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THESIS PROPOSAL - Fixed-term contract

Modelling of plasma-assisted combustion for the control of combustion instabilities

Reference: CFD-2023-CUE-02
Team: CFD
Research unit: Energetics and propulsion
Salary: 33.6 K€/year (gross)
Duration: 36 months - **Starting date**: from February to September 2024
Level of education required: Master of science

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HOST LABORATORY

The **Cerfacs** is a fundamental and applied research center specializing in modelling and digital simulation. Through its resources and expertise in high-performance computing, it addresses major scientific and technical problems in public and industrial research. The Cerfacs teams develop innovative methods and software solutions to meet the needs of the aeronautics, space, climate, energy and environment sectors. Cerfacs works in close interaction with its seven associates: **Airbus**, **Cnes**, **EDF**, **Météo France**, **Onera**, **Safran** and **TotalEnergies**.

JOB DESCRIPTION

Topic(s): Combustion Hydrogen Plasma High Performance Computing

Context:

The rising importance of hydrogen combustion in the context of decarbonization, particularly within the aerospace and energy production sectors, is evident. The potential challenges related to combustion instability are expected to emerge as a primary concern with these new hydrogen engines, like what has been experienced in the past with kerosene engines, particularly when aiming for lean combustion regimes to reduce NOx emissions. To address these challenges, disruptive solutions have to be found accompanied with the development of numerical tools that can be used in both academic and industrial environments.

An emerging solution is to use non-equilibrium plasma discharges to actively control the combustion. These discharges operate with a low power (usually <1% of the thermal flame power) and have been found to be able to stabilize flame in a wide range of conditions for many hydrocarbon fuels. Initial findings suggest that this method may also offer effective control over hydrogen flames.

Mission:

CERFACS has a long expertise in modelling turbulent reactive flows. Recently, plasma-combustion models have been developed for the investigation of plasma-assisted combustion processes. This includes fully-coupled simulations for plasma-assisted ignition in canonical cases [1] and phenomenological modelling of flame stabilisation in a semi-industrial burner [2]. The overall objective is to understand and analyse the impact of Nanosecond Repetitively Pulsed (NRP) discharges on combustion and combustion instabilities. In particular, a Large Eddy Simulation (LES) closure for plasma-assisted hydrogen combustion will be incorporated in AVBP (https://www.cerfacs.fr/avbp7x/), in order to perform the 3D simulation of a lab scale configuration for validation. Based on detailed simulations of NRP discharges in turbulent flows using the code AVBP-PAC, a low-order model will be derived, able to reproduce the impact of NRP discharges on turbulent reacting mixtures in both fresh and burnt gas conditions. Then, the TUB configuration will be simulated in conditions of increasing complexity with the code AVBP: stable combustion without plasma, combustion instabilities without plasma, combustion instabilities with plasma. In all conditions, systematic comparison with available measurements will be performed to validate the numerical model. These simulations aim to generate valuable insights and recommendations regarding the prospective use of non-equilibrium plasma in future hydrogen gas turbines.

Expected Results:

- Model of NRP discharges suitable for 3D Large Eddy Simulation of turbulent combustion
- Understand the interaction between NRP discharges and reacting mixtures in fresh and burnt gases, and of the underlying mechanisms of plasma-controlled instabilities
- Recommendations on the design and use of plasma-assisted combustion devices.

The PhD position is part of the ICHAruS project (DC6 - https://icharus.eu/), a MSCA doctoral network funded by the European Community. The project brings together leading research institutions in Europe, industrial partners and international universities to develop innovative technologies for the safe and efficient utilization of hydrogen in transportation and power generation. The Ph.D. candidate will participate to network-wide training activities, workshop and conferences, along with secondments periods in network partners' laboratories.

Application must be done following the procedure detailed at: https://euraxess.ec.europa.eu/jobs/177738.

[1] N. Barleon, L. Cheng, B. Cuenot, O. Vermorel, A. Bourdon, Investigation of the impact of NRP discharge frequency on the ignition of a lean methane-air mixture using fully coupled plasma-combustion numerical simulations, Proceedings of the Combustion Institute 39 (4) (2023) 5521–5530.
[2] N. Barleon, B. Cuenot, O. Vermorel, Large-eddy simulation of swirled flame stabilisation using NRP discharges at atmospheric pressure, Applications in Energy and Combustion Science 15 (2023) 100163.

DESIRED PROFILE

Background required:

Numerical simulation | Fluid dynamics | Programming Python/Fortran/C++

Abilities:

Capacity for analysis and synthesis **Innovation capacity** **Ability to work independently**
Relational qualities **Rigorous**