PhD position in PC2A (CNRS/Université de Lille)

Towards low-pollutant combustion technologies: Experimental studies of ozone-assisted combustion

Combustion-driven processes are still responsible for a large proportion of energy production and conversion worldwide. Thus major reductions in pollutant emissions and improvements in fuel efficiency should be sought, and can be reached by means of fuel-lean mixtures of renewable fuels. Controlled initiation of the combustion is however a crucial step towards widespread application of such conditions, with wide ranges of application including piston engines, constant volume combustors, gas turbines and aeronautic engines. In all these cases, reproducible initiation of the combustion phase is sought, and multipoint or volumetric ignition being preferred. However, fuel ignition is highly dependent on the chemical kinetics associated with Low Temperature Combustion (LTC).

The chemical mechanisms relevant to LTC include the formation of unstable peroxides, the structure of which reflects the initial fuel. The reactivity of a fuel in this temperature regime is therefore highly constrained by its structure. This is also true for next generation biofuels, whose oxidation pathways can be strongly different from "traditional" fossil fuels. Such species include ethers, whose weak C-O bond causes strong reactivity in the Low-Temperature Combustion regime. To facilitate ignition of such fuels, ozone-seeding has been suggested as a practical and easily-implemented solution. The effect of this addition however remains to be described with accuracy, especially in the fuel-lean cases of interest.

To investigate the potential of this technology, a burner dedicated to the study of stabilized cool flames has been designed and validated in PC2A. The potential to perform detailed kinetic studies through a number of optical and analytical diagnostics, including Planar Laser Induced Fluorescence (PLIF), chemiluminescence, thermometry and gas chromatographic techniques, has been demonstrated. These data can be used to validate kinetic models of the LTC chemistry under these rarely investigated conditions. Moreover, the potential of Particle Imaging Velocimetry (PIV) techniques for the determination of cool flame propagation velocities has been established. This paves the way towards exciting upcoming experimental developments:

1- Among them, the panel of diagnostics associated to the burner will be extended to VUV photoionization mass spectrometry/PhotoElectron PhotoIonization Mass Spectrometry, in collaboration with the DESIRS beamline of Synchrotron SOLEIL, allowing the selective detection and quantification of elusive products, such as the hydroperoxides responsible for radical-chain branching.

2- The stabilization and kinetic study of two-stage flames, ie. comprising a cool and a 'hot' flame, will be undertaken.

3- Further developments of the PIV technique towards better determination of cool flame burning velocities will be achieved.

Keywords: Low Temperature Combustion, Kinetics, Pollutant reduction, bio- and e-fuels, optical and analytical diagnostics.

Academic Requirements: A Master's degree or an Engineering Degree in the fields of Chemistry, Chemical Engineering, and a strong taste for experiments are required. Additional knowledge in the fields of Combustion and/or laser spectroscopy techniques will be beneficial.

Doctoral School: ED Sciences de la Matière, du Rayonnement et de l'Environnement (https://edsmre.univ-lille.fr)

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Laboratory: PC2A

Supervisors: Guillaume VANHOVE, Laure PILLIER

Duration and starting date: 3 years, starting from October 2022

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About PC2A

PC2A (Physico-Chimie des Processus de Combustion et de l'Atmosphère) is a joint laboratory of the CNRS and the University of Lille, in which transdisciplinary research has been performed for more than 60 years in the fields of combustion and atmospheric chemistry. Based on a strong interaction between experimental and modeling work, the researchers in PC2A crave at building better understanding of the science behind the challenges of the current society, such as clean and safe energy, and the mitigation of, and adaptation to climate change.