Hydrogen gas burner LES data thermoacoustic instability analysis

Introduction

My work is investigating the combustion instability of a hydrogen gas burner LES dataset. The dataset is based on 'FlameSheet' burner, which is a versatile burner used in gas turbine that can accommodate various fuel types.

Method

DMD (Dynamic Mode Decomposition) is mainly used as a data analysis tool, which extracts oscillating spatial pattern with associated frequency. Dataset comprises 998 timesteps (0.2 sec – 0.3 sec), and equivalence ratio φ increases linearly from 0.3 to 0.53 over time. The dataset is divided by 19 segments with 50% overlapping (100 timesteps for each segment), and DMD is applied on them. 1st, 9th, and 17th are to be presented as results (in paper) which correspond to at φ ≈ 0.3, 0.4 and 0.5.

Objective

Analyze the thermoacoustic instability, flame flashback, and hydrodynamics from the hydrogen burner LES dataset.

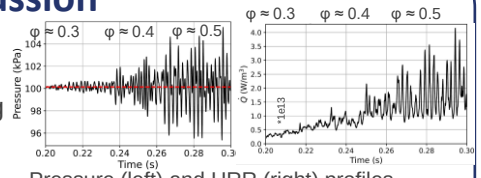
Keywords

Thermoacoustic instability: Heat release rate oscillation Q' generates acoustic oscillation P' (with velocity oscillation coupling V'=P'/ρc), and generated acoustic oscillation modifies heat release rate oscillation Q' (feedback loop between P' and Q'). If these P' and Q' are in phase, heat release oscillations amplifies and intrigue thermoacoustic instability.

Flame flashback: Flame propagates to the opposite direction (to the fuel injector direction). This undesired situation occurs when flame propagation speed is faster than fuel flow velocity.

Results & Discussion

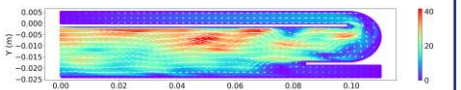
Pressure and velocity profiles are showing oscillation with increasing amplitude at 500 Hz component over time.



Pressure (left) and HRR (right) profiles. Equivalence ratio increases linearly over time

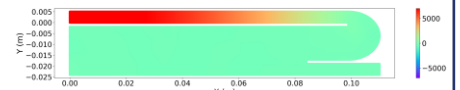
Pressure DMD mode represents quarter-wave global and local acoustic resonances at 500 Hz and 1000 Hz, for all equivalence ratios.

Pressure DMD mode at φ ≈ 0.5 and f ≈ 500 Hz

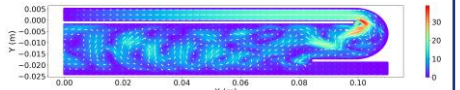


Velocity DMD mode at φ ≈ 0.5 and f ≈ 500 Hz

Velocity DMD mode at φ ≈ 0.3 illustrates velocity field mainly driven by hydrodynamics, while at φ ≈ 0.5, it performed strong velocity field oscillation derived by global and local acoustic resonance at 500 Hz and 1000 Hz, respectively.

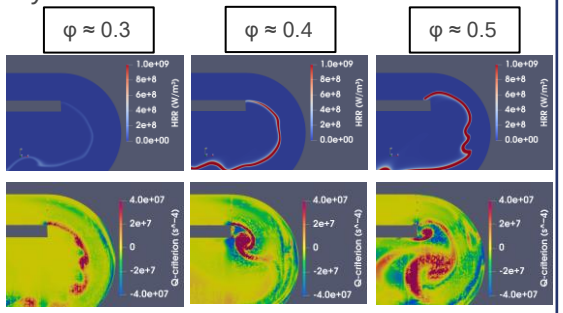


Pressure DMD mode at φ ≈ 0.5 and f ≈ 1000 Hz



Velocity DMD mode at φ ≈ 0.5 and f ≈ 1000 Hz

Partial periodic flashback is observed. This is attributed to changing vortex shedding frequency and size at the U-bend tip, (from 2500 Hz small size at φ ≈ 0.3, to 500 Hz large size at φ ≈ 0.5)



Heat release rate field indicating shape of flame (up) and *Q*-criterion field showing vortex shedding pattern (down)

Global acoustic resonance at 500 Hz → Velocity field oscill. (P'—V' coupling, V'=P'/ρc) → Partial periodic flashback at 500 Hz due to changed vortex shedding pattern (2500Hz →500 Hz)

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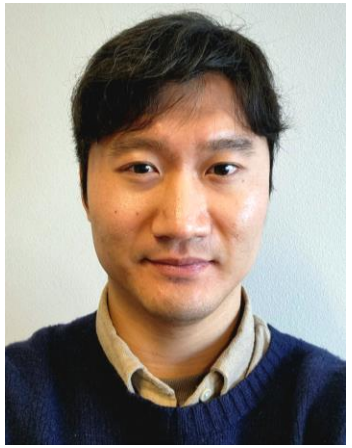
Related projects: LowEmission , Hydrogen gas turbines



MSc. Energy and Environment Technology from University of South-eastern Norway (USN), 2021-2023

BSc. Mechanical Engineering from Kyushu University, 2015-2019

Estimated progress of the PhD project:

Just started ...	< 50 %	> 50 %	Almost done ☺

Publications

- Shin J., Henriksen M., Bjerketvedt D., Hydrogen and Ammonia Combustion
- Henriksen M., Shin J., Bjerketvedt D., Laminar Burning Velocities of Hydrogen and Ammonia Blends (ongoing)
- M.Ibrahim O., Shin J., Sikka R., Hansen P.M., Vågsæther K., Experimental study on hydrogen pipeline leakage: Negative pressure wave characteristics and inline detection method

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