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Experimental study of flow and scalar mixing in swirl-stabilised burners

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Contents

- Introduction.
- Swirl-stabilised burner.
- Optical arrangement.
- Flow structure.
- Scalar mixing and combustion.
- General conclusions.
Swirling flows are used: (Syred & Beer, Comb. and Flame 23, 1974)

1. To reduce combustion length by producing higher rates of mixing.

2. To improve flame stability as a result of the formation of recirculation zones.

3. To minimize flame impingement on the burner.
Objectives

1. To further understand the flow dynamics in reacting and non-reacting swirling flows in practical configurations.

2. To gather complete experimental data from practical configurations (velocity, temperature, scalar distribution).

Typical test cases

1. Cabra flames
2. Sandia flames
3. Rod-stabilized flames

1. http://www.me.berkeley.edu/cal/vcb/data/VCHNData.html
Swirl-Stabilised Burner

Methods used:

- **a) non-reacting case**
  1. LIF (acetone)
  2. PIV

- **b) reacting case**
  1. Rayleigh
  2. PIV

S = 0.3, 0.58, 1.07
Re = 29000
V = 8.46 (m/s)
\( \lambda_\beta = 0.3 \) (mm)
Optical Arrangements

Typical energy at laser exit:
LIF: $\approx 120$ (mJ/pulse)
Rayleigh: $\approx 960$ (mJ/pulse)
Flow Structure (Mean velocity; S=0.3)

- isothermal
- reacting

$V, m/s$

0 2 4 6 8 10 12

10 50 100 150 mm

$-1.57 -1.18 -0.78 -0.39 \text{ x/R} 0.39 0.78 1.18 1.57$

$-0.39 -0.78 -1.18 -1.57 -10 < \text{mm} > -0.39 -0.78 -1.18 -1.57$

$20 30 40$
Flow structure (Mean velocity; $S=1.07$)

- **a)** isothermal
- **b)** reacting

Velocity $V, m/s$
Scalar mixing and Combustion ($S=0.3-1.07$)

Instantaneous distribution at $y=15\text{mm}$ of \{ top to bottom: $S=1.07$, 0.58, 0.3 \}:

Mixture fraction

Temperature
Scalar mixing and Combustion ($S=0.3$)

Distribution of mean:

Temperature, Mixture fraction
Scalar mixing and Combustion ($S=1.07$)

Distribution of mean:

Temperature, Mixture fraction
Parameters evaluated (as a function of 'S')

Isothermal case:
✓ Mixture fraction statistics.
✓ Scalar dissipation rate (instantaneous, mean, fluctuations, conditional).
✓ Filtered density functions (in the context of LES).
✓ Velocity statistics.
✓ Vorticity and flow structure (proper orthogonal decomposition).

Reacting case:
✓ Temperature statistics.
✓ Thermal dissipation rate.
✓ Velocity statistics.
✓ Vorticity and flow structure.
General Conclusions

1. Isothermal and reacting swirling flows produced by a 'real' burner were investigated.

2. Statistics were obtained and relevant quantities were assessed.

- S=0.3 flame was not stabilised by the recirculation zone.
- S = 0.58 and S=1.07 flame was stabilised by the recirculation zone.
- Highly inhomogeneous instantaneous scalar and temperature distributions near the burner exit.
- High scalar and temperature fluctuations near the burner exit.

Specific conclusions (on scalar dissipation rate, temperature statistics etc.) are not presented here.
Thank you

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