau **https://arxiv.org/abs/1502.00323**) dans ses retranchements (en y incluant la déformation solide de la glace **https://fr.wikipedia.org/wiki/Contact_de_Hertz**), la prévision de cette dimension augmente mais demeure faible.

Nous souhaiterions, pour résoudre ce problème, avoir une meilleure connaissance de ce qu'il se passe réellement sous un patin, dans une patinoire. Le stage consistera à trouver ce qu'il est intéressant et possible de mesurer et à équiper/modifier/créer une lame de patin. Bien que cette question soit simple de prime abord, elle se pose depuis longtemps et l'absence de mesures témoigne de la difficulté du problème. Des premières mesures permettraient de confirmer la théorie existante ou d'orienter son développement.

Le problème étant ouvert, il est nécessaire d'avoir une grande curiosité pour la physique en général, pour la mécanique des fluides en particulier mais aussi pour l'expérience et la mesure.

7.1.3 Highly viscous fluid flows : experiments and modelling

Code : Suisse-03
Responsable du stage : L. Keiser and F. Gallaire



Typical drainage of a centimetric highly viscous cylinder suspended from its top end. Most of the deformation is localized in the upper part of the cylinder, which ultimately endures a sudden elongation followed by a rupture after a time t_s. This finite-time singularity, partially characterized in the lab, will serve as a starting basis for the student who will build up a more comprehensive description of these original types of fluid flows.

For this internship, we propose to study the flow of highly viscous fluids, such as lava, magma or molten glass. As these geological and industrial fluids are obviously difficult to handle in the lab, we propose to model them with the commercial Silly Putty polymer. At low shear rates, the Silly Putty is a Newtonian fluid one hundred million times more viscous than water, as the fluids mentioned above. At low Reynolds numbers, the viscous friction is the main force opposing the flow of liquids. Inertial forces may thus be neglected and the Stokes law accounts for the modelling of the dynamics. Stokesian flows are often observed and studied at small length scales, with liquids of moderate viscosities. However, highly viscous fluids may undergo Stokesian flows at higher length scales, and may be set into motion by bulk forces like gravity or centrifugal acceleration, which allows macroscopic and visual experiments.

For this internship, the student will combine experimental, numerical and theoretical approaches to study these geo-inspired flows. Her/His creativity will be more than welcome to build-up on the first promising results already obtained in the lab. The student will take part of a project involving postdoctoral and PhD students, with whom she/he will interact on a daily basis.

Chapitre 8

USA

8.1 University of California at Santa Barbara

8.1.1 Flow of suspension : from transport to clog

Code : USA-01
Responsable du stage : Alban Sauret

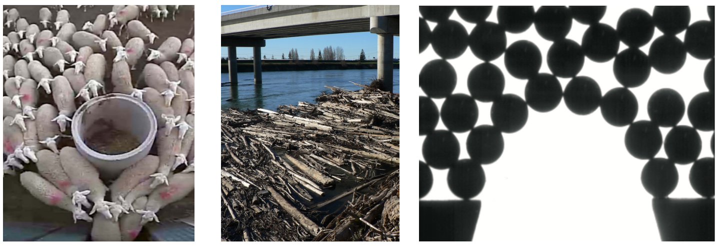
UC SANTA BARBARA engineering

Flow of suspension: from transport to clog

Location: UCSB, Santa Barbara, California (USA)

Contact: Alban Sauret
`asauret@ucsb.edu`
`https://engineering.ucsb.edu/~asauret/`

Flowing particles are present in many everyday life situations as well as in industrial, biological and geophysical processes. When a channel becomes suddenly smaller, particles can form arches. This results in the clog formation that have dramatic consequences for the transport of particles as shown in Fig. 1(a)-(c) with sheep, floating pieces of wood and glass beads, respectively. Predicting the complex dynamics associated with the clogging is thus of great interest for technological fields ranging from water purification to biomedical devices. To describe such processes, a good understanding of the coupling between particles, fluid flow and boundaries is necessary. In most systems, this coupling is not trivial as geometrical features, fluid dynamics, and particle interactions determine the behavior of interest.



(a) (b) (c)

Figure 1: Example of clogging of "particles". (a) Sheep passing a door (Garcimartín *et al.*, 2011). (b) Log jams at a bridge with a pier. (c) Grains forming an arch at a constriction (Janda *et al.*, 2008).

The aim of this internship is to study such coupling experimentally by considering the flow of a model suspension in a channel presenting a constriction. The intern will track the position and the trajectory of the particles. The tracking will lead to a prediction of the clogging events, depending on the geometry of the system, the concentration of particles, their properties, the flow rate, etc. A comparison with the dynamics of silo will be performed to highlight the analogy and difference with the classical situation.

8.1.2 Cohesive Sediment Dynamics in Turbulent Flow

Code : USA-02
Responsable du stage : Eckart Meiburg

UC SANTA BARBARA engineering

Cohesive Sediment Dynamics in Turbulent Flow

Location: University of California at Santa Barbara, USA (UCSB)

Contact:
Eckart Meiburg
meiburg@engineering.ucsb.edu
https://sites.google.com/site/ucsbcfdlab/

Cohesive sediment are present in ecologically sensitive environments such as rivers, lakes, estuaries, and fisheries. Reliable prediction of contaminant and nutrient transport in these environments requires accurate models of cohesive sediment dynamics. We currently lack such models. For the small particles in cohesive sediments, attractive forces between particles due to electric charges frequently dominate hydrodynamic and gravitational forces. While these attractive forces can cause the particles to form larger aggregates or "flocs", turbulent fluid stresses tend to break up the flocs. Hence, the size distribution of cohesive sediment flocs is governed by a delicate balance of interparticle and turbulent stresses, which affects their transport rates.

