PLIF Measurements of Nitric Oxide and Hydroxyl Radicals Distributions in Swirled Stratified Premixed Flames

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HIGHLIGHTS

• Simultaneous OH- and NO-PLIF performed on swirled stratified lean premixed methane/air flames.
• Specific OH-PLIF analysis allows measurement of the flame curvature and thickness.
• Elevated NO concentration (230 ppm) emerged from prompt NO mechanisms rather than thermal process.

ABSTRACT

Environmental and economic concerns have pushed aeronautical authorities to set stringent environmental regulations on fuel consumption, noise production, and pollutant emission. Engine manufacturers are developing novel staged injection concepts to ensure their respect. The injection staging creates a fuel-air mixture stratification involving new combustion processes not fully understood. This paper presents the experimental investigation of NO production for known swirled and/or stratified lean premixed flames. The fuel staging parameter defined as the stratification ratio is studied for values of 1, 2, and 3, while the swirl fractions are 0, 25 and 33%, changing the flowfield from non-swirling conditions to high swirl numbers (up to 0.55). The implementation of simultaneous OH- and NO-PLIF imaging techniques is achieved using high energy pulsed laser systems, able, for instance, to deliver 30 mJ/pulse around the 226-nm UV wavelength for NO excitation. OH-PLIF is used to characterize the flame structure through the commonly extracted curvature, and also through the measurement of the flame thickness. These results show to be more accurate than thickness obtained from temperature profiles measured by Raman/Rayleigh laser diagnostics. NO-PLIF is used to quantify the pollutant concentration. To this end, preliminary work was done to select the Q(29.5) transition as it the least temperature dependent excitation scheme with high fluorescence levels. After realizing a specific calibration of the NO-PLIF technique, the studied flames presented concentrations ranging from traces (20 ppm) to high levels (230 ppm). Further analysis of these results reveals that for high stratification ratios the prompt NO is favored and is responsible for the elevated level of NO pollutant.

Fig. 1 Sample images of a long-exposure photograph (left), of an instantaneous OH-PLIF distribution (center), and of an instantaneous NO-PLIF distribution (right), for one of the studied flames (Swirl Fraction = 25% and Stratification ratio = 2).