Post-doctoral position on

Large Eddy Simulation of plasma-assisted combustion of turbulent hydrogen flames

Energy transition context

Hydrocarbon combustion, involved in more than 80% of the worldwide primary energy consumption, produces most anthropogenic CO_2 emissions. Because batteries exhibit a lower energy density than fuels, electrification will not replace combustion in the short term, especially in aircraft engines. Answering the climate change challenge, therefore, requires the decarbonization of combustion systems.

A solution for CO_2-free combustion is to burn e-fuel produced from renewable energy sources through, for instance, the electrolysis of water. Within this context, Airbus announced the simultaneous launch of three full hydrogen aircraft projects, which are expected to lead to a commercial program by 2035. This ambitious objective raises great scientific challenges.

Indeed, while e-fuel flames do not emit CO_2, they are characterized by high-temperature regions, which promote the formation of nitrogen oxides (NOx). A solution to limit the combustion chamber temperature is to decrease the mixture equivalence ratio. NOx production is well decreased, but the low flame temperature induces slower chemical reaction rates, often resulting in incomplete combustion. Such low-temperature regimes are also subject to flame instabilities and extinctions, causing safety issues [1].

An emerging solution to enable flame stabilization in leaner regimes, suitable to a wide range of combustion applications, is to generate electrical discharges at the flame basis. High-voltage electric discharges are generated between two electrodes located inside the combustion chamber. They locally generate a plasma, which interacts with the combustion. The Nanosecond Repetitively Pulsed (NRP) discharges [2,3] are particularly efficient; they allow the stabilization of lean premixed flames on several laboratory-scale hydrocarbon-air flames [4-6] and even in a test rig representative of a gas turbine environment [7] with plasma powers typically less than 1% of the power released by the flame.

The use of NRP discharges to enhance the stabilization of future decarbonized combustion chamber is promising but raises fundamental questions which deserve to be addressed by High Performance Computations. For that reason, EM2C combustion and plasma teams have developed a simplified description of these kinetic processes using a phenomenological model based on the observation that the main effects of nanosecond pulsed discharges are the electronic and vibrational excitations of nitrogen molecules and the dissociation of species by direct electron impact [8,9]. Preliminary results of the first simulation of turbulent flame stabilization by NRP discharges are shown in Fig. 1.

Post-doctoral objectives.

The post-doctoral study is part of the PLasma-Assisted combustion of Turbulent HydrOgeN flames (PLATHON) project, funded by the *Foundation Simone et Cino Del Duca*. PLATHON objectives are to develop means to stabilize lean hydrogen-air turbulent flames with low NOx emissions with NRP discharges.

Experiments and simulations will be conducted to study the impact of NRP discharge on H2 Air stabilization and to understand the formation of NOx. A combustion chamber will be designed to operate plasma-assisted lean H2-Air flames in an environment representative of aeronautical conditions. The post-doctoral researcher will be in charge of performing High Performance Computations of this combustion chamber by including complex chemistry effects into highly resolved turbulent reactive flow simulations. The impact of plasma on the combustion will be handled by the semi-empirical NRP discharge model developed by Castela et al. [10]. The retained solver is the high-order CFD code YALES2 [11] developed by the CORIA laboratory's combustion modeling group in Rouen (France). The candidate will strongly interact with the experimental teams during the project.

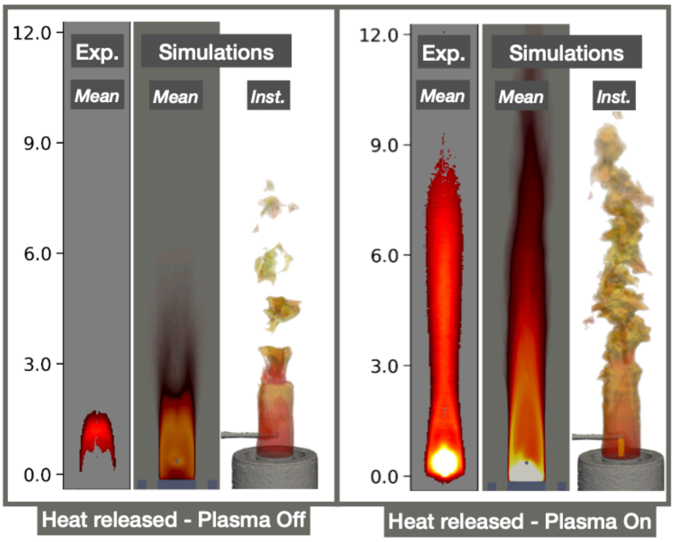

Figure 1*. Large-scale simulations of the stabilization of the plasma-assisted Mini-PAC burner. From Bechane (simulation) and Blanchard (experiments) PhD thesis (EM2C, ANR PASTEC, 2021).*

Skills required

The candidate must hold a Ph.D. degree with a significant experience in Large Eddy Simulations of turbulent combustion. Knowledge in plasma science will be appreciated

Location and supervision

The post-doctoral studies will take place at the EM2C-CNRS laboratory located at CentraleSupélec, Université Paris-Saclay (Gif-sur-Yvette, France). The post-doctoral researched will be supervised by Benoît Fiorina, professor at CentraleSupélec.

Application

Send a CV, transcript records and references to benoit.fiorina@centralesupelec.fr

References

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