The aim of this internship is to explore cohesive sediment dynamics in turbulent environments via numerical simulations as illustrated in Fig. 1. The intern will work on the development of reliable, predictive tools for the transport of nutrients and contaminants in the environment.

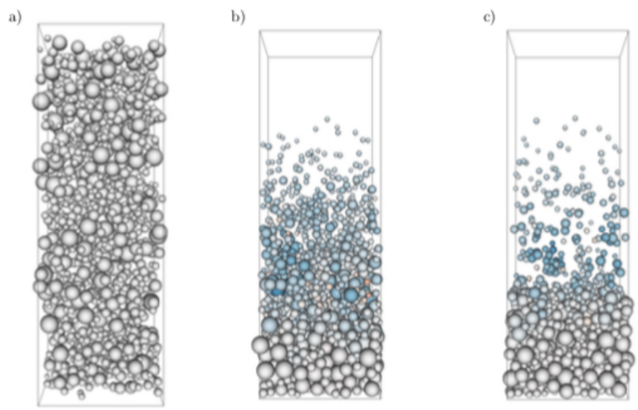


Figure 1: Example of numerical simulations showing settling particles in a closed container. a) initial particle distribution, b) cohesionless grains, c) cohesive particles. Snapshots b) and c) are taken at the same time. Particles are colored by their velocities.

The internship will be carried out in the Mechanical Engineering department at the University of California at Santa Barbara (USA).

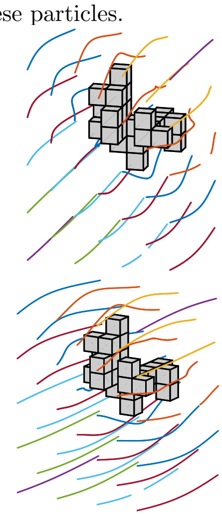
8.2 University of California at Merced

8.2.1 Stochastic modeling of marine aggregation

Code : USA-03
Responsables du stage : François Blanchette & Changho Kim

Stochastic modeling of marine aggregation
University of California, Merced
François Blanchette and Changho Kim

Project. Marine aggregates are particles composed of inorganic and organic matter ranging from micro-organisms to exuded polymers to detritus and sediment. They form near the ocean surface and eventually settle [1] to the deep ocean (they are often seen in the background of deep-ocean exploration images). Marine aggregates play a significant role in the carbon cycle. Carbon dioxide in the surface ocean is taken up by phytoplankton that end up in settling marine aggregates. As they reach the ocean floor, marine aggregates take this carbon out of circulation. We are interested in developing a realistic model of the formation of these particles.
Our research has recently led to the efficient computation of the flow around aggregates, as shown in the figure. We propose to incorporate hydrodynamical effects, which we can now readily compute, in a model of aggregation. Previous studies on aggregation had to make important assumptions on the mobility of aggregates as a function of their size and of the proximity of their neighbors. Our computations allow for a significant improvement on how realistically the aggregation process may be modeled. Using a Langevin approach [2], our particles will, in addition to drag and gravity, be subject to a random force. Larger particles will settle faster due to their greater weight, and have less mobility due to their greater drag. As they settle they will sweep smaller particles in their path and progressively increase in size. However, the statistical properties of the resulting aggregates have yet to be determined. An accurate model will allow for a much more precise description of the dynamics of this important aspect of the oceanic carbon cycle.



Location. UC Merced is the newest campus of the University of California (it opened in 2005) and the first American research university of the 21st century. It is conveniently located at the heart of California, between San Francisco Bay area and Yosemite National Park, featuring world-class climbing, hiking, and outdoor activities.
Mentors. Professor Blanchette, at UC Merced since 2006, studies fluid dynamics, specializing in multiphase and geophysical flows. Professor Kim, at UC Merced since 2018, studies stochastic simulations of hydrodynamical system.
Support and Contact information. UC Merced will provide office space and, if needed, cover most of the costs toward the obtention of a visa. In addition, the intern will receive a stipend of $800 per month and help in finding lodging. Contact us at fblanchette@ucmerced.edu and ckim103@ucmerced.edu with any questions.

[1] Panah, Blanchette, & Khatri, *Phys. Rev. Fluids*, **2**, 114303, 2017.
[2] Bian, Kim, & Karniadakis, *Soft Matter*, **12**, 6331, 2016.

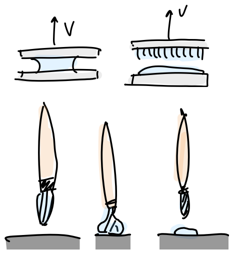
8.3 Princeton

8.3.1 Wet but not slippery

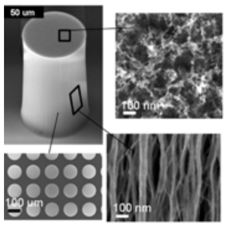
Code : USA-04
Responsables du stage : PT Brun

PT Brun | **Wet but not slippery** | LE.LAB

We are seeking curious, hard working, and innovative students interested in working in an exciting interdisciplinary environment: http://scienceido.com/LELAB .

