JOB OFFER – PhD

Large-Eddy Simulation of an Aeronautical Fire Resistance Test: Alternative Fuels and Outgassing Phenomena

OFFER INFORMATION

Reference: E&S-25-TJ-01
Team: Energy and Safety

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Salary: 33 K€/year (gross)
Period: 3 years - from: 01/10/2025

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HOSTING TEAM - E&S

The Energy & Safety team, formerly the CFD-Combustion team, focuses on cross-disciplinary activities aimed at developing, optimizing and deploying scientific codes dedicated to advanced combustion calculations in industrial geometries. The team focuses on the simulation of flows, applying them to aircraft, rockets, helicopters, car engines, turbines and more. The result is essential tools for a wide range of applications, with the leitmotiv: let's calculate systems before we build them. More specifically, team members develop models and tools covering chemical reduction, turbulence, combustion, two-phase systems, combustion instabilities, etc., to meet both academic and industrial challenges. Thanks to its position, the team collaborates with numerous scientific groups, design offices of CERFACS associates, and other CERFACS teams.

CONTEXT

In the current context of energy decarbonization, aircraft engine manufacturers are exploring the replacement of kerosene with non-fossil, lower-emission fuels, known as Sustainable Aviation Fuels (SAFs). Aeronautical standards require the certification of both metallic and composite materials through experimental fire resistance tests, the outcomes of which can vary significantly depending on the type of fuel used.

Fire resistance assessment is currently based on standardized torch flame tests, where a flame is directed at the material sample, as illustrated in Figure 1. These tests are time-consuming and costly for aircraft manufacturers, and involve complex physics, coupling the flame behavior, radiative heat transfer, thermal response of the material, and its degradation—including outgassing phenomena.

In this context, the development of a numerical test bench capable of reproducing these experiments would allow for a better understanding of the underlying physical mechanisms, and would help reduce development time for successful fire testing using both conventional fuels and SAFs.

Figure 1 : Fire certification test on a kerosene burner (DGA Techniques Aéronautiques)

OBJECTIVES

The challenge in reproducing a fire test lies in the diversity and disparity of the physical and temporal scales involved. From a combustion perspective, the specific properties of alternative fuels (SAFs) can significantly affect the flame structure. Beyond the modeling of reactive flows, a numerical fire test requires the representation of multiphysics couplings to account for other phenomena such as heat conduction in solids, as well as effects whose importance still needs to be assessed, such as radiation and soot formation. The degradation of composite materials leads to outgassing phenomena, which may result in ignition or auto-ignition of the released gaseous species.

The ultimate objective of this work is to reproduce a certification fire test, in which a material sample is exposed to an impinging flame from a certification burner. As previously mentioned, a complete simulation of such a test requires the implementation of a multiphysics simulation chain that accurately captures the spray flame dynamics from the burner, the heat transfer to the sample in the impact zone, and potentially other heat transfer mechanisms. Setting up such a simulation chain represents both a scientific and technical challenge, particularly in terms of coupling strategy, due to the disparity of timescales involved (less than 1 ms for combustion, ~10 ms for fluid dynamics, and several minutes for transient heat conduction in the solid).

ORGANIZATION OF RESEARCH WORK (36 months)

Based on these observations, several research axes have been identified:

1. **Modeling of SAF Spray Flames in a Certification Burner**
   Setting up a numerical fire test requires accurately reproducing key characteristics of the certification burner flame: flame length, temperature levels at the torch outlet, and flame dynamics. Large Eddy Simulations (LES) of this type of burner have already been carried out at CORIA [Boulet2018]. The

specificities of SAFs will be addressed by building on the expertise developed at CERFACS on this topic [Shastry2021, Wirtz2022, Lesaffre2025].

2. **Multiphysics Coupling Methodology**
   The multiphysics nature of the problem requires the implementation of a coupled simulation chain, including thermal transfer in the solid. This involves coupling the AVBP reactive flow solver (CERFACS) with thermal solvers such as AVTP (CERFACS) or MODETHEC [Dellinger2024] — an ONERA code for anisotropic heat conduction and material degradation. This requires the development of an efficient coupling strategy. For predicting the transient thermal response of the wall over durations representative of an experimental test, thermal timescales are much longer than those of the reactive flow, requiring a suitable coupling approach [Errera2013], building on ongoing PhD work at CERFACS.
3. **Modeling of Outgassing Phenomena**
   Another research axis focuses on extending the coupling strategy to wall configurations with outgassing. This involves understanding the physics of the outgassing process and assessing its impact on wall thermal loads. Outgassing can lead to ignition or auto-ignition phenomena, which must also be modeled and incorporated into the simulation chain.

PLANIFICATION

The research work will be structured over the three years as follows:

- Literature review
- Work on the different research axes**,** including:
  - Modeling of alternative fuels for fire testing
  - Simulations of representative configurations (academic test cases, fire test burners)
  - Development and improvement of coupling algorithms
  - Modeling of the outgassing phenomenon in the gas phase
- Writing the dissertation

PROMOTING RESEARCH WORK

The research work will be presented at various national and international conferences and is expected to lead to publications in peer-reviewed journals. Strong interaction with industrial stakeholders in the aeronautics sector (Airbus, SAFRAN, ONERA, Hutchinson) is also anticipated throughout the course of this PhD project.

TRAINING

The PhD candidate will attend various training sessions over the course of the three years, including:

- Fundamentals of combustion
- Fundamentals of Large-Eddy Simulation (LES)
- HPC simulation tools (meshing, massively parallel computing, etc.)
- Coupling tools
- Doctoral school courses to support career development
- Etc.

DESIRED PROFILE

- Master's degree (MSc) or Engineering degree
- Background in fluid mechanics, combustion, and heat transfer
- Programming skills (Fortran or Python)
- Motivation and curiosity
- Ability to manage and coordinate tasks
- Strong interpersonal skills, with the ability to interact effectively with academic and industrial partners

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To apply, please send your CV and covering letter to Thomas Jaravel (jaravel@cerfacs.fr) , applications are open until 01/09/2025.

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