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Effects of exhaust gas on CH$_4$-air-O$_2$ turbulent swirling flames

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**Context and objectives**

- Study of non-premixed turbulent flames stabilized by a swirl
  - Improve performances of combustion plants
  - Reduction of pollutant emissions / emissions standards
- Investigations on flame characteristics
  - Effects of oxygen enrichment
  - Effects of steam and CO$_2$ dilution
  - Effects of swirl intensity

**Experimental setup**

- Coaxial swirl burner
  - Two concentric tubes with a swirl in the annular part
  - Combustion chamber: 25 kW, dimensions 0.5x0.5x1 m$^3$
- Measurement and analysis of flue gases
  - Concentrations of NO$_x$, CO, CO$_2$, O$_2$, and SO$_2$ in the flue gases are measured.
  - ABB 220 and HORIBA PG250 multi-gas analyzers
- OH$^*$ chemiluminescence technique
  - Apparatus: ICCD camera, a 105 mm UV lens, a 306 nm filter, an acquisition card with a computer.
  - OH$^*$: Spontaneous emission on the band (0-0) at 306.4 nm
  - Visualization of flame front: stability, lift-off heights, frame lengths.
- Stereo-PIV system
  - 2 Planes of velocity measurements
  - 3 Positions in the transverse plane

**Results and discussions**

**Pollutant emissions**

- NOx and CO emissions are reported for $\phi$=0.8, $\Omega$ = 25%O$_2$, Sn = 1.4 in the case of diluting with CO$_2$ and H$_2$O separately (Fig. a), and for Sn=0.8 in the case of EGR (H$_2$O+CO$_2$) (Fig. b).

**Flame structures**

- Lift-off height = f(%CO$_2$), Sn=0.8, $\phi$=0.8, 21%O$_2$

**Velocity mean fields of non reacting and reacting flows**

- Recirculation zone at the flow center, and the swirling jet in the peripheral flow.
- Reacting flow: greater radial expansion + larger recirculation zone.
- Higher velocities

**Conclusion**

- Better stabilization is obtained with O$_2$ enrichment. The dilution with EGR destabilizes slightly the flame without blowout (up to 20%).
- Dilution with CO$_2$, H$_2$O and EGR decreases highly NO$_x$ emissions and increases CO emissions.
- Swirling part of the flow and the central recirculation zone are clearly identified by Stereo-PIV measurements.

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