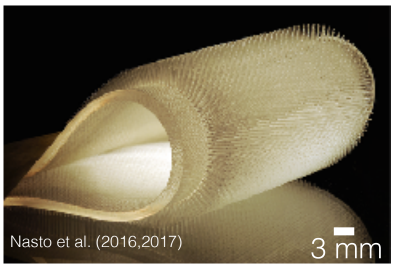


The project is concerned with wet adhesion, the **capillary and viscous forces generated by the fluid-filled joint between two wet substrates**. While these dynamic mechanisms are known to be fundamental to animal locomotion, they remain poorly understood. In particular, the question as to how can animals generate sufficient friction despite a fluid-based adhesion mechanism remains open. This class of elasto-capillary problems have become an important research area in recent years because of the increased feasibility of fabricating **biomimetic adhesives**. However, the technological relevance of wet adhesion exceeds by far the domain of biomechanics. For instance, they are central to new fabrication pathways for printed electronics, which is the main focus of the project.



Collaborators from MIT recently developed a **flexographic printing technique** for low-cost, high through-put production of printed electronic devices. Very much like painters, they use a brush, which they press against a canvas so as to transfer a controlled volume of ink. The "only" difference is that their brush are made by growing vertically aligned carbon nanotubes (CNTs), their ink is a conductive colloidal silver nanoparticle solution and they typically draw µm features. The capabilities and limitations of this new printing technology are ultimately determined by the process of ink transfer from the nanoporous brush. We propose to study the mechanics of ink transfer in detail, to understand how we can better control the printing process. The scale of the problem makes it hard to investigate as such. We thus propose to scale it up using dimensional analysis so as to ease our observations, while ensuring that the physics remains the same. The project is rooted on the basis of recognizing model experiments as a valuable and powerful tool for discovery and exploration, in turn seeding the development of formal and predictive models.

The experiments will be performed using a probe-tack geometry, the system being made of two parallel surfaces separated by a variable gap. The lower plate is a smooth solid substrate while the upper plate is a compliant "hairy surface" mounted on a moving probe attached to a force sensor. The dynamics will be observed using a system of cameras. The overall goal of the project is to model this problem, confront our predictions to experiments and use our insight to inform technological advance.



Nasto et al. (2016,2017)

Participation to international conferences (APS, AiChE) and summer schools (Europe, US) can be expected. Contact pbrun@princeton to discuss the project further.

Liquids & Elasticity | http://scienceido.com/LELAB | PT Brun

8.3.2 Artificial Compound Eyes

Code : USA-05
Responsables du stage : PT Brun

Artificial Compound Eyes

We are seeking curious, hard working, and innovative students interested in working in an exciting interdisciplinary environment: http://scienceido.com/LELAB .

Have you ever taken a blurry picture? Most likely yes, and most likely because it was out of focus camera. But what if you could focus everywhere at once? It turns out this is possible if you have thousands of lenses like most flying insects. While there has been research in this direction in the past years, progress has been hindered by the difficulty to manufacture complex 3D textured object. The PI has recently unraveled a way to harness interfacial instabilities in polymer melts so as to fabricate self-assembled architected soft materials. In this proposal, we aim to leverage the robustness and scalability of instabilities towards the meter scale assembly of soft structured materials with submicron surface resolution. Despite the recent progress of 3D printing, the fabrication of such structures spanning a wide range of sizes remains difficult or impossible, prompting the development of new fabrication pathways. Our instability-mediated new methodology offers a greatly improved scalability, design flexibility, robustness, simplicity and ultimately cost compared to existing techniques.

The research objective of this project is to fabricate and formalize a new class of topologically and hierarchically architected soft materials (ASM) using interfacial instabilities. Specifically, thin liquid elastomeric coatings are destabilized to generate drop-shaped smooth structures with tailored geometrical properties. As the elastomer cures these fluid-mediated structures yield an elastic material. The project is concerned with **the directed control of these instabilities** to robustly fabricate and control the size, the arrangement, and the morphology of our ASM and ultimately **tailor their functionality:** optical, mechanical and surface properties.

While instabilities are traditionally regarded as a route towards failure in engineering, the PI aims to follow a different path; taming fluidic instabilities and harnessing the patterns and structures they naturally form. This methodology capitalizes on the inherent periodicity, scalability, versatility and robustness of instabilities. This new design paradigm – building with instabilities – calls for an improved understanding of instabilities and pattern formation in complex media. While stability analysis is a classic topic in fluid mechanics, little is known on the so called inverse problem: finding the optimal set of initial conditions and interactions that will be transmuted into a target shape without direct external intervention. While the epicenter of the research is in fluid mechanics, utilizing instabilities to structure soft materials opens new research directions in the study of the behavior and deformations of architected soft materials, inspired by natural soft-materials that self-assemble into well defined structures to display remarkable properties.

Contact pbrun@princeton to discuss the project further.

Artificial compound eyes: An array of lenses is produced harnessing the Rayleigh-Taylor instability. The resulting elastic material is inflated to form a spherical shape. https://www.nature.com/articles/ncomms11155

Liquids & Elasticity | http://scienceido.com/LELAB | PT Brun

8.4 Cornell

8.4.1 Insect Flight

Code : USA-06
Responsables du stage : Jane Wang

Insect Flight

From Newton's law to Neurons

Dragonflies, Fruit Flies, Falling Paper and Maple Seeds

Computational Modeling

Table top experiments

Aerodynamics, Dynamics, and Feedback Control

why do organisms move the way they do

http://dragonfly.tam.cornell.edu

Chapitre 9

France

9.1 Institut de Recherche sur les Phénomène Hors Equilibre (Marseille)

9.1.1 STRONG REACTION WAVES and EXPLOSIONS

Code : France-01
Responsable du stage : Paul Clavin et Bruno Denet

La propagation d'onde de combustion dans un milieu gazeux réactif peut se faire sous deux formes : déflagration (onde quasi isobare à vitesse subsonique) ou détonation (onde supersonique précédée d'une onde de choc) se propageant à plusieurs kilomètres par seconde avec une très forte surpression produisant de violents effets destructeurs. Ces phénomènes sont de grande importance dans de nombreux domaines allant de l'*astrophysique* (explosion des étoiles) à la *sécurité industrielle* en passant par la *production d'énergie* et la *propulsion*. De nombreux aspects de ces ondes (découvertes au 19 eme) restent totalement incompris et non maîtrisés, et ce malgré les progrès récents en diagnostic optique et simulation numérique directe.

