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THE FRENCH AEROSPACE LAB

PhD PROPOSAL

Numerical investigation of flame dynamics in porous media combustion

Reference : **MFE-DMPE-2024-03**
(to recall in all correspondence)

Thesis start date: October 2024 (can be adjusted)	**Application deadline:** if you got this document online, you can still apply

Key words

Combustion, porous, flame describing function, numerical simulations

Ideal Candidate

We seek a highly motivated, innovative, and detail-oriented candidate with a strong background in computational fluid dynamics, combustion, or related fields. Proficiency in numerical modeling and simulation techniques is essential. The candidate should possess a genuine interest in pushing the boundaries of knowledge within the realm of porous media combustion.

Flames in porous media, a sub-realm of combustion physics, hold the potential for advancements in energy efficiency, emissions control, and combustion system design, as the energy conversion within porous media can occur at operating conditions that can otherwise not be achieved. This doctoral research project entails detailed numerical simulations and in-depth analysis to unravel the complex relationship between porous solid structure and flame characteristics. As an example, Fig. 1 shows a snapshot of the flow through a porous medium obtained from a numerical simulation.

Thesis Overview

Under certain conditions (e.g. lean premixed combustion, high energy density systems), **combustion instabilities** can occur, leading to system fatigue or damage, and additional pollutant emission. The focus of the project is to overcome these instabilities by means of porous media combustion, immersing the flame within a solid and inert porous matrix. In this comprehensive study, the selected PhD candidate will study the domain of porous media combustion and explore new relations between the porous solid structure and combustion instabilities.

This research project involves conducting **high-fidelity simulations** using state-of-the-art numerical methods to study flames immersed within various porous solids, exploring a broad spectrum of pore topologies and sizes while gradually increasing the complexity of the considered physics, like conduction within the solid and heat radiation, to assess their impact on the flame. This flame behavior is quantified by the **flame describing function** (FDF) as a function of both the frequency and the amplitude of perturbations prescribed at the inflow.

Figure 1 Snapshot of the flow through a porous medium

The investigation **focuses on understanding how flames respond to perturbations in the complex spatial configurations of the pore network**, identifying key parameters that affect the FDF, flame stabilization, propagation, and extinction in porous structures, with a specific emphasis on correlating these findings with porous parameters such as porosity and tortuosity. In addition, linear stability tools will be used to investigate the flame response.

The research will culminate in the development of low-order models that encapsulate the insights gained, crucial for future porous burner optimization, and will be complemented by collaboration with experimental researchers to validate the numerical results, ensuring the practical applicability and accuracy of the developed models in real-world scenarios.

Additional reading on the topic can be done, starting e.g. with Ref 1 and Ref 2 to get an overview of the state of the art research on porous media combustion experiments, Ref 1 and Ref 3 for more details on the volume-averaged modeling challenges in this field, as well as Ref 3 for more details on pore-level simulations, similar to the ones that will be undertaken in the present PhD work.

Benefits

The PhD candidate will have the opportunity to work at the forefront of combustion research, within the scope of the **ERC starting grant POROLEAF**, contributing to the development of clean and efficient energy conversion technologies. This research offers a platform to enhance computational skills and expertise in numerical simulations and modeling. Findings from this study can have profound implications for industries such as power generation, transportation, and environmental engineering.

Supervising team

The research will **take place at ONERA in Toulouse**, France, and will be supervised by Dr. Roncen. This Ph.D. thesis will also benefit from the co-direction and supervision of Professor Stein from **KIT** (Karlsruhe Institute of Technology) and Dr. Zirwes from the **University of Stuttgart**, Germany. To strengthen this international collaboration, the PhD research project will also encompass regular annual visits of the PhD researcher to KIT / Stuttgart.

References

Ref 1: Zirwes, Thorsten, et al. "Improving volume-averaged simulations of matrix-stabilized combustion through direct X-ray µCT characterization: Application to NH3/H2-air combustion." Combustion and Flame 257 (2023): 113020.

Ref 2: Vignat, Guillaume, et al. "Experimental and numerical investigation of flame stabilization and pollutant formation in matrix stabilized ammonia-hydrogen combustion." Combustion and Flame 250 (2023): 112642.

Ref 3: Masset, Pierre-Alexandre, et al. "Modelling challenges of volume-averaged combustion in inert porous media." Combustion and Flame 251 (2023): 112678.

Planned collaborations

This PhD thesis will be co-supervised between **ONERA** (Toulouse, France), **KIT** (Karlsruhe, Germany), **University of Stuttgart** (Stuttgart, Germany), with the physical location being at ONERA.

Hosting lab at ONERA	**Thesis director**
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