Internship offer

Title of the internship:
Modeling of acoustic boundaries in high-fidelity simulations of H2/Air engines.

Background:
Hydrogen (H2) serves as an energy carrier enabling the transition towards a sustainable society. It is generated through electrolysis powered by sustainable electricity and can be harnessed to release stored chemical energy. One way of recovering this energy is to burn the H2 in a conventional thermal engine. This combustion process does not emit any CO2.

When designing combustion devices, one of the major challenges is to predict and mitigate the so-called **thermoacoustic instabilities**, also known as combustion instabilities. In a nutshell, the thermoacoustic feedback loop goes as follows. Unsteady flames release heat at a time-varying rate. This fluctuation generates acoustic waves that propagate within the engine. Like all confined geometries, the engine possesses resonant acoustic modes, leading to the amplification of specific wavelengths. The unsteady acoustic waves are reverberated on physical acoustic boundaries (walls, inlets, oulets or other engine elements) and, then, perturb the flow field, resulting in fluctuation in heat release rate. When these fluctuations become coherent with the resonant acoustic modes, the constructive thermoacoustic feedback amplifies these specific acoustic waves, **resulting in high-amplitude acoustic pressure and velocity fluctuations**.

When thermoacoustic instabilities appear, in the best cases, they lead to exceedingly loud operating engine that can injure the operator's hearing. In other cases, they lead to engine failure (flame blow off, flash back, …) or even catastrophic failures, hence, **destroying the entire engine** in the span of a few milliseconds.

Since H2 is an exceptionally potent fuel compared to traditional hydrocarbon fuels (the combustion of 1 kg of H2 releases 120 MJ while a kg of natural gas only releases 50 MJ), it is particularly prone to thermoacoustic instabilities.

High-fidelity simulations, including Large-Eddy Simulation and Direct Numerical Simulation, are powerful tools commonly employed in both industry and academia to aid in the design of stable H2/Air combustors.

As such, it is necessary for LES models to correctly predict thermoacoustic instabilities. Due to the specific properties of this fuel, the modeling of H2 combustion in itself is a challenge. Furthermore, for accurate prediction of thermoacoustic instabilities, it is imperative to anticipate the **actual acoustic modes of the engine** that depend on the nature of the **physical acoustic boundaries**.

Consequently, particular attention must be paid to the modeling of acoustic boundary conditions in LES/DNS. In this context, the very popular Navier-Stokes Characteristic Boundary Condition (NSCBC) method will be studied and modified to **improve the prediction of thermoacoustic instabilities in real H2/Air engines**.

Research project:
This internship is associated with the European Research Council grant SELECT-H (SafE and reliabLE Combustion Technologies powered by Hydrogen), and a PhD position is scheduled to open in October 2024, offering potential continuation of this work for highly motivated candidates.

Work program:
The internship will consist in the following steps:

- Conducting a literature review of the acoustic treatment in high-fidelity simulations.
- Co-implementing the methods in CERFACS high-fidelity solver for reacting Navier-Stokes equations (AVBP).
- Validating the method initially on canonical cases and, then, progressing to simulate a real H2/Air engine.

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