JOB OFFER – STAGE

Numerical Simulation of Non-Equilibrium Plasma Assistance for Ammonia Combustion Technologies

OFFER INFORMATION

Reference: E&S-2025-NB-1

Location: 42 Avenue Gaspard Coriolis – 31057 Toulouse

Team: E&S

Supervisors:

- Nicolas Barléon
- Thomas Lesaffre

Gratification: 800€ net per month - M2 level or last year at engineering school

Period: 6 months - from: 03/02/2026

Key words: Low-Carbon Fuel – Plasma-Assisted Combustion – Lean-Blow-Out – Chemistry – Large Eddy Simulations - Ammonia

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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

Today, it is crucial for our society to have access to a reliable energy source with a low impact on the environment and climate. In this context, projects are currently underway to use decarbonized fuels such as NH3 as an energy carrier. These fuels can be produced using intermittent energy sources (wind, solar, etc.), serving as a form of storage and can be used in a controlled manner. However, using ammonia in current combustion chambers is not immediately possible and requires an adaptation phase to meet safety and pollutant emission standards, such as NOx. To achieve this, it is natural to move towards lean combustion regimes, unfortunately prone to instabilities and more difficult to ignite. A common solution is to introduce highly reactive species in the mixture, such as hydrogen, to enhance combustion as shown in the figure below. However, the amount of hydrogen introduced must stay limited to avoid NOx increase. An emerging solution to enhance ammonia flame is to use Nanosecond Repetitively Pulsed Discharges. This type of discharge is known to be able to mitigate instabilities encountered in combustion chambers and is also effective for ignition, with low electrical power compared to that of the flame (<1%).

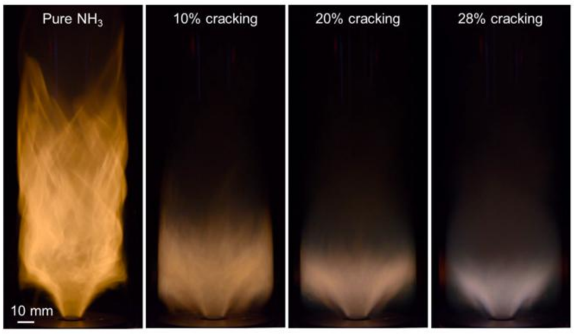

Figure 1: Flame images at different ammonia cracking ratio reproduced from [Shohdy_2023]

MISSION

Recently, a semi-analytical model for PAC has been developed in a previous internship based on the analysis of reaction rate mechanism [Gillingham_2025]. The model showed excellent results compared to a detailed kinetic mechanism as shown in Fig. 2.

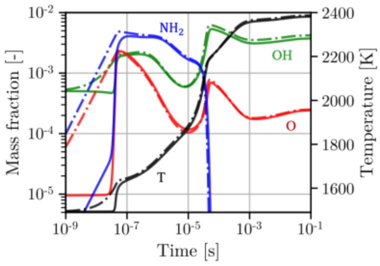

Figure 2: Temporal evolution of the temperature and radicals mass fraction for a pulse in NH3-H2 mixture with water recirculation: (solid lines) the detailed kinetics and (dashed lines) the phenomenological PACMIND-SA model.

While the model significantly improves computational efficiency, two major challenges remain:

- The identification of key plasma-chemical processes is currently performed empirically through manual analysis of path fluxes in detailed plasma-combustion kinetic simulations.
- The selected processes are limited to the computation of major species, while intermediates produced by the discharge are neglected.

The first part of this internship will focus on addressing these two issues.

Then, the model will then be applied to a swirled turbulent NH3-H2 flame to study its response to Nanosecond Repetitively Pulsed (NRP) discharges. Simulations will be conducted using the AVBP code on the lab-scale PACCI burner developed at KAUST. Building on previous work involving pure NH3 (see Fig. 3), the new study will explore lean NH3-H2 flames near extinction. A specific blending ratio of 28\% H2 by volume will be investigated, as experimental observations indicate that under such conditions, plasma actuation may induce flame extinction. This undesired effect must be thoroughly understood to prevent its occurrence in future PAC systems. Plasma-induced stretch is a potential mechanism contributing to the extinction of lean flames with low stretch extinction limits

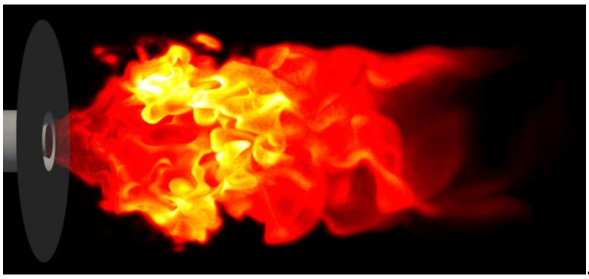

Figure 3: Instantaneous volume rendering of the heat release rate of a pure ammonia flame.

Scientific program:

1. Assimilation of the plasma discharge physics, including non-equilibrium chemistry (literature review) and taking hand in the newly developed plasma-assisted combustion model developed in the frame of a previous internship.
2. Improve the global chemical process definition in the phenomenological model based of global pathway analysis.
3. Simulation of NH3-H2 flame with and without plasma to analyze flame extinction behavior and response to plasma-induced stretch.

Technical program:

1. Develop and improve pre-processing or post-processing scripts in Python.
2. Carry out developments in the Fortran language within the AVBP code.
3. Analysis of the results

[Shohdy 2023] Shohdy et al., Transfer Functions of Ammonia and Partly Cracked Ammonia Swirl Flames, Energies], 2023.
[Shohdy 2024] Shohdy et al., Quantitative comparison of the benefits of cracking and nanosecond repetitive pulsed discharges on the lean blow-off, emissions, and topology of ammonia premixed swirl flames, Combust. Flame], 2024.
[Gillingham 2025] Gillingham et al., A semi-analytical model for Plasma- Assisted Combustion: Application to NH3-H2-air mixtures, Submitted to Combust. Flame], 2025.

DESIRED PROFILE

- Master's degree (M2) or engineering school
- Background in fluid mechanics and energy
- Training in CFD (Computational Fluid Dynamics)
- Knowledge of combustion and/or plasma is a plus
- Programming skills (Fortran, C, or C++ and Python)
- Proactive, curious, and autonomous

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HOW TO APPLY ?

To apply, please send your CV and covering letter to nicolas.barleon@cerfacs.fr and thomas.lesaffre@cerfac.fr , applications are open until 30/04/2026.

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