EXPERIMENTAL STUDY OF NON-PREMIXED METHANE AIR FLAME LIFTING BY AIR-SIDE OR FUEL-SIDE DILUTION

M. Marin, F. Baillot

y.marin@coria.fr

CORIA, UMR 6614, CNRS-Université et INSA de Rouen, France

Dilution is a crucial topic which plays an important role as much in exhaust gas recirculation combustion systems to improve combustion efficiency and diminish pollutants as in fire safety applications for which extinction is aimed.

In the non-premixed regime where oxidant and fuel are separately injected, mixing of reactants is a key element in several basic phenomena among which flame stabilization (lifting, extinction…) and pollutant formation (CO, NO_x, soot…) are noted. Consequently, diluting reactants directly impacts the abovementioned processes as shown in preceding studies [2, 3]. However, this influence on flame stabilization and pollutant formation is not yet clearly understood. In particular basic differences are noted according to the way dilution is performed, either in the oxidant side or in the fuel side.

The aim of this work is to investigate the response of a non-premixed flame, initially attached to the burner, when the oxidant-side and fuel-side are separately or simultaneously diluted by a weakly chemical or inert diluent (CO_2, N_2, H_2Ov or Ar). Here the flame is issued from a methane jet ($U_{CH4} \sim 0.1\text{-}14$ m/s) surrounding by an air coflow ($U_{air} \sim 0.1 - 0.4$ m/s). The experimental procedure chosen here allows to highlight how the ability to break the anchored flame stabilization is modified. The analysis is carried out by introducing the critical flow rate ratios at lifting, $(Q_{diluent}/Q_{oxydant})_{lifting}$ and $(Q_{diluent}/Q_{fuel})_{lifting}$, which characterize flame lifting due to the adding of a diluent in the oxidant side or fuel side respectively. Results show that $[(Q_{diluent}/Q_{fuel})_{lifting}]/[(Q_{diluent}/Q_{oxydant})_{lifting}]$ is ~ 10 whatever the diluents. For diluents (CO_2, N_2 and Ar) an analysis of physical mixing (fuel + diluents) proprieties shows a homothetic behavior at lifting with the Peclet fuel number.

The difference between the amounts of the critical flow rate ratios necessary to lift the flame measured in the oxidant and fuel sides is interpreted via a leading-edge flame-stabilization approach for which reactants are mixed around stoichiometric proportions in the vicinity of the leading-edge. Indeed the amount of diluent, useful to lift the flame, is found to have the same order of magnitude for the two sides when it is conditioned by stoichiometry; this shows the leading edge drives lifting phenomenon at the main order. Moreover a non-linear behavior of the critical quantities, $(Q_{diluent}/Q_{oxydant})_{lifting}$ and $(Q_{diluent}/Q_{fuel})_{lifting}$ is revealed when both sides are simultaneously diluted. $(Q_{diluent}/Q_{oxydant})_{lifting} / (Q_{diluent}/Q_{oxydant})^0_{lifting}$ expressed as a function of $(Q_{diluent}/Q_{fuel})_{lifting} / (Q_{diluent}/Q_{fuel})^0_{lifting}$, where $()^0$ are the critical amounts obtained when dilution is only performed in the oxidant side or in the fuel side, evolves as a symmetric curve according to the bisector of the first quadrant angle (line " y= x"). This result reinforces the leading edge interpretation in the lifting phenomenon.

References
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