A cyclonic burner as a test case for combustion systems with high level of dilution and internal recirculation

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Abstract

A small-scale cyclonic burner is tested as a system to perform combustion studies under MILD (Moderate and Intense Low-oxygen Dilution) [1, 2] operating conditions, namely for mixtures with a high level of dilution and strong preheating of the fresh reactants by means of a massive recirculation of exhausted gases. Under these operating conditions, the oxidation process assumes peculiar chemical/physical features, very different from typical flame conditions. This novel combustion regime has been achieved in various industrial configurations [3, 4] that reveal a process with intensive and extensive parameters homogeneity. The auto-ignition process along with a complex interplay between auto-ignition and characteristic reactive diffusive structures has a key role in the oxidation stabilization mechanism. A clear understanding of such a process is still far from being reached. The identification of simple reactors that allows to properly address these features represent a crucial step for a systematic evaluation of the combustion characteristics under such an unconventional regime. They should be as simple as possible to change the process parameters independently from each other while keeping the appropriate level of fluid-dynamic complexity. Under these constraints, a novel laboratory-scale cyclonic flow reactor was realized for combustion systems working in MILD combustion regimes. Fig. 1 shows a picture (a) and a section b) of the burner.

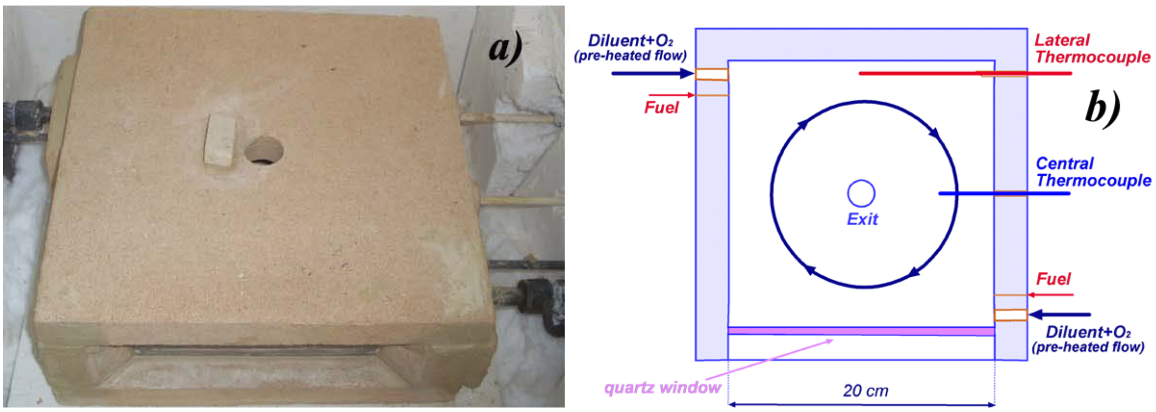

Fig. 1 Photograph (a) and sketch of the section (b) of the cyclonic combustion chamber

The main pre-heated flow (composed by oxygen and diluent) and the fuel flow are fed inside the combustion chamber from one side. On the opposite side, the feeding configuration is diametrically reproduced. The feeding configuration is shown in Fig. 1b. The gas exit is located on the top of the chamber. The flow injection configuration and the exit location induce cyclonic flow field inside the combustion chamber.

A survey of possible achievable regimes was carried out varying external parameters, namely inlet temperatures (up to 1200K) and equivalence ratio (lean to reach mixtures).

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Different combustion regimes were observed as a function of such operating parameters (Fig. 2). The auto-ignition and the oxidation stabilization process were proven to occur when a sufficient entrainment of hot combustion products in the fresh oxidant and fuel jets was reached by means of an efficient turbulent mixing, for propane/oxygen mixtures diluted in N_2 or CO_2. The strong heat/mass internal recirculation and the long residence times induced by the cyclonic flow pattern ensured the stabilization process. This configuration is a successful strategy to study the MILD Combustion features and represents a powerful tool to gain important information on the complex multi-dimensional interactions between fluid mechanics and chemical kinetics by the implementation of real time optical and chemical measurements.

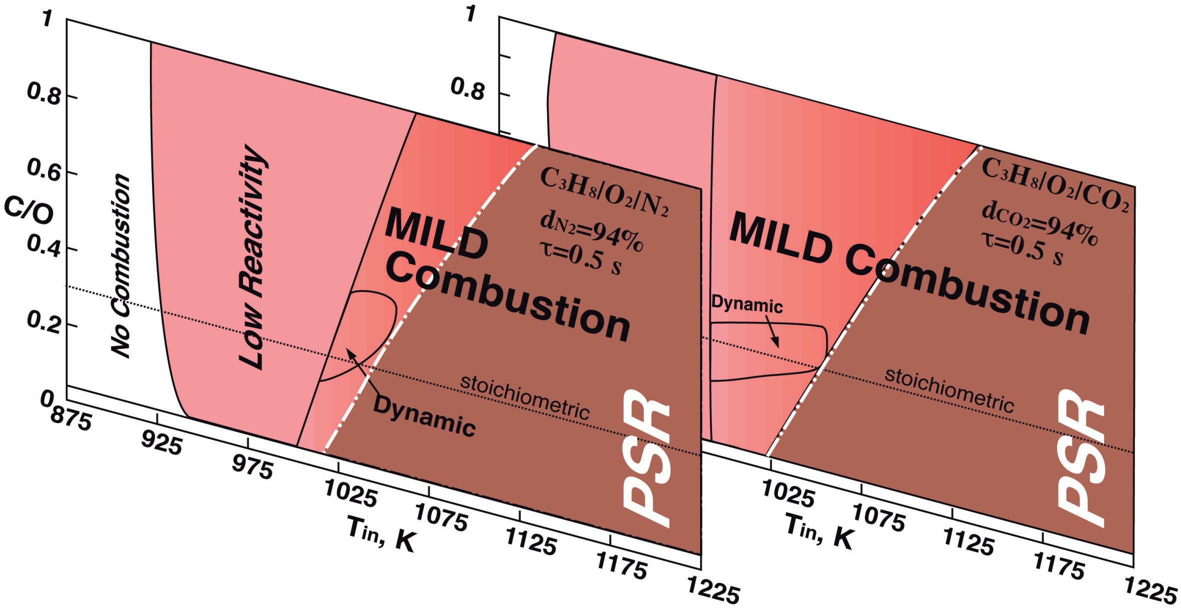

Fig. 2 Comparison between T_{in}-C/O maps obtained for propane/oxygen mixtures diluted in N_2 and CO_2 at 94% of dilution.

References

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