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Effects of exhaust gas on CH₄-air-O₂ turbulent swirling flames

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Context and objectives

- Study of non-premixed turbulent flames stabilized by a swirler
  - Improve performances of combustion plants
  - Reduction of pollutant emissions / emissions standards
- Investigations on flame characteristics
  - Effects of oxygen enrichment
  - Effects of steam and CO₂ dilution
  - Effects of swirl intensity

Experimental setup

- Coaxial swirl burner
  - Two concentric tubes with a swirler in the annular part
  - Combustion chamber: 25 kW, dimensions: 0.5x0.5x1 m³
- Measurement and analysis of flue gases
  - Concentrations of NOₓ, CO, CO₂, O₂, and SO₂ 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, flame 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 φ=0.8, Θ = 25%O₂, Sn = 1.4 in the case of diluting with CO₂ and H₂O separately (Fig.a) and for Sn=0.8 in the case of EGR (H₂O+CO₂) (Fig.b).

![Graph a](image)

![Graph b](image)

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

Flame structures

- Lift-off height = f(%CO₂), Sn=0.8, φ=0.8, 21%O₂

![Graph](image)

- Lift-off height = f(%H₂O), Sn=0.8, φ=0.8, 21%O₂

![Graph](image)

- Lift-off height = f(%O₂), Sn=0.8, φ=0.8, EGR (10CO₂-10H₂O)

![Graph](image)

Conclusions

- Better stabilization is obtained with O₂ enrichment. The dilution with EGR destabilizes slightly the flame without blowout (up to 20%).
- Dilution with CO₂, H₂O and EGR decreases highly NOₓ emissions and increases CO emissions.
- Swirling part of the flow and the central recirculation zone are clearly identified by Stereo-PIV measurements.