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A Reheat Combustor Experiment for the Analysis of Dynamic Behavior of a Hydrogen flame

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Motivation

- Sequential combustion provides possibilities for low-emission fuel-flexible operation
- Suceptibility of lean premixed gas turbines to thermoacoustic instabilities
- Experimental investigation of the dynamics of partially auto-ignition stabilized flames in lean premixed conditions [1]

„Evaluation of dynamic flame response of hydrogen flames in reheat conditions.“

Project Goals

- Unsteady response of H_2 reheat flames to perturbations of mixture-reactivity:

Acoustic influence $FTF_u(\omega) = \frac{\dot{Q}(\omega)/\bar{\dot{Q}}}{u'(\omega)/\bar{u}}$

Temperature influence $FTF_T(\omega) = \frac{\dot{Q}(\omega)/\bar{\dot{Q}}}{T'(\omega)/\bar{T}}$

Mixture reactivity influence $FTF_\Phi(\omega) = \frac{\dot{Q}(\omega)/\bar{\dot{Q}}}{\phi'(\omega)/\bar{\phi}}$

Combustor Setup

① Vitiator

Provides inlet conditions for reheat stage:

- Vitiated air (exhaust gas + cooling air)
- $\dot{m}_{exit} = (0{,}35 - 0{,}65\,\frac{kg}{s})$
- $T_{exit} = (900 - 1700K)$
- $y_{O2} \approx 15$ V%