L'IRPHE est réputé à l'échelle internationale pour le développement d'études analytiques qui ont permis ces dernières années la compréhension de la dynamique de ces ondes, notamment en réduisant le problème à une équation intégrale dont la solution est obtenue numériquement et comparée à de la simulation numérique directe. Cette thématique à fait l'objet d'un ouvrage récent qui peut être consulté pour se faire une idée de la thématique et des méthodes utilisées : *Combustion waves and fronts in flows : flames, shocks, detonations, ablation fronts and explosion of stars*, P. Clavin, & G. Searby, Cambridge University Press (2016).

L'objet du stage est de familiariser l'étudiant avec ces méthodes analytiques couplées à la simulation numérique en traitant un exemple physique concret faisant l'objet de nombreuses controverses : détermination des conditions critiques d'initiation d'une détonation.

Le stage pourra se poursuivre par la préparation d'une thèse soit sur la *transition déflagration-détonation* soit sur l'*explosion des étoiles en fin de vie (supernovae)*. Le financement de la thèse sur le premier sujet est assuré par un contrat de l'Agence Nationale de la Recherche.

Publications sur le sujet :

-Clavin, P., & Denet, B. (2018). Decay of plane detonation waves to the self-propagating Chap-man–Jouguet regime. *Journal of Fluid Mechanics*, **845**, 170-202.

-Clavin, P. (2017). Nonlinear dynamics of shock and detonation waves in gases. *Combustion Science and Technology*, **189** (5), 747-775.

-Lodato, G., Vervisch, L., & Clavin, P. (2016). Direct numerical simulation of shock wavy-wall interaction : analysis of cellular shock structures and flow patterns. J*ournal of Fluid Mechanics*, **789**, 221-258.

-Denet, B., Biamino, L., Lodato, G., Vervisch, L., & Clavin, P. (2015). Model equation for the dynamics of wrinkled shockwaves : comparison with DNS and experiments. *Combustion Science and Technology*, **187**(1-2), 296-323.

9.2 Ecole Centrale de Lyon

9.2.1 Advection chaotiquedans l'écoulement entre deux cylindres excentriques

Code : France-02

Responsable du stage : Benoît Pier (benoit.pier@ec-lyon.fr) & Florence Raynal (florence.raynal@ec-lyon.fr)

Proposition de stage avec possibilité de faire une thèse

Benoît PIER (benoit.pier@ec-lyon.fr) Florence RAYNAL (florence.raynal@ec-lyon.fr)
Laboratoire de mécanique des fluides et d'acoustique, École centrale de Lyon, Écully.

Dans le cadre d'une collaboration avec l'université de Cambridge (BP Institute et DAMTP).

Advection chaotique dans l'écoulement entre deux cylindres excentriques

C'est un problème tout à fait fondamental avec (au moins) une application très concrète.

Du point de vue théorique, il s'agit d'étudier l'écoulement entre deux cylindres, c'est le cylindre intérieur qui tourne et son axe peut être excentrique (i.e. les cylindres intérieur et extérieur ont des axes parallèles mais différents). L'écoulement de Taylor–Couette (deux cylindres concentriques qui tournent) est bien documenté ; on connaît assez bien également Taylor–Couette avec un débit axial ou le cas de deux cylindres excentriques mais sans débit axial. En revanche le cas général n'a été traité que très récemment : rotation du cylindre intérieur excentrique avec débit axial.

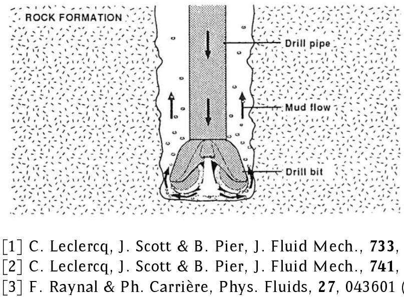
Le problème pratique qui nous intéresse se pose dans l'industrie pétrolière et plus particulièrement lors du forage. De nos jours on creuse de plus en plus profond et souvent en biais. Pour creuser on utilise une vrille montée sur un très long câble. Le câble est creux et a un diamètre de l'ordre de la moitié du diamètre du trou qu'on creuse. On évacue les débris de roche en injectant au fond de la boue qui descend par l'intérieur du câble et remonte par l'espace laissé libre entre le câble et la paroi. Autant l'écoulement à l'intérieur du câble ne pose pas de problème, autant l'écoulement de retour entre le câble et le puits déjà creusé est complexe. Nos études récentes [1,2] ont permis de mieux comprendre la dynamique de cet écoulement et ses instabilités. Nous souhaitons étudier maintenant comment le transport se fait entre le fond et la surface.

