Postdoc position available: Experimental/numerical investigation of hydrogen-air flames propagating in thin layer vessels.

A postdoc position is open at IMI (Institut de Mécanique et d'Ingéniérie) in the field of Physics / Fluid Mechanics / Reactive Systems / Optics / Combustion.

Deadline : July 1^{st}, 2020.

Scientific context

The scientific consensus on the necessity to reduce the greenhouse gases, like carbon dioxide (CO2), tends to ban the use of carbon-based fossil energy. This leads to intense research on alternative sources of energy. One of the most promising is hydrogen, but it rises questions in terms of safety and control that need to be clarified in order to use it in domestic, transportation and industrial processes. Its wide range of flammability limit (from 4% to 75%) and its small quenching distances (around 600μm) increase the potential risk of hydrogen leaks. The precise description of the phenomena at play during flame propagation is of prime importance, especially in confined environment like the internal geometry of fuel cell stack [1]. In such configurations, the closeness of burner walls can have either a damping effect, by absorbing the thermal energy of the flame, or facilitating effect, by imposing distortion [2] and acoustic coupling [3]. As a result, some unexpected flame propagation modes can emerge [4] (example on Fig. 1). The precise description of the local phenomena at play and the global implication on the dynamics of the whole flame propagation have to be investigated both experimentally and numerically, in order to draw the limits of potential risk of flame propagation in a defined configuration.

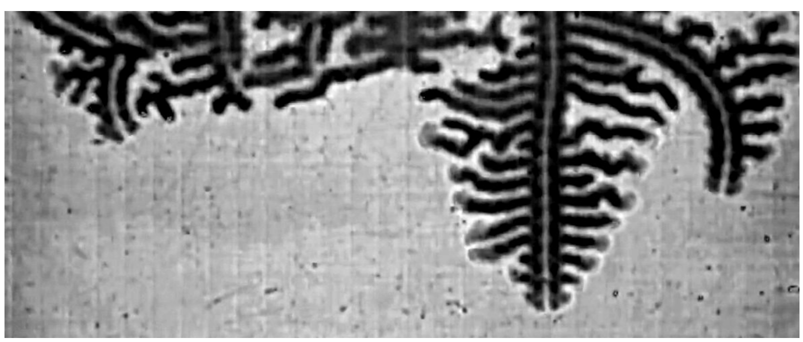

FIGURE 1 – Downward propagation of a lean premixed hydrogen-air flame in a 2mm gap between plates. Condensed water streaks make the flame path visible. From Veiga et al.[4].

Our group research

A collaboration has recently started between IRPHE and M2P2 on the propagation of premixed flames in thin layer. Experiments in Hele-Shaw cells [5, 6], conducted by Christophe Almarcha at IRPHE, have just been favourably compared to numerical simulations conducted by Pierre Boivin at M2P2 [7]. Preliminary results reproduced numerically the non linear evolution of propane-air flames (see Fig. 2).

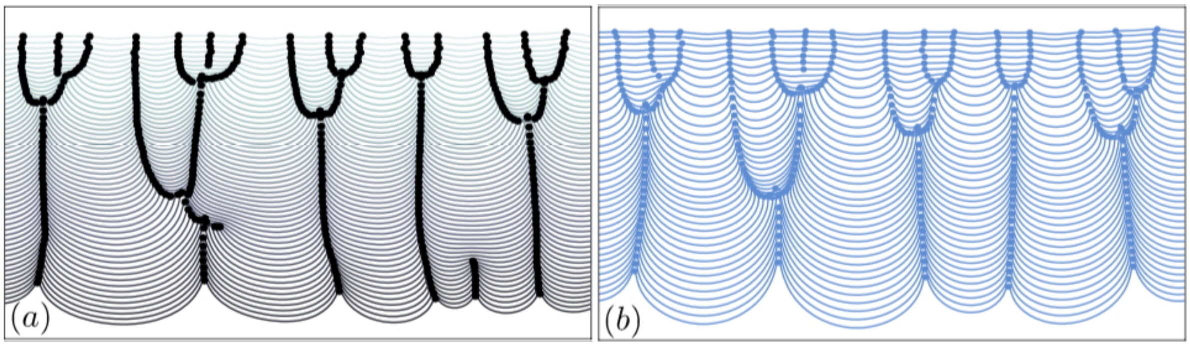

FIGURE 2 – Non linear evolution of Darrieus-Landau instability[7] : (a) Experimental@IRPHE, (b) Numerical@M2P2 results starting from the same initial condition extracted from the experiment.