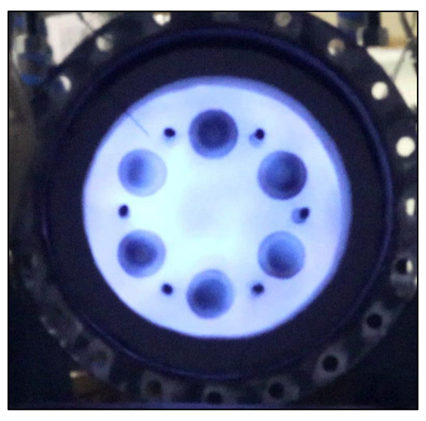


Fig. 1 Vitiator view

Auto-Ignition Control

- Control of T_{SEVin} to adjust auto-ignition delay time τ_{AI}

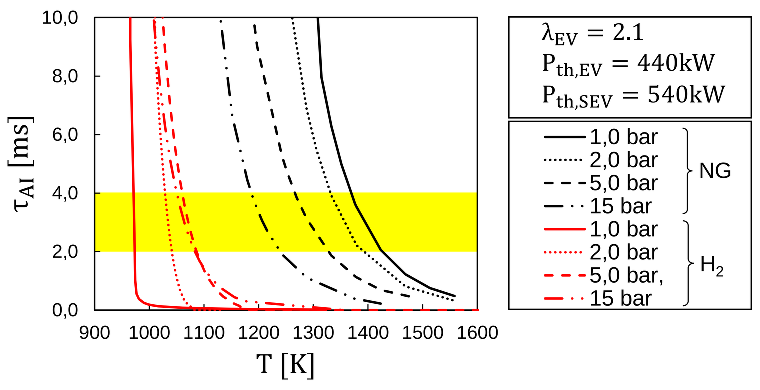


Fig. 2 Auto-ignition delay time

⑦ Reheat Combustor

- High power density [2]
- Fuel flexibility

Flame stabilization regions:
- – – Propagation
- – – Auto-ignition

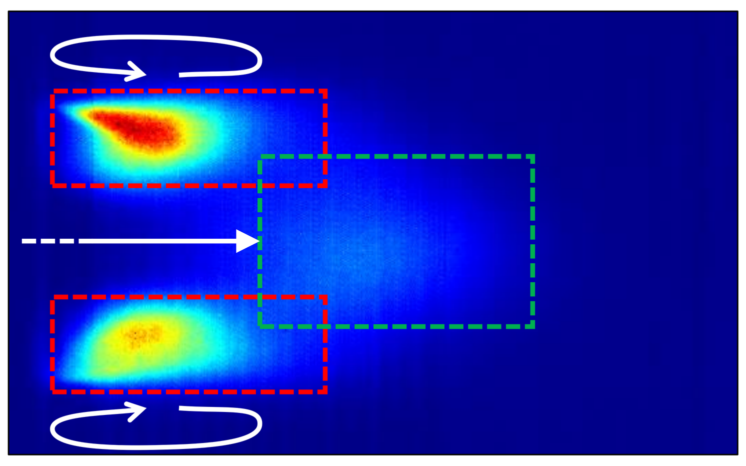
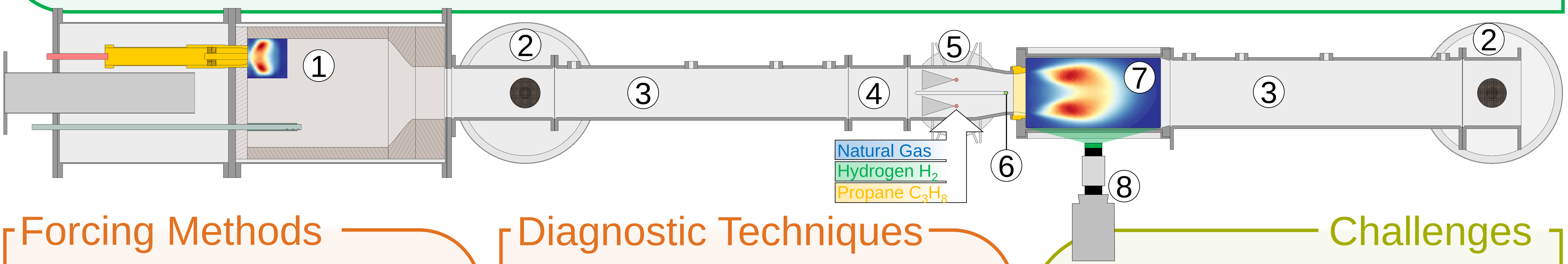


Fig. 3 Mean image reheat flame



Forcing Methods

② Acoustic Forcing u' & p'

- Acoustic drivers
- Modulation of acoustic velocity and pressure

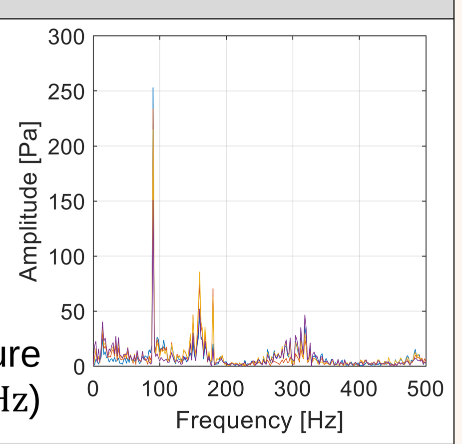


Fig. 4 Acoustic pressure ($@f_{Forcing} = 90Hz$)

④ Temperature Forcing T'

- Modulation of cooling air injection throughout acoustic cycle
- T'≈1%

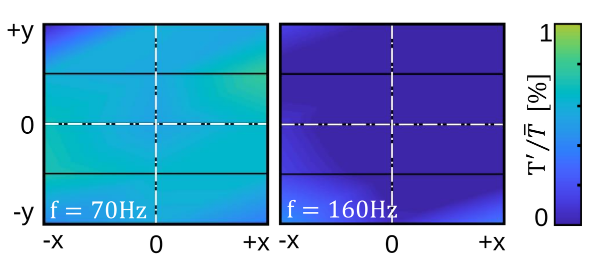


Fig. 5 Temperature amplitudes at reheat-combustor inlet plane

⑤ Fueljet Forcing Φ'

- Adjustment of fueljet velocity to fluctuating crossflow velocity
- Modulating mixture process