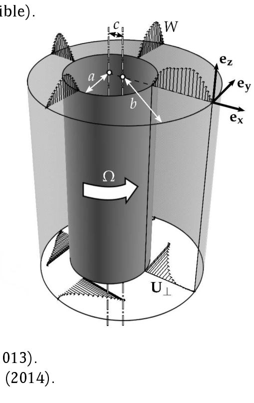
La structure de la roche est connue approximativement avant la mise en place du forage. Pour affiner la connaissance du sous-sol, des échantillons sont analysés au cours du forage. Comme le prélèvement de ces échantillons se fait à la surface, il y a une incertitude quant à la profondeur précise à laquelle ils ont été arrachés. En effet, vu la structure de l'écoulement et la profondeur du puits (souvent plusieurs kilomètres), le transport des débris depuis le fond vers la surface est un processus complexe : lors de la remontée sur de grandes distances, la dispersion est très importante et il en résulte de très grands écarts de temps de parcours.

L'objectif de cette étude est d'étudier la distribution de ces "temps de vol" [3] avec des outils mathématiques rigoureux et à l'aide de simulations numériques.

Le but du stage consiste à étudier les propriétés d'advection et de dispersion de l'écoulement de base (champ de vitesse permanent et invariant dans la direction axiale) et de les comparer au cas concentrique et ainsi de caractériser l'effet de l'excentricité.

Cette étude peut se poursuivre en thèse en considérant les différents régimes non linéaires (périodiques, quasi-périodiques, ...) auxquels cette configuration donne lieu lorsque de petites perturbations sont présentes (séjour au BP Institute de Cambridge possible).





[1] C. Leclercq, J. Scott & B. Pier, J. Fluid Mech., **733**, 68–99 (2013).
[2] C. Leclercq, J. Scott & B. Pier, J. Fluid Mech., **741**, 543–566 (2014).
[3] F. Raynal & Ph. Carrière, Phys. Fluids, **27**, 043601 (2015).

9.3 ONERA

9.3.1 Development of an accurate filtering approach for the post-processing of DG solutions in the new generation CFD solver RHEA

Code : France-03
Responsable du stage : Marta de la Llave Plata

ONERA
THE FRENCH AEROSPACE LAB

www.onera.fr

PROPOSITION DE STAGE EN COURS D'ETUDES

Référence : **DAADA-2018-039**
(à rappeler dans toute correspondance)

Lieu : Châtillon

Département/Dir./Serv. : DAAA/NFLU

Tél. : 01 46 73 42 23

Responsable(s) du stage: Marta de la Llave Plata

Email. : Marta.de_la_Llave_Plata@onera.fr

DESCRIPTION DU STAGE

Thématique(s) : Discontinuous Galerkin (DG), filtering of DG solution,

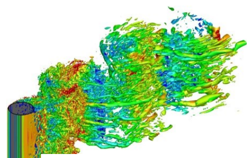
Type de stage : ☒ Fin d'études bac+5 ☒ Master 2 ☐ Bac+2 à bac+4 ☐ Autres

Intitulé : Development of an accurate filtering approach for the post-processing of DG solutions in the new generation CFD solver RHEA.

Sujet: The development of novel numerical approaches constitutes a central part of Onera's 2020/2030 roadmap. The aim is to go beyond the current level of accuracy and parallel capabilities of traditional methods in the context of scale-resolving simulations, and make high-order methods gradually available to the aerospace industry. In this context, Onera, in cooperation with Airbus and DLR, is working on the development of the new generation CFD solver RHEA which integrates within the same infrastructure finite volume and discontinuous Galerkin (DG) methods.

High-order DG methods rely on the variational projection of the Navier-Stokes equations onto a hierarchy of local polynomial basis. Due to the locality of the basis functions representing the solution within each element, the continuity of the solution is not ensured across interfaces. An important question arising in the analysis of DG flow solutions is thus the way in which these artificial discontinuities should be dealt with in order not to introduce spurious information in the analysis. This is of particular importance in the case of LES (marginally resolved) simulations for which the jumps of the solution at the inter-element boundaries are expected to be significant.

In this research, different ways of dealing with these discontinuities will be investigated together with their effect on the analysed quantities. The focus will be placed on the development of the so-called SIAC (Smoothness-Increasing Accuracy Preserving) filters (Ryan et al. 2015) which have been shown to enhance the accuracy and increase the smoothness of DG approximations. The results from this research will be implemented in an external module to be plugged into FSDM (Flow Simulator Data Manager) on which the RHEA solver relies. The results from this research will be assessed on fundamental and advanced configurations generated using the RHEA solver.
External collaborations: DLR, Airbus


LES of flow past a circular cylinder at Re=140000

Est-il possible d'envisager un travail en binôme ? **Non**

Méthodes à mettre en oeuvre :

☒ Recherche théorique ☐ Travail de synthèse
☒ Recherche appliquée ☐ Travail de documentation
☐ Recherche expérimentale ☒ Participation à une réalisation

Possibilité de prolongation en thèse : **Possibilité dans le cadre coopératif ONERA/Airbus/DLR**

Durée du stage : Minimum : 5 Maximum : 6 mois (sur dérogation)

Période souhaitée : March-July 2019

PROFIL DU STAGIAIRE

Connaissances et niveau requis :	Ecoles ou établissements souhaités :
Analyse numérique, CFD,C++	Grandes écoles, MR2 analyse numérique, mécanique

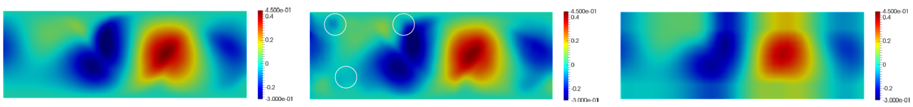
9.3.2 Modélisation du bruit rayonné par un jet par méthode statistique

Code : France-04
Responsable du stage : Maxime Huet, Fulvio Sartor.

