FACULTY OF AEROSPACE ENGINEERING

TRAPPED-VORTEX CONCEPTS IN THE CONTEXT OF LEAN PREMIXED TECHNOLOGY

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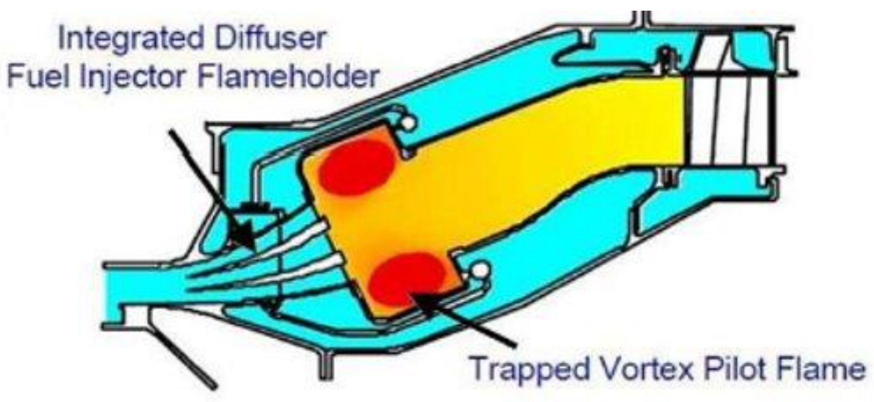
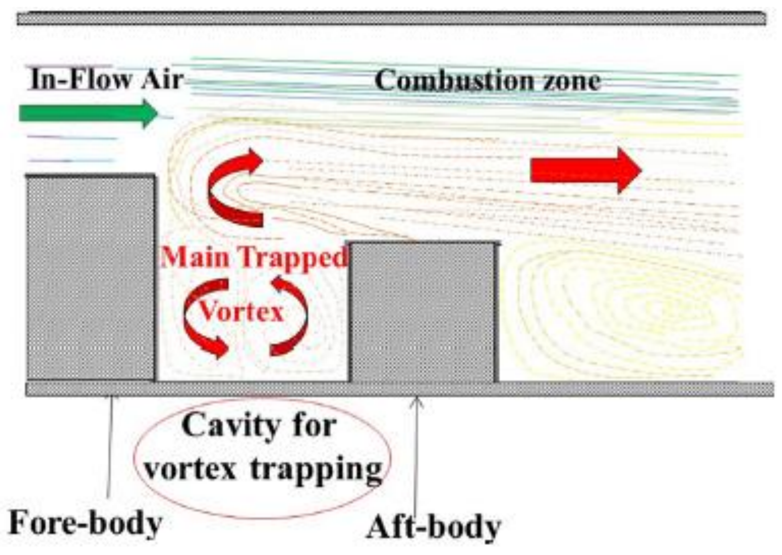
Trapped vortex combustors

Characteristics

- Recirculation zone - Flow stabilization
- Reducing the size of the combustor
- May be used as an RQL concept, by injecting a rich mixture inside of the cavity
- Potential for hydrogen combustion



Trapped vortex combustor [1]



Trapped vortex in a cavity [2]

Rich-Quench-Lean (RQL)

- Rich-burn – enhances stability by producing radicals
- Quick-mix – transition to lean mixture. Quick mixing is important.
- Lean-burn – finally, combustion at low-temperature lean conditions.
- By avoiding high temperatures, NOx emission are severely reduced

Research Goals

The high fidelity Direct numerical simulation (DNS) allows an in-depth study of RQL-TVC configurations in the context of lean premixed flames, more susceptible to instabilities, in the effort to reduce emissions. Moreover, it will serve as a validation case for the development of lower order models, e.g. LES with presumed FDF-based model, more computationally affordable for design purposes

1) Improvements in the modelling

- Analysis of DNS data - Validation of various models
- Development of a FGM/PSR method, based on LES
- Validate the low order method against the DNS simulation

2) Study of the RQL-TVC concepts

- Radial acceleration - Effect of swirl
- Hydrogen combustion, emissions
- Impact of the combustor geometry

DNS case

A DNS computation of the RQL-TVC configuration with two cavities is performed. The obtained data can be filtered to have an insight into the subgrid scale quantities in the development of a presumed FDF model for LES.

