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Effects of exhaust gas on CH_4-air-O_2 turbulent swirling flames

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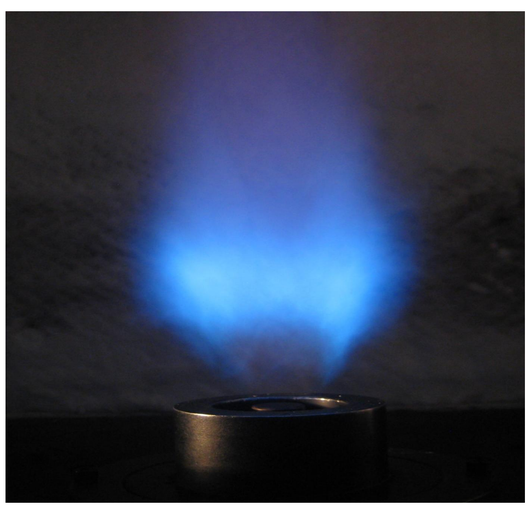
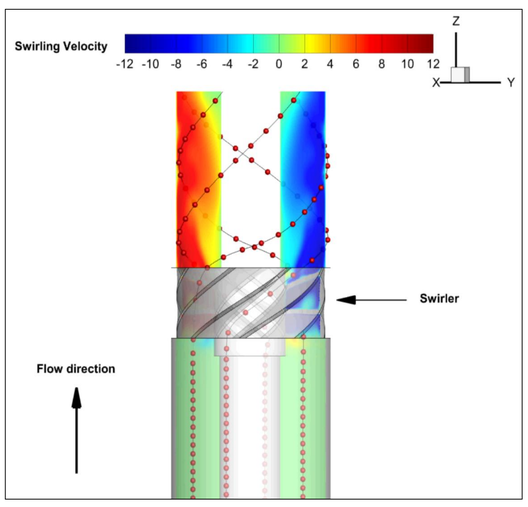


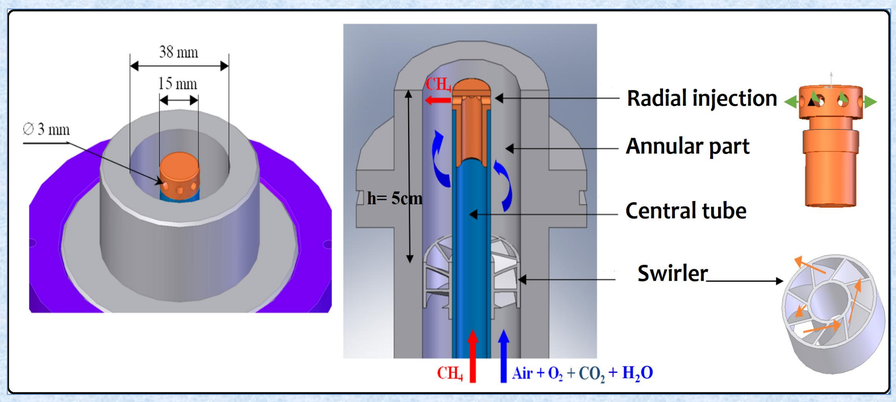
Context and objectives

- **Study of non-premixed turbulent flames stabilized by a swirler**
  - 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



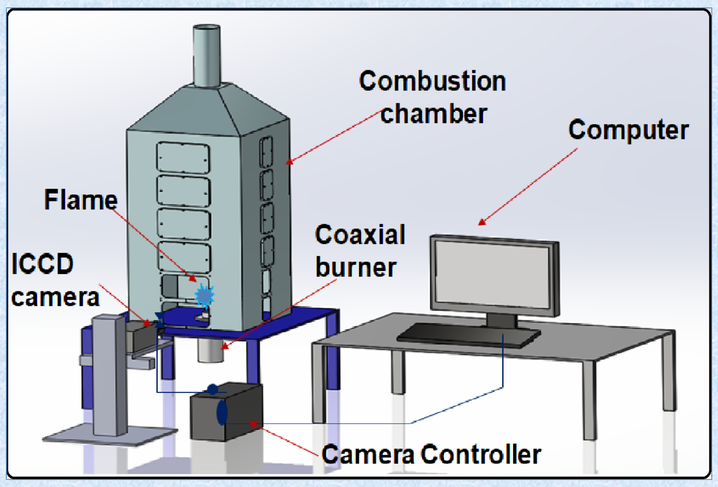
✓ Two concentric tubes with a **swirler** in the annular part
✓ Combustion chamber : 25 kW, dimensions 0.5x0.5x1 m^3