Malgré les efforts très importants réalisés au cours de ces cinquante dernières années, le bruit de jet issus des moteurs reste la principale source de nuisance sonore d'un avion pendant la phase de décollage. La réduction de cette source de bruit reste un objectif important afin de pouvoir satisfaire les règlementations de plus en plus contraignantes sur les nuisances autour des zones aéroportuaires.
La réduction de cette source implique d'être capable d'en prévoir le niveau lors de la phase de conception du moteur. Pour ce faire, l'ONERA a développé différents outils de modélisation en aérodynamique et en acoustique. Le jet et les sources de bruit sont calculés par une simulation aérodynamique instationnaire puis le bruit généré est propagé en champ lointain. Cet ensemble logiciel est performant mais nécessite des capacités de calculs relativement importantes et sur de longues durées de manière à capter les phénomènes turbulents de l'écoulement.
Cependant, la durée de restitution de ces simulations numériques instationnaires est parfois incompatible avec les besoins des études, par exemple dans les phases d'avant-projet. Une alternative est alors d'utiliser un modèle statistique qui s'appuie sur les grandeurs moyennes de l'écoulement, déterminées par un calcul RANS, pour prévoir le niveau de bruit rayonné. Au cours de ce stage, on s'intéressera au modèle de Tam & Auriault, développé initialement pour les jets simple flux isothermes puis étendu ensuite à des configurations plus complexes comme les jets chauds, les jets double flux et la présence d'un effet de vol, par exemple. Les aspects théoriques de ce modèle ont déjà fait l'objet d'études à l'ONERA et ont conduit à un premier démonstrateur pour les jets simple flux (code sAndrA), dont le développement doit être repris et étendu aux configurations de type industriel.
Dans la première partie de l'étude, le/la stagiaire fera une étude bibliographique sur le modèle proposé par Tam & Auriault et choisira la version du modèle à utiliser pour la suite de l'étude. La formulation retenue sera implémentée dans une nouvelle version du code sAndrA, à concevoir entièrement par le/la stagiaire. Ce code sera ensuite validé sur des configurations de complexité croissante.
Le/la stagiaire aura la charge des aspects aérodynamiques et acoustiques de l'étude : il/elle sera encadré(e) par deux référents en simulation numérique et en acoustique pour la réalisation des travaux (calculs CFD, rayonnement acoustique, analyses). Selon l'avancement des travaux, l'outil développé pourra être utilisé dans le cadre d'un projet interne ONERA afin de prévoir le bruit de jet pour un essai en cours de préparation ainsi que pour fournir des premières informations sur la position des sources de bruit de ce jet.

9.3.3 Augmentation of experimental measurements of the flow around a bluff body at high Reynolds numbers through data assimilation

Code : France-05
Responsable du stage : Vincent Mons and Benjamin Leclaire.



(a) Ground truth. (b) Assimilated solution. (c) Synthetic PIV.

Experimental fluid dynamics (EFD) is by essence the preferred means to obtain information about real-world flows. However, data obtained from EFD approaches are usually limited in space and time, and can not provide a full description of the flow. An emerging and promising approach to increase the resolution of EFD data consists in combining them with computational fluid dynamics (CFD) tools, so that the measurements are extrapolated, and their resolution and smoothness improved, while being constrained by the numerically resolved conservation laws of fluid motion. This so-called data assimilation (DA) [1] approach may be implemented based on Kalman filtering, where the statistics related to the confidence in a numerical prediction are sequentially updated in time using the available measurements. However, a limitation of this approach may be the relatively large computational cost required to propagate in time the covariance matrix associated to the flow state, which is usually equivalent to 10-100 forward simulations. In a recent study [2], several approximations were proposed to drastically lighten the burden of the covariance matrix propagation step in the case of incompressible flows, thus greatly facilitating the application of Kalman filtering to complex configurations.
The primary goal of this internship is the implementation of a technique similar to that proposed in [2] and to assess the latter in the context of flow estimation based on particle image velocimetry (PIV) data. The developed approach should allow to augment PIV measurements at a limited computational cost and for various flow configurations. It will be first assessed relying on synthetic data and then employed to improve flow estimation from available 3D time-resolved PIV data on the flow around a wall-mounted cube in the presence of laminar or turbulent boundary layer and at various Reynolds numbers.

[1] Lewis, Lakshmivarahan and Dall, Dynamic Data Assimilation approach: A Least Squares Approach, Cambridge University Press, 2006.
[2] Meldi, Poux, A reduced order model based on Kalman filtering for sequential data assimilation of turbulent flows, J. Comput. Phys., 2017.
[3] Yegavian, Leclaire, Champagnat and Marquet, Performance assessment of PIV super-resolution with adjoint-based data assimilation, 11th Int. symp. on particle image velocimetry, Santa Barbara, USA, 2015.

9.3.4 CFD simulations on supersonic civil aircraft for Sonic Boom prediction

Code : France-06
Responsable du stage : G. Carrier, O. Atinault.

Over the past 20 years, ONERA has been working continuously on modeling and simulation tools for accurate sonic boom prediction and their application to low-boom civil transport aircraft design. This field has received a renewed interest over the past few years at international level with ongoing actions of the International Civil Aviation Organization (ICAO) towards a possible future regulation on sonic boom. Experimental research actions in Japan (D-SEND programs) and in the USA (QueSST program with very recent launch of the X57 low-boom demonstrator program) have provided and will provide new experimental results (both wind tunnel and flight test data) for the validation of numerical simulations to accurately predict sonic boom levels of low-boom aircraft. In Europe, the EU-funded project RUMBLE has been launched in November 2017 and gathers both EU and Russian research efforts on sonic boom.