High performance computing

- The open source software package OpenFOAM is used
- 2000 processors are employed
- It would take about 32 days to complete the simulation

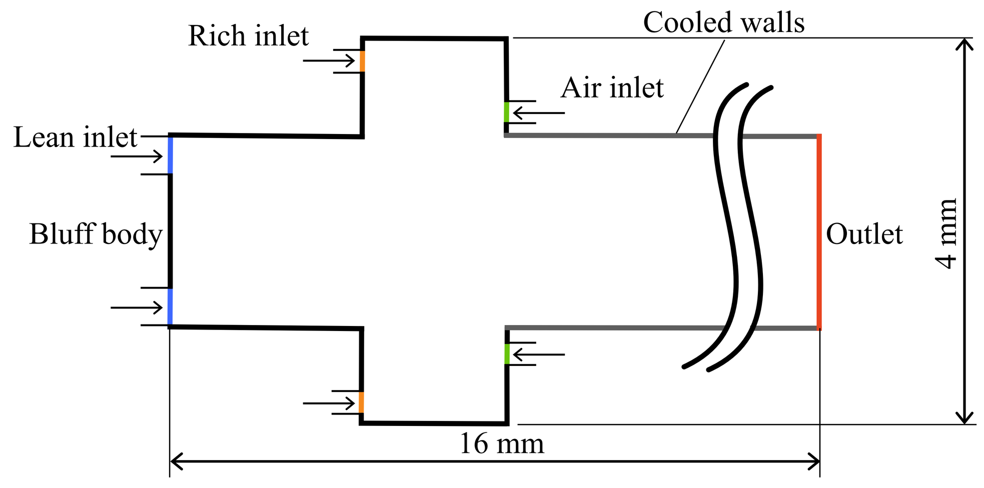
Computational details

Boundary conditions

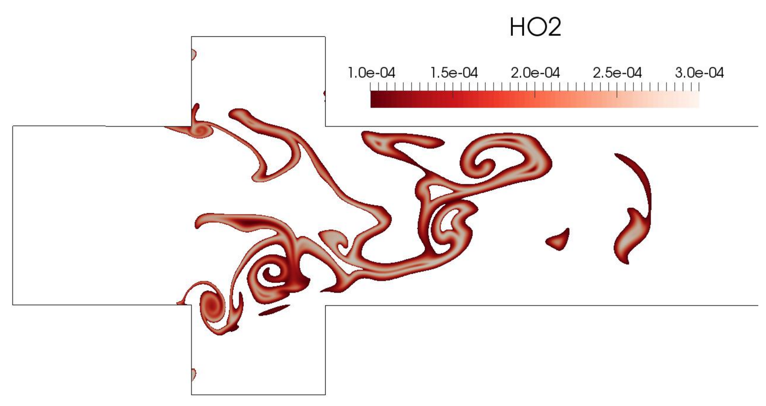
- Inflow temperature – 600 K
- Cooled wall temperature – 300 K
- Inflow velocity – 50 m/s
- Lean inlet – $\phi = 0.5$
- Rich inlet – $\phi = 1.5$

Computational mesh

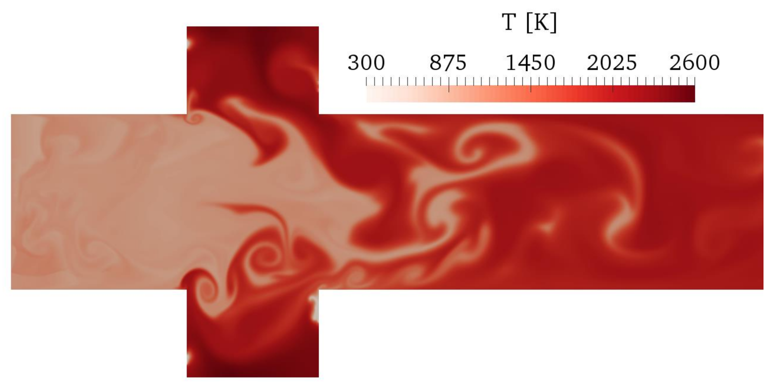
- 280 million cells
- Smallest cell size – 24 μm



DNS computational domain



Flame tracking



Temperature field

Future work

- The FGM method will be validated according to the DNS data
- An optimized combustor will be designed by performing a range of FGM simulations

Even the Prometheus torch can burn with hydrogen!*

*This is not the official TU Delft logo

References

[1] Shouse, D. T. "Trapped vortex combustion technology." *slides projected at MITE Workshop*. 2000.

[2] Zhao, Dan, Ephraim Gutmark, and Philip de Goey. "A review of cavity-based trapped vortex, ultra-compact, high-g, inter-turbine combustors." *Progress in Energy and Combustion Science* 66 (2018): 42-82.

Acknowledgment

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