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## Laser-induced ignition and plasma spectroscopy in a turbulent liquid fueled combustor

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Two different swirlers are used in co-rotating arrangement. Two quartz walls are used to allow a good optical access and several diagnostics are used simultaneously to provide conditionally based analyses. To actually measure the equivalence ratio as well as the deposition of energy and initial kernel size, a two-dimensional Laser Induced Plasma Spectroscopy technique (2D-LIPS) has been recently developed [4]. This requires the use of two ICCD equipped with interferential filters centered on specific atomic transition (hydrogen and oxygen). Without a precise calibration in presence of droplets, this technique only provides the atomic H/O ratio, which is monotonically linked to mixture fraction. Two high repetition rate lasers (10kHz) are synchronized with a fast camera (Photron, 20kHz) to actually image the droplets of the spray in a plane of the chamber. This allows also applying statistical analysis, such as correlation tools to estimate the displacement of droplets within two laser pulses. Laser induced ignition was achieved by focusing the second harmonic of a Nd:YAG through a lens of focal 100 mm. The position of the laser and the lens could be changed with respect to the chamber so as to investigate different points.

### 3. Results and discussions

Several experiments were performed in order to first investigate statistical properties of the laser-induced ignition. Some points had a very high probability of ignition (in the recirculation zone) whereas those located mainly in the outer recirculation zone of the spray had little success. It was decided to specifically concentrate on points with relatively low probability to sort out success and failures based on actual time resolved measurements. Among the main results, the actual H/O atomic ratio (representing the equivalence ratio), the size of the initial kernel are obtained by 2D-LIPS. To take into account the dynamics of the flow, dedicated post-processing tools have been used to estimate the actual growth/decay of the aerodynamic structure (PVC : precessing vortex core) based on planar measurements of Mie scattering by droplets. Seven ignition events were analyzed versus 12 failed cases. Overall results are displayed in Figure 2 with both local H/O ratio versus initial kernel and varying strength of the PVC. It can be seen that many igniting cases had a higher kernel size for a similar H/O as compared to failed attempts. This is explained by the existence of a critical kernel to overcome heat losses by convection. Among the eight sparks that had a good H/O together with an initial kernel above the critical size, the only case that failed corresponded to a case for which the PVC tended loose energy. PVC is considered as being an important feature for ignition in the inner recirculation zone as offering a region of lower pressure, hence easing the convection of an initial kernel towards the injector.

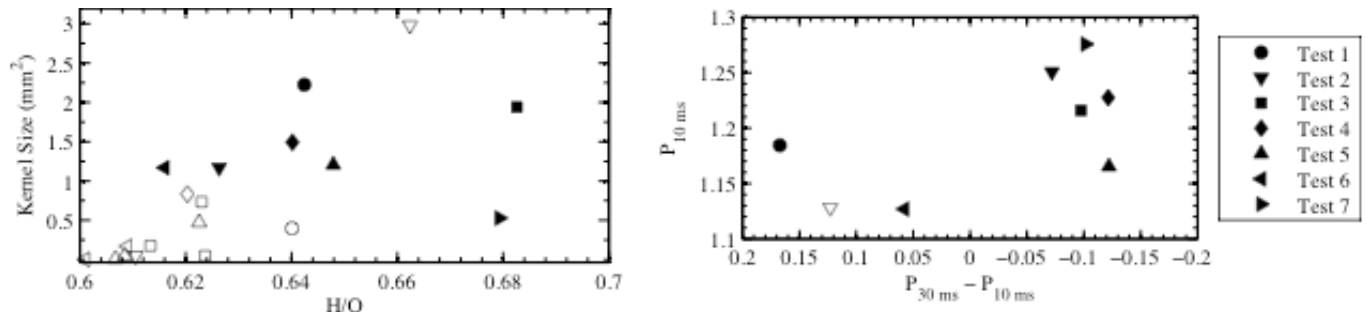


Fig. 2. Actual mean H/O ratio versus initial kernel size (left) and decay of the strength of the precessing vortex core 10ms before spark as compared to 30ms.

### 4. Conclusions

Combined measurements of H/O, kernel size and aerodynamic structures could explain most of ignition attempts. This strategy opens new experimental investigations based on the detailed characterization of single events rather than based on statistical analysis only. This may ease comparisons with numerical simulations for which statistically converged data remains out of reach.

### 4. References

- [1] C. Cardin, B. Renou, G. Cabot and A. Boukhalfa, "Experimental Analysis of Laser-Induced Spark Ignition of Lean Turbulent Premixed Flames," *Comptes Rendus Mécanique* 134, 191-200 (2013)
- [2] T. Marchione, S.F. Ahmed and E. Mastorakos, "Ignition of turbulent swirling n-heptane spray flames using single and multiple sparks " *Combust. Flame* 156, 166-180 (2009)
- [3] T. Providakis, L. Zimmer, P. Scouflaire and S. Ducruix, "Characterization of the Acoustic Interactions in a Two-Stage Multi-Injection Combustor Fed With Liquid Fuel", *Journal of Engineering for Gas Turbines and Power* 134, 111503 (2012)
- [4] T. Agarwal and L. Zimmer, "Two dimensional Laser Induced Plasma Spectroscopy for the measurements of local composition in gaseous flow and sprays," 16th Int Symp on Applications of Laser Techniques to Fluid Mechanics, Lisbon, Portugal, 09-12 July (2012)