Postdoc's description

The postdoc will consist in adapting such a study to hydrogen-air flames. Visualization issues will have to be addressed to get the flame position and the velocity field, in particular close to the walls of the burner. These quantities will give insight into the physical transfer of momentum and energy to the burner's walls. Schlieren and interferometric techniques [8, 9] are indirect visualization techniques that will be used to track the global hydrogen flame shape and the global quantities like the flame speed. However, from the images which are the integration of refractive index fluctuation in the depth, precise shape and local informations are difficult to extract. For this reason, we will use in addition LASER Particule Image Velocimetry (PIV) techniques to obtain velocity fields on a slice of the domain. We plan to extend the microscopic analysis with LASER Induced Fluorescence LIF [10] by seeding the reactants with acetone. Precise description at small scale will be facilitated by the use of numerical simulations in connection with the experiments. For this purpose, use and extension of a Lattice-Boltzmann method (LBM) dealing with multi-component reactive flows [11, 12] is in the scope of the postdoc position. The method is particularly interesting as its cost is five to ten-fold lower than classical NS solvers, allowing to simulate the full-scale experimental set-up at a reasonable cost [12]. A numerical analysis to test hydrogen reduced chemical schemes [13] would allow large scale numerical simulations in the future.

Candidate's profile

Essential Requirements : Applicants will hold a Ph.D. degree in Physics or Mechanical Engineering. The position requires some of the following skills :

— Experimental and visualization technique skills, to adapt the existing experiments to hydrogen flames.

— Coding and software development skills in order to adapt the existing Reactive Lattice Boltzmann Method to the hydrogen reaction and physical parameter, and to the experimental configurations.

Conditions

— Application due date : July 1^{st}, 2020.

— Starting date : September–November.

— Contract duration : one year, possible extension.

Net salary according to AMU standards depending on experience : from 1958€/m (less than three years after PhD) to 2291€/m (over three years).

How to apply

Email to christophe.almarcha@univ-amu.fr and pierre.boivin@univ-amu.fr :
- CV,
- cover letter,
- references, if applicable.

References related to the project

[1] M Kuznetsov et J Grune. “Experiments on combustion regimes for hydrogen/air mixtures in a thin layer geometry”. In : *International Journal of Hydrogen Energy* 44.17 (2019), p. 8727-8742.

[2] Vitaly Bychkov, Damir Valiev et Lars-Erik Eriksson. “Physical mechanism of ultrafast flame acceleration”. In : *Physical review letters* 101.16 (2008), p. 164501.

[3] Arkady Petchenko, Vitaly Bychkov, V’yacheslav Akkerman et Lars-Erik Eriksson. “Violent folding of a flame front in a flame-acoustic resonance”. In : *Physical review letters* 97.16 (2006), p. 164501.

[4] Fernando Veiga-López, Mike Kuznetsov, Daniel Martinez-Ruiz, Eduardo Fernández-Tarrazo, Joachim Grune et Mario Sánchez-Sanz. “Unexpected propagation of ultra-lean hydrogen flames in narrow gaps”. In : *Physical Review Letters* 124.17 (2020), p. 174501.

[5] **E. Al Sarraf, C. Almarcha, J. Quinard, B. Radisson et B. Denet. “Quantitative Analysis of Flame Instabilities in a Hele-Shaw Burner”. en. In : *Flow, Turbulence and Combustion* 101.3 (oct. 2018), p. 851-868. issn : 1386-6184, 1573-1987.**

[6] **Basile Radisson, Juliette Piketty-Moine et Christophe Almarcha. “Coupling of vibro-acoustic waves with premixed flame”. In : *Physical Review Fluids* 4.12 (2019), p. 121201.**

[7] **Muhammad Tayyab, Basile Radisson, Christophe Almarcha, Bruno Denet et Pierre Boivin. “Experimental and numerical Lattice-Boltzmann investigation of the Darrieus-Landau instability”. In : *Combustion and Flame* under review (2020).**

[8] **Christophe Almarcha, Philip MJ Trevelyan, Patrick Grosfils et Anne De Wit. “Chemically driven hydrodynamic instabilities”. In : *Physical review letters* 104.4 (2010), p. 044501.**

[9] Stephanie A Coronel, Josué Melguizo-Gavilanes, Rémy Mével et Joseph E Shepherd. “Experimental and numerical study on moving hot particle ignition”. In : *Combustion and Flame* 192 (2018), p. 495-506.

[10] Alexandre Moutte. “Etude de jets turbulents à masse volumique variable : impact de la variation de masse volumique sur la structure fine et le mélange”. Thèse de doct. 2018.

[11] **Yongliang Feng, Muhammad Tayyab et Pierre Boivin. “A Lattice-Boltzmann model for low-Mach reactive flows”. In : *Combustion and Flame* 196 (2018), p. 249-254. issn : 0010-2180.**

[12] **Muhammad Tayyab, Song Zhao, Yongliang Feng et Pierre Boivin. “Hybrid regularized Lattice-Boltzmann modelling of premixed and non-premixed combustion processes”. In : *Combustion and Flame* 211 (2020), p. 173-184.**

[13] **Pierre Boivin, Carmen Jiménez, Antonio Luis Sánchez et Forman Arthur Williams. “An explicit reduced mechanism for H_2–air combustion”. In : *Proceedings of the Combustion Institute* 33.1 (2011), p. 517-523.**