Effect of H_2-enrichment on flame stabilization mechanisms in 3D printed PMB.

E. Flores-Montoya*[1], T. Schuller[1], and L. Selle[1]

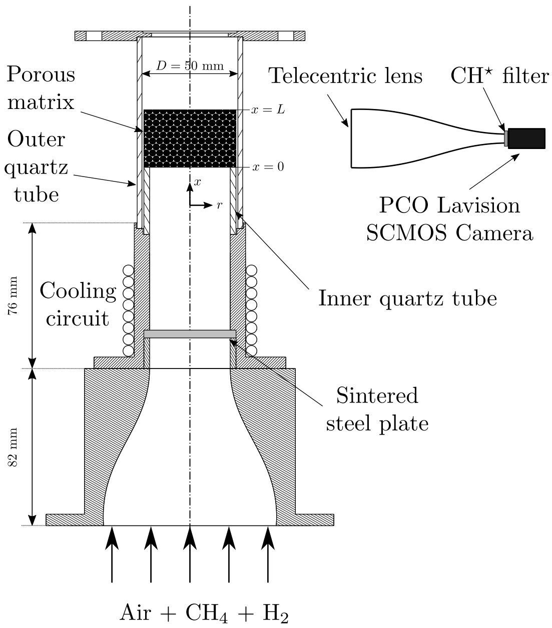
[1]Institut de Mécanique des Fluides de Toulouse (IMFT), Toulouse, France

Context

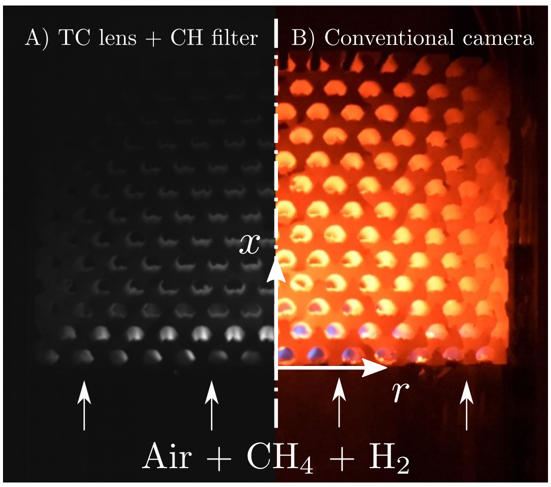
Submerged combustion inside Porous Media Burners (PMB) is a promising technology featuring fuel-flexibility, low pollutant emissions and broad power range [1, 2]. Behind these achievements stands the recirculation of heat from the burnt to the fresh gases via the porous matrix. In particular, the preheating of the gases ahead of the flame front enables a stable combustion of ultra-lean mixtures below the classical flammability limit, which in turn permits operation at reduced temperatures of minimal NOx emissions. Regarding the energy transition, the fuel-flexibility of PMB makes them a relevant candidate to harness the full spectrum of H_2-CH_4 blends, thereby enabling CO_2 abatement.

Project description

With the aim of improving the existing volume-averaged and asymptotic models describing porous burners at the macroscopic scale, a thorough understanding of the flame stabilization mechanisms and associated pore-level structure is mandatory [3]. Unfortunately, the use of opaque, reticulated ceramic foams has so far prevented a direct visualization of the flame front inside realistic porous matrices - which has only been achieved in 2D configurations [4]. So as to circumvent this issue, the IMFT has developed the first optically accessible fully 3D PMB. This is achieved by means of a novel experimental setup that combines mathematically-defined porous geometries, additive manufacturing techniques and a telecentric lens.



(a) Schematic of the POROSITO test rig.



(b) 1 kW thermal power Methane-Hydrogen-Air flame with $\phi = 0.4$ and $\alpha_P = 0.4$ stabilized inside the porous matrix.

The POROSITO test rig (see Fig 1(a)) consists of a porous burner placed inside a quartz tube. Additive manufacturing is employed to produce a cylindrical porous matrix made of 316L stainless steel alloy. The burner geometry is generated with the aid of an inhouse python code. The fluid-solid interface is defined by a diamond triply-periodic minimal surface [5]. In these topologies, pore size and porosity level can be independently controlled. This offers full control of the topological parameters and allows us to systematically study their influence on the burner stability and performance. Moreover, the resulting geometry features several see-through directions in 3D, allowing extensive visual access to the interior of the porous matrix and an exact probing of the flame location for given operating conditions (see Fig 1(b)). A sCMOS camera equipped with a bandpass filter centered

*Contact: enrique.floresmontoya@imft.fr

at $\lambda = 430$ nm ($CH^{\star}$ radical emission peak) and a telecentric lens allow to obtain a line-of-sight integrated image of the flame front inside the burner, free of the black-body radiation. A telecentric lens is used to remove perspective distortions, yielding an entire visualization field of the burner. This setup is complemented by more classical thermocouple measurements and pollutants characterization. Different fuel compositions ranging from 100% CH_4/0% H_2 to 20% CH_4/80% H_2 (thermal power fraction) can be tested. Hydrogen blending allows us to evaluate the influence of hydrogen enrichment on the flame stabilization mechanisms. Flame position inside the PMB can, for the first time, be unequivocally related to the burner operating conditions and compared with existing theoretical models [3, 6].

The student will work on several aspects related to the POROSITO test rig.

1. Development and improvement of the control and acquisition tools of the experiment.
2. Parametric study with different burner configurations: porosity and pore size variations.
3. Evaluation of the influence of hydrogen on the stabilization mechanisms.
4. Time permitting, application of RAMAN Scattering laser technique to perform local temperatures measurements of the gas pahse inside the porous matrix.

Candidate requirements

The selected master student will be mostly working in a laboratory, gathering, post-treating and analyzing experimental data. A minimum level of attraction/curiosity for experimental work is envisaged. The position requires a solid background in fluid dynamics, heat transfer and thermodynamics. Advanced skills in python are also necessary. Labview is envisaged but not disqualifying. Above all, motivation, curiosity and passion for science are the most valued features.

Applicants are asked to send their CV and a cover letter to the email address `enrique.floresmontoya@imft.fr`. Do not hesitate to ask for further details about the position.

Keywords: porous media combustion, additive manufacturing, fuel-flexibility, hydrogen, low emissions burners

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