Experimental study of stratified lean premixed methane/air low-swirl turbulent flames – distribution and transport of formaldehyde

J. Rosell1*, P. Petersson1, J. Olofsson2, M. Christensen1, S-I. Möller1, M. Richter1, M. Aldén1
1: Division of Combustion Physics, Lund University, Lund, Sweden
2: Dantec Dynamics A/S, Skovlunde, Denmark
* Correspondent author: joakim.rosell@forbrf.lth.se

Keywords: Combustion laser diagnostics, PIV, LIF, High-repetition rate, Lean premixed combustion, Formaldehyde transport

HIGHLIGHTS

- Simultaneous high-repetition rate (3 kHz) CHO PLIF and PIV were performed in in turbulent stratified lean premixed methane/air flames to investigate the flame and flow dynamics.
- Detailed statistical data are obtained, including the velocity field, the mean flame location; preheat layer thickness, flame brush thickness and the flame surface density.
- The results reveal a distinct shift in flame shape occurring when the equivalence ratio, $\phi$, is increased from 0.6 to 0.7. For $\phi > 0.7$ the thermal gas expansion from the flame is sufficient to counteract the flow stagnation, created by the swirling flow field, along the centre axis encountered for the leaner cases.

ABSTRACT

Simultaneous high-repetition rate (3 kHz) CHO planar laser-induced fluorescence (PLIF) and particle image velocimetry (PIV) measurements were performed in in turbulent low swirl stratified premixed methane/air flames to investigate the large-scale spatial and temporal evolution of the flame and flow dynamics. In addition, PLIF of OH and CH.O at a low-repetition rate (10Hz) were carried to study the global effect of equivalence ratio, $\phi$, on the flame. A low swirler burner was used to stabilize a wide range of flames, from close-to-quenching lean flames to close to stoichiometric flame with $\phi = 0.9$. The flames exhibit a laminar flamelet structure in the leading front and thickened flame structure with local quenching at the trailing edge. Detailed statistical data are obtained, including the velocity field, the mean flame location; preheat layer thickness, flame brush thickness and the flame surface density. These data provide a useful database for comparison of combustion model simulations. The results reveal interesting flame behaviour; depending on the equivalence ratio the large scale interaction between the flame and the flow field takes different forms. In particular the shift in flame shape occurring when $\phi$ is increased from 0.6 to 0.7 is characteristic for the investigated flame sensitivity to a varying equivalence ratio. Whereas the leading edge of the flame, protected from the surrounding shear layers, maintains its form the trailing edge and post-flame region can drastically change with $\phi$. The flow field is also clearly modified by the combustion process. When $\phi$ is increased the flame volume and the thermal gas expansion is increased together with the mean flame position moving upstream - all these parameters influence the flow field. For $\phi > 0.7$ the thermal gas expansion from the flame is sufficient to counteract the flow stagnation along the centre axis encountered for the leaner cases. The flame surface density was investigated for $\phi$ =0.6, 0.7, 0.8 and 0.9. For $\phi >0.7$ the peak in flame surface density was found at radial distance corresponding to the inner shear layer where the flame front is strongly wrinkled by the large scale vortices. At this location the fuel mixture is relatively unaffected by the dilution of the ambient air and the freely propagating flame can interact with the turbulent flow. With increasing HAB the ambient air dilution to the fuel becomes significant, which can lead to local flame quenching.