Diagnostic Techniques

③ Multi-Microphone Method

- Reconstruction of acoustic modeshape

⑥ Dynamic Thermocouples

- Correction for thermal inertia thorugh flow field calibration

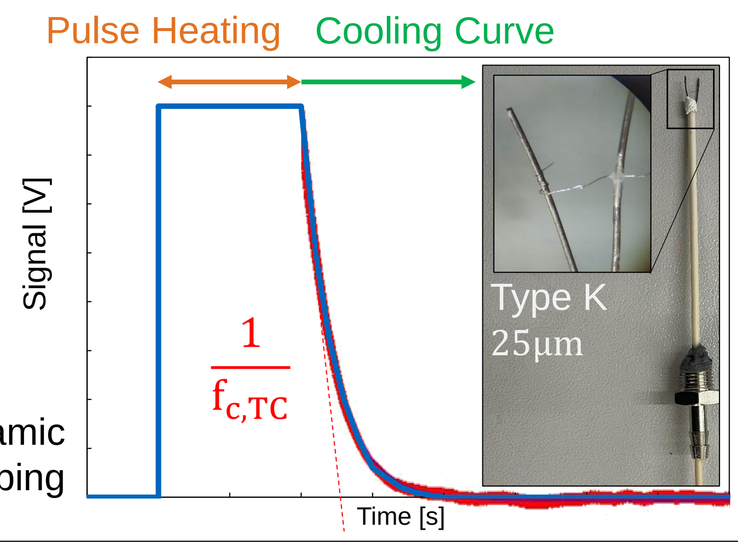


Fig. 6 Method dynamic thermocouple probing

⑧ Optical Diagnostics

Photomultiplier:
- Integral OH^* emission intensity

Image-intensifier + high-speed camera
- Temporal & spatial evolution of OH^* intensities

Challenges

- Consistently strong acoustic forcing at all frequencies

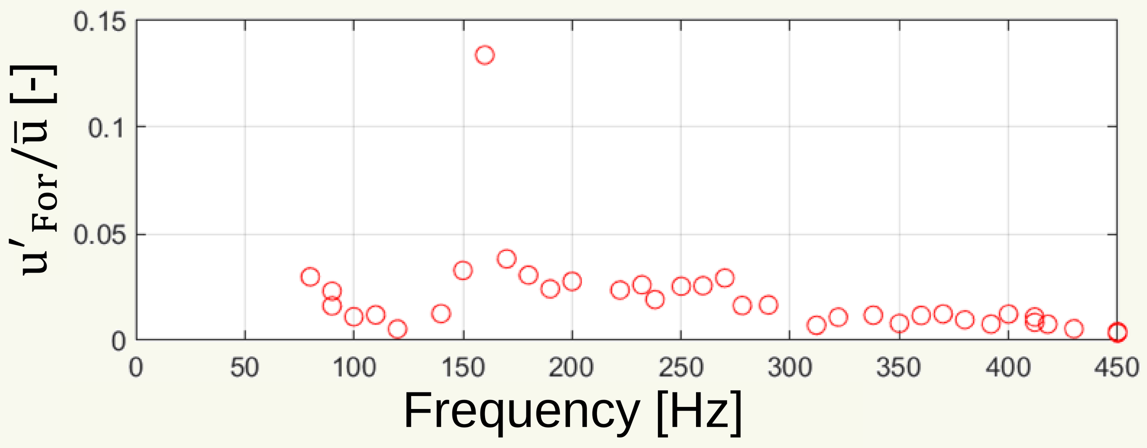


Fig. 7 Acoustic velocity over frequency range

- Improvement of flame stabilization

[1] Ciani, A., Bothien, M.R., Bunkute B., Wood J.P., and Früchtel G. (2009). Superior fuel and operational flexibility of sequential combustion in Ansaldo Energia gas turbines. Journal of the Global Power and Propulstion Society. 3: 630-638.
[2] Berger, M.F., Hummel, T., Romero, P. Schuermans, B., Sattelmayer, T., A Novel Reheat Combustor Experiment for the Analysis of High-Frequence Flame Dynamics - Concept and Experimental Validation. ASME Paper No. GT2018-77101.

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