PhD Thesis Offer at CORIA
(UMR 6614 CNRS – Université Rouen Normandie – INSA Rouen Normandie)

2023 – 2026

An experimental investigation of CO_2 diluted oxycombustion for decarbonized industry

Carbone capture by oxycombustion falls within the low-carbon national strategy, which aims at achieving carbon neutrality in France by 2050. In anthropogenic CO_2 emissions reduction scenario such as the roadmap recently released by the International Energy Agency for the transition to net zero emission, CCUS is always mentioned as one of the key pillars to achieve this goal in the industry sector. Most of industry sectors using boilers for utility are concerned by heat production and the development of oxycombustion processes is of primary interest for thermal power plants and industry in manufacturing sectors with high temperature process and high carbon emission like glass, steel, petrochemicals or cement plants for which the CCS technologies are the most effective solution to reduce significantly the carbon footprint [1-2].

The present PhD offer is part of the OXY3C targeted project of the French National Research Program PEPR SPLEEN (France 2030) and is co-funded by Normandy Region. The PEPR SPLEEN aims at improving knowledge and skills in CCUS oxycombustion technologies for decarbonization and intensification processes. The concentration of carbon dioxide in flue gas can be optimised by associating oxycombustion (i.e. with oxygen as oxidizer thanks to prior separation of nitrogen from air) and dilution with CO_2 coming from dry exhaust gas recirculation [3-4]. Such specific operating conditions have an impact on turbulent flame features [5-6]: limits of stability, flame structures, heat release levels and locations, changes of heat transfer to the load, as well as on flue gas with NOx emissions in the case that some amount of nitrogen remains in the reactants or if air inlets occur in the combustion chamber [5-8], or with CO emissions if the combustion is not complete because of large carbon dioxide dilution [5, 7]. The objective of the thesis is to characterize experimentally in a lab-scale facility the specificity of oxycombustion diluted by carbon dioxide to point out and enlighten these phenomena.

The first part of the experimental work will be devoted to the design of the burner in a canonical representative configuration with (CH_4-CO_2) blend as fuel (representative of natural gas and biogas) and (O_2-CO_2) blend as oxidizer. This burner will be implemented on the CORIA lab-scale multi-fluid combustion facility which modular features enable in-flame optical and laser diagnostics [5-6]. Then, a stability diagram will be established depending on thermal power and CO_2 proportions. The association of chemiluminescence imaging, wall temperature and flux measurements, thermal balance and flue gas emissions will give a characterization of the different types of turbulent flames generated. A few operating conditions of CO_2 diluted oxyflames with be then selected for a detailed analysis by laser diagnostics. The limits of stability of the massively diluted turbulent flames will be studied thanks to the coupling of high-speed (several kHz) Particle Image Velocimetry (PIV) and OH Planar Laser Induced Fluorescence. Time-resolved measurements will highlight the correlations between the flame extinction phenomena and the local aerodynamic conditions [9-10]. Last part of the work will consist

on the application of Spontaneous Raman Scattering (SRS) developed in CORIA [11-12], in the multi-fluid combustion chamber in order to obtain instantaneous and simultaneous measurements of temperature and (CH_4, O_2, CO_2, N_2, CO, H_2, CO_2, H_2O) species concentrations in the confined turbulent flames. The whole of the results and their analysis will give a comprehensive database for high fidelity LES simulation that will be performed by other research group within the OXY3C project, and will provide new insights in CO_2 diluted oxycombustion for the deployment of CCUS for the decarbonation of industry.

Keywords: combustion, burner, CCUS, optical diagnostics, PIV, LIF, Spontaneous Raman Scattering

Required skills

Applicants will hold a Master degree in Physics or Mechanical Engineering. Background and experience in experimental study in fluids mechanics (reactive or not) and/or optical diagnostics will be considered. Ability to work in a team on collaborative projects. Finally, fluency in spoken and written French or/and English is a requirement.

Application procedure

Candidates must submit their application (CV and cover letter) to Armelle Cessou (✉ armelle.cessou@coria.fr – ☏ +33 (0)2 32 95 36 02).

References

[1] Sergey Paltsev, Jennifer Morris, Haroon Kheshgi, Howard Herzog.Hard-to-Abate Sectors: The role of industrial carbon capture and storage (CCS) in emission mitigation. Applied Energy, vol. 300, 2021, 117322

[2] Srivastava, Kartik. “Carbon Capture and Sequestration: An Overview.” International Journal for Research in Applied Science and Engineering Technology (2021).

[3] Buhre B.J.P., Elliott L.K., Sheng C.D., Gupta R.P., Wall T.F. - Oxy-fuel combustion technology for coal-fired power generation. Progress in Energy and Combustion Science, vol. 31, 2005, pp. 283-307

[4] Scheffknecht G., Al-Makhadmeh L., Schell U., Maier J. – Oxy-fuel combustion - A review of the current state-of-the-art. International Journal of Greenhouse Gas Control, vol. 5S, 2011, pp. S16-S35

[5] S. Juma, D. Honoré, B. Lecordier, C. Gobin, X. Paubel, A. Cessou. Study of the CO2 injection strategy in diluted Oxy-fuel combustion. European Combustion Meeting 2013, Lund (Suède) 2013

[6] S. Juma, D. Honoré, B. Lecordier, X. Paubel, A. Cessou. On the effect of separated oxygen and carbon dioxide injections on the stabilisation of diluted oxyfuel flames. 11th European Conference on Industrial Furnaces and Boilers, Albufeira (Portugal) 2017

[7] Glarborg P., Bentzen L.L.B. - Chemical effects of a high CO2 concentration in oxy-fuel combustion of methane. Energy and Fuels, vol. 22, 2008, pp. 291-296

[8] Normann F., Andersson K., Johnsson F., Leckner B. – NOx reburning in oxy-fuel combustion: a comparison between solid and gaseous fuels. Int. Journal of Greenhouse Gas Control, vol. 5S, 2011, pp. S120-S126

[9] K. Rajamanickam, F. Lefebvre, C. Gobin, G. Godard, D. Honoré, C. Lacour, B. Lecordier, A. Cessou. On The Relationship between H2 Addition, Local Extinction And Hydrodynamic Instability In Non-Premixed Bluff-Body Stabilized Flames. 20th International Symposium on the Application of Laser and Imaging Techniques to Fluid Mechanics. Lisbon (Portugal) – July 2022

[10] K. Rajamanickam, F. Lefebvre, C. Gobin, G. Godard, C. Lacour, B. Lecordier, A. Cessou, D. Honoré. Effect of H2 Addition on the Local Extinction, Flame Structure, and Flow Field Hydrodynamics in Non-Premixed Bluff Body Stabilized Flames. Physics of Fluids, 2023, 35 (4), pp.047110. ⟨10.1063/5.0142921⟩

[11] F. Guichard, N. Valdez, P. Boubert, D. Honoré, C. Lacour, B. Lecordier, A. Cessou. Multi-scalar and velocity measurements in a turbulent Bluff-Body flame using spectral fitting of spontaneous Raman scattering and PIV. 9th European Combustion Meeting - Lisbon, Portugal - April 2019

[12] K. Rajamanickam, S. Idlahcen, A. Mahuthannan, B. Lecordier, C. Lacour, D. Honoré, A. Cessou. Multi-scalar measurements in hydrogenated bluff-body stabilized turbulent flames using 1D spontaneous Raman scattering and OH –PLIF. 11th European Combustion Meeting - Rouen, France - April 2023