Numerical predictions of sonic boom usually rely on a three-stage process: prediction of the sonic boom sources by CFD (Computational Fluid Dynamics) evaluations of the pressure field around the aircraft, sonic boom propagation through the atmosphere and quantification of the annoyances due to the sonic boom by means of specific metrics (such as PLdB, A-SEL, C-SEL, …). The proposed internship will concentrate on the first stage of this numerical process; which intends to accurately predict the sonic boom sources from the aerodynamic pressure perturbations around an aircraft of known geometry in supersonic flight conditions.

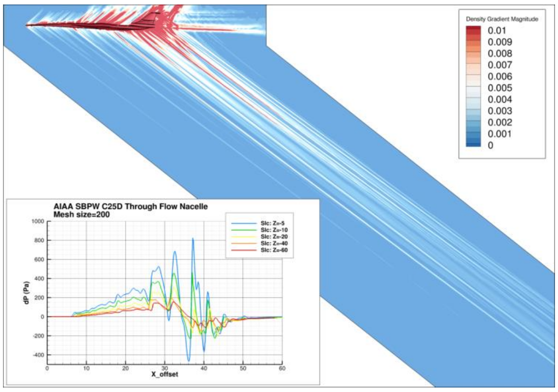


Figure 1: Near field prediction of sonic boom using elsA CFD code

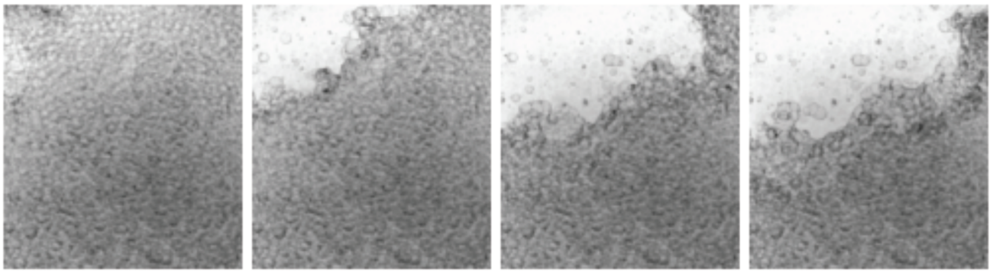
The internship will consist in :

*performing steady (Euler and RANS) simulations of the flow around supersonic aircraft configuration representative of future low-boom aircraft in existing or new CFD meshes (from the AIAA Sonic Boom

9.4 Institut Lumière Matière (Université Lyon 1)

9.4.1 Avalanches in collapsing foams

Code : France-07
Responsable du stage : Anne-Laure Biance, Marie Le Merrer, François Detcheverry

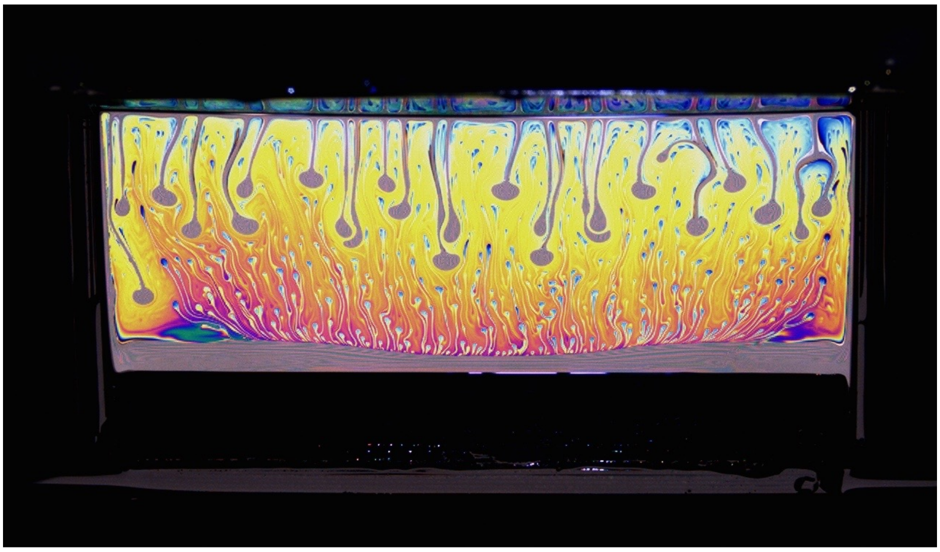


Foams are short-lived materials used in many applications —nuclear decontamination, oil recovery, detergency or fire-fighting. Among the different mechanisms of foam destabilization, the most dramatic and efficient is **coalescence**, i.e. the rupture of films which separate neighbouring bubbles. In particular, foam collapse proceeds through collective coalescence events, called avalanches, in which many bubbles break one after the other (figure). Though crucial to control the destabilization of foams to fully exploit their potential, few measurements of coalescence avalanches exist, mostly through acoustic measurements (Vandewalle PRL 2001) or in model 2D foams (Ritacco PRL 2007).
The objective of the internship is therefore to use video imaging and data processing to characterize the dynamics and statistics of **coalescence avalanches** in collapsing 3D foams, in particular the avalanche size, duration and frequency, and how they are affected by the foam structure (e.g. polydispersity). Experimental results will be compared to models from statistical physics.

9.5 Institut de Physique de Rennes

9.5.1 Ecoulements locaux dans les mousses liquides

Code : France-08
Responsable du stage : Isabelle Cantat



Champ d'épaisseur dans un film de savon, juste après un étirement brusque.