Measurement and analysis of flue gases

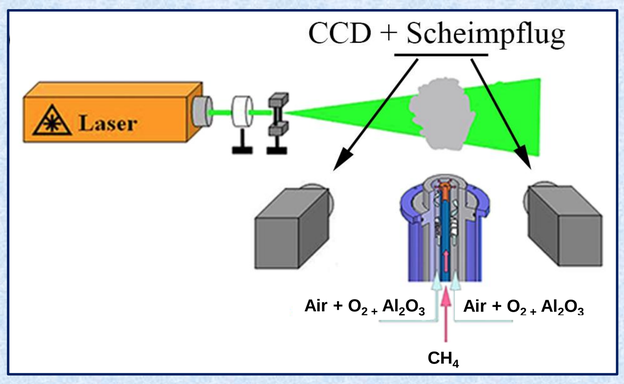
✓ Concentrations of NO_X, CO, CO_2, O_2 and SO_2 in the flue gases are measured.
➢ ABB 220 and HORIBA PG250 multi-gas analyzers.

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, flame lengths.



Stereo-PIV system



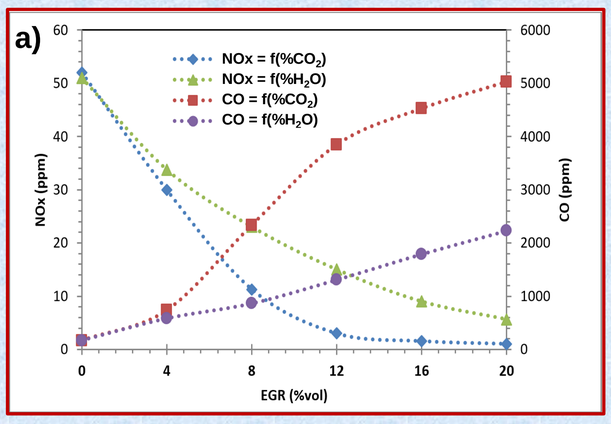
✓ 2 Planes of velocity measurements
✓ 3 Positions in the transverse plane

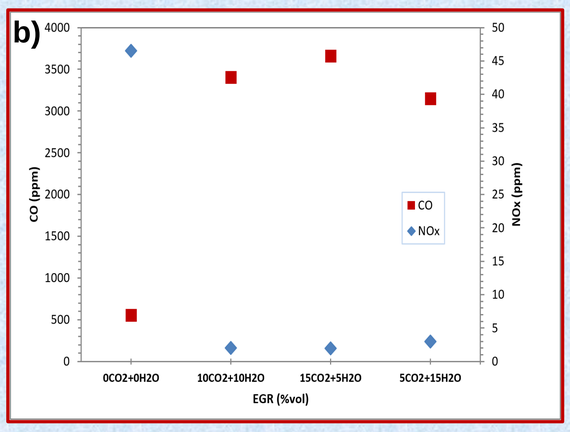
Apparatus: a double-pulsed Nd:YAG laser (25 mJ/pulse) at 532 nm, 10 Hz. **2 cameras** TSI Powerview Plus 4MP **CCDs**, 12-bit output and **2048 x 2048 px²**. **Scheimpflug** adapters. Seeding : Al_2O_3 0.5-1 µm.

Results and discussions

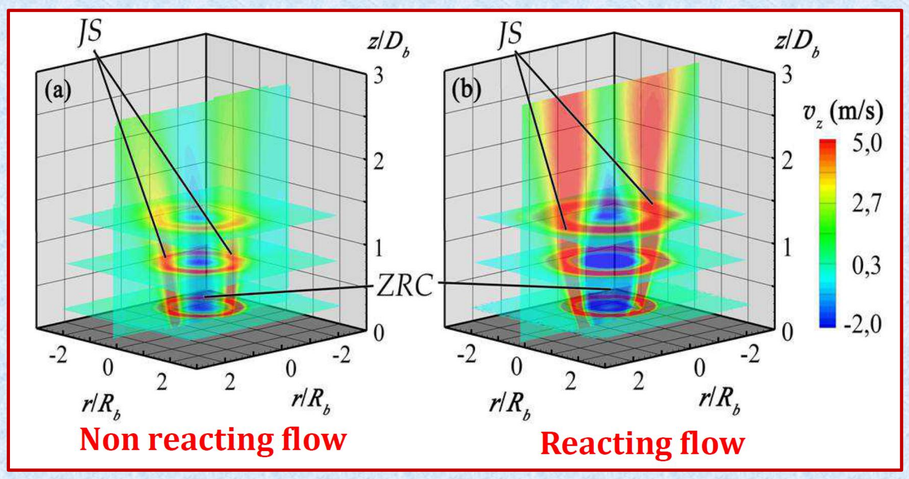
Pollutant emissions

➲ NOx and CO emissions are reported for ϕ=0.8, Ω = 25%O_2, Sn = 1.4 in the case of diluting with CO_2 and H_2O separately (Fig.a) and for Sn=0.8 in the case of EGR (H_2O+CO_2) (Fig.b).





Velocity mean fields of non reacting and reacting flows

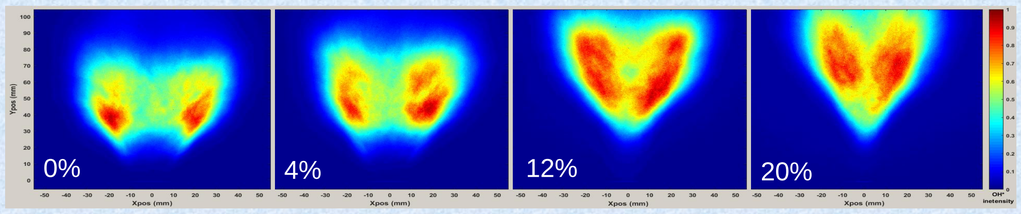


➲ Axial velocity (Vz) : Sn = 1.4, ϕ = 0.8 and 21% of O_2

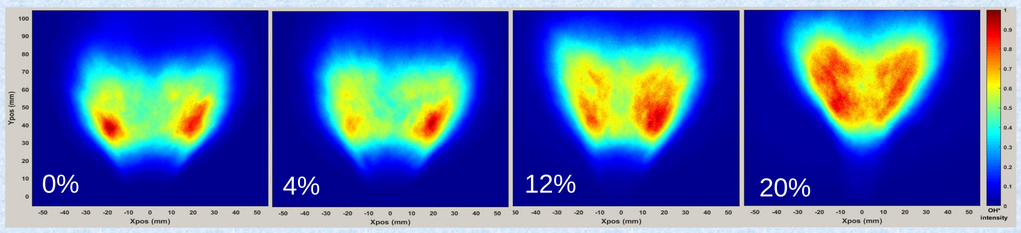
- Recirculation zone at the flow center, and the swirling jet in the peripheral flow.
- Reacting flow: - greater radial expansion + larger recirculation zone.
  - higher velocities

Flame structures

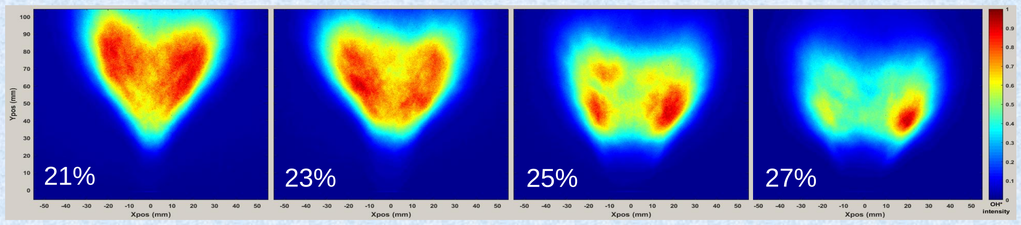
Lift-off height = f(%**CO_2**), Sn= 0.8, ϕ =0.8, 21%O_2

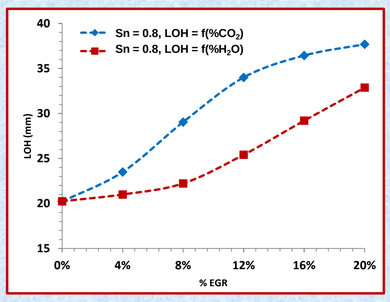


Lift-off height = f(%**H_2O**), Sn= 0.8, ϕ =0.8, 21%O_2

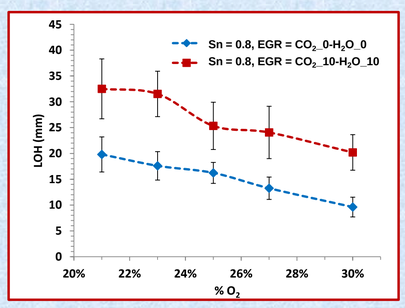


Lift-off height = f(%**O_2**), Sn= 0.8, ϕ =0.8, EGR (10CO_2-10H_2O)

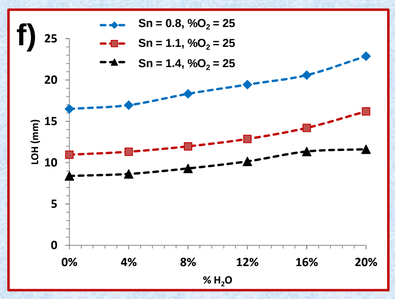




➲ EGR dilution promotes flamme fluctuations and increases the lift-off heights about 60% compared to the case without EGR (Fig. g).



➲ CO_2 dilution disrupts more the flame compared to water vapor dilution (Fig. e). In both cases, lift-off heights increase when increasing dilution ratios.



➲ In the case of H_2O dilution (Fig. f), the flame becomes leaner, appears more lifted and remains compact.

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_2O 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.

Acknowledgments

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