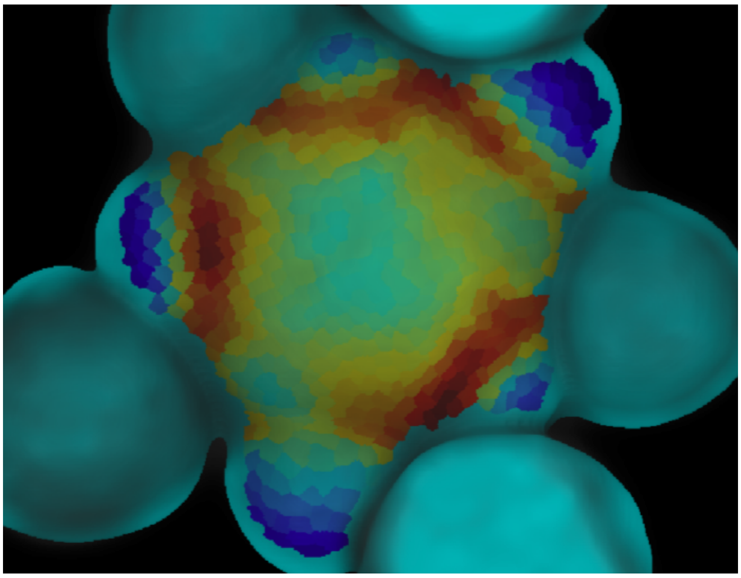
Les mousses liquides sont utilisées dans de nombreux domaines industriels (cosmétique, agroalimentaire, BTP, pétrole, extraction minière,...). La viscosité apparente de ces matériaux, constitués essentiellement d'air et d'eau, peut atteindre 1000 fois la viscosité de l'eau. Cette viscosité macroscopique n'est pas modélisée, car les écoulements locaux ne sont pas connus. Cette question relève, fondamentalement, de la mécanique des fluides au voisinage d'interfaces déformables et de la physico-chimie des interfaces.
L'objectif du stage est de mesurer et de modéliser les écoulements dans une structure de quelques films, soumise à une déformation contrôlée. Le champ d'épaisseur est obtenu avec une caméra spectrale et le champ de vitesse par mesure de fluorescence. La modélisation repose sur la prédiction des gradients de tension de surface dans le film.
Le stagiaire devra avoir de bonnes connaissances en mécanique des fluides et en physique expérimentale.

contact: isabelle.cantat@univ-rennes1.fr
https://perso.univ-rennes1.fr/isabelle.cantat/

9.6 ENS Lyon

9.6.1 The chemomechanical basis of morphogenesis

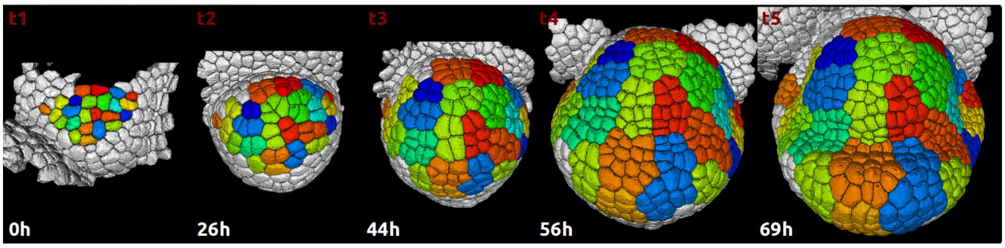
Code : France-09
Responsable du stage : Arezki BOUDAOUD



Morphogenesis is the remarkable process by which a living organism achieves a well-defined shape. We employ approaches from continuum mechanics to investigate the mechanisms behind patterns in plants. A long-standing hypothesis is that reaction-diffusion biochemical systems can spontaneously yield Turing patterns, that are well-known in the context of animal skin colors such as in zebras or giraffes. However the search for the molecules that would mediate such reaction-diffusion systems has been unsuccessful.
The main objective of the proposed internship is to investigate the alternative hypothesis that the coupling between the continuum mechanics of a growing tissue and biochemistry can lead to Turing-like patterns. In practice, this work will combine the theoretical construction of continuum models, the study of their linear stability, and numerical simulations (which could also be discretized on a cell basis). The models will be developed in connection with observations (e.g. protein distributions as in the figure) and will aim at feeding back on experiments. Overall, the work proposed will help renew the current vision of the emergence of patterns in living organisms.

9.6.2 Towards the constitutive law of growth in plant tissues

Code : France-10
Responsable du stage : Arezki BOUDAOUD



Morphogenesis, the remarkable process by which a living organism achieves a well-defined shape, relies on changes in tissue mechanics during growth of the organism. Over the last decades, the mechanics of living tissues has been characterized using standard approaches from mechanical engineering, generally leading to viscoelastic constitutive laws. In this context, we work on plants, because their mechanics is relatively simple, being dominated by cell walls and hydrostatic pressure, so that they may be viewed as viscoelastic closed foams with inner pressure. Now, the challenge is to characterize growing tissues. This task is notoriously difficult because growth involves addition of matter and is coupled with biochemical processes.
Our long-term aim is to simultaneously measuring the strain rate of a growing tissue and compute the stress field in this tissue; the relation between the two would be the constitutive law of growth. To achieve this aim, we combine experiments and mechanical modeling. We first use nano- and micro-indentation to probe tissue mechanics at sub-cellular resolution. We then turn to cell-based or finite-element models to infer the tissue static mechanical properties and then the mechanical stress field. Finally, we image growing tissues in 4D (space + time) using confocal optical microscopy, in order to quantify growth strain at cellular resolution. As this program is very broad, the internship will focus on one of the sub-projects. The work proposed will help understanding the mechanical basis of morphogenesis.