Digital stakeholders' workshop
HyTunnel-CS project
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The pressure peaking phenomenon in garages: CFD model

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Aim of the research

Pressure Peaking Phenomenon for jet fires

- This research aims at the development and validation of a CFD model for predictive simulation of pressure peaking phenomenon for hydrogen jet fire in large scale scenarios.
- CFD modelling complements a engineering tool:
  - Simulation of diversified scenarios that can not be represented by engineering tool assumptions.
  - Calculation of thermal load on the structure.
  - Calculation of hazard distances by thermal effects in the external surroundings of the enclosure.

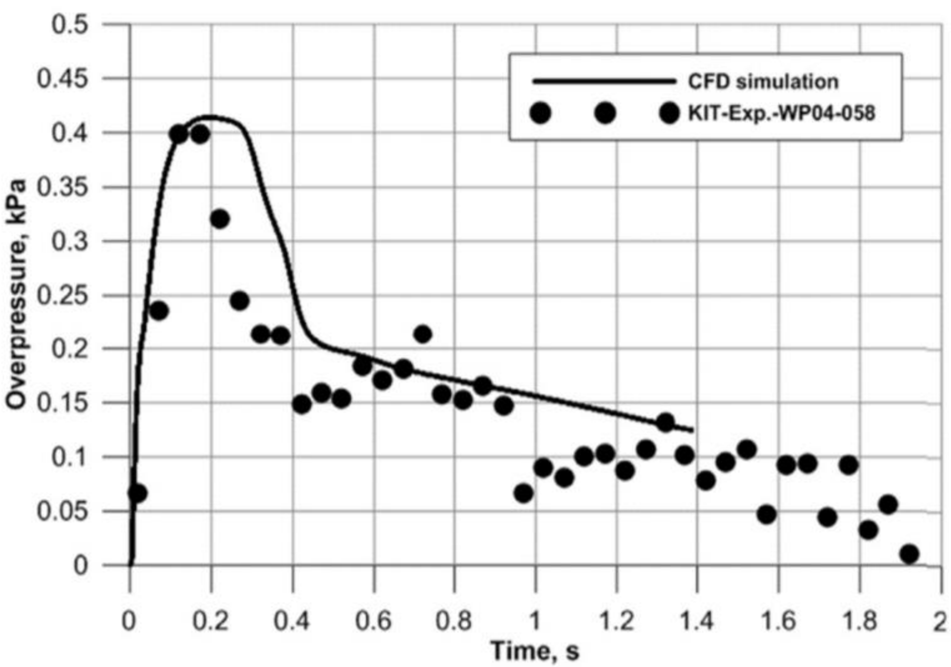
Previous work on PPP

CFD model validation against KIT tests

CFD model was validated against 4 experimental tests performed in KIT for a 1 m³ enclosure.

Results for test:

- $\dot{m} = 0.55\ g/s$
- Vent size: 3x30 cm



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Numerical validation of pressure peaking from an ignited hydrogen release in a laboratory-scale enclosure and application to a garage scenario

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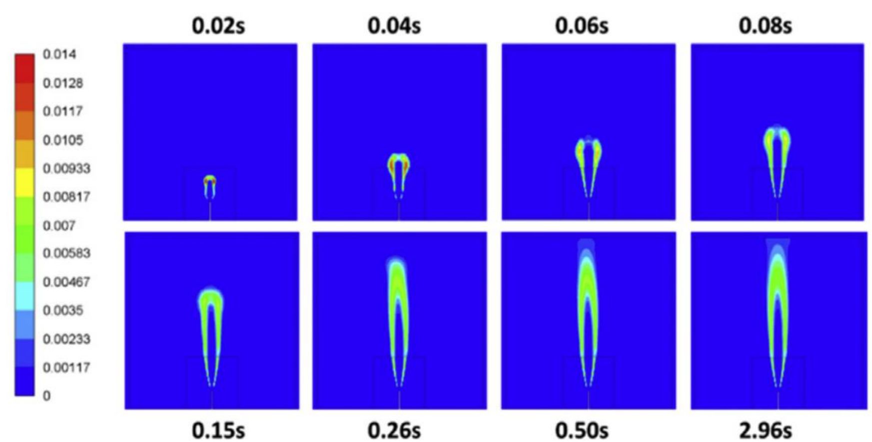


OH mole fraction distribution

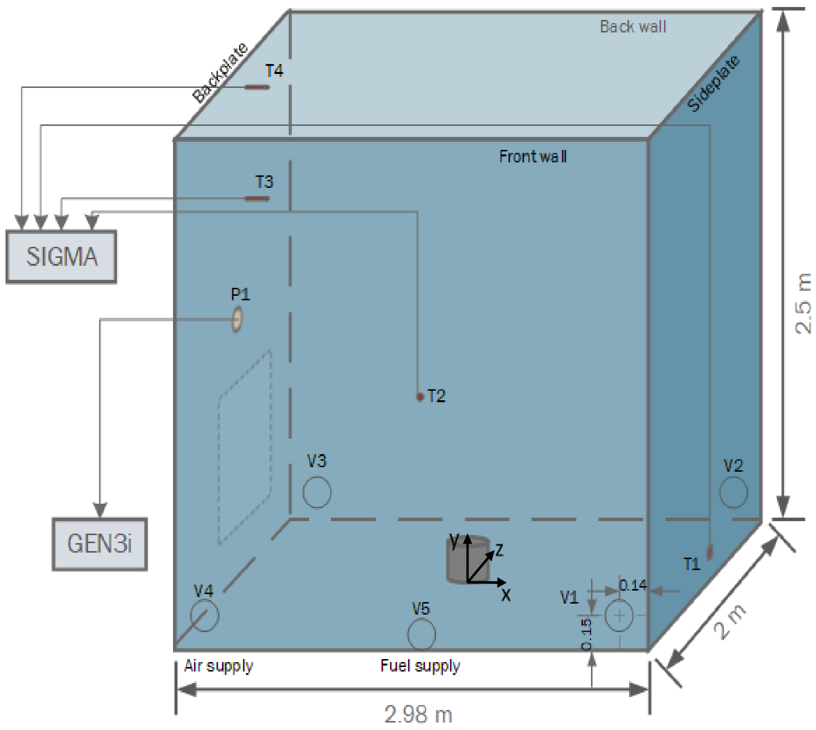
USN validation experiments

Details and advancements

- Large scale scenario: 15 m³ enclosure.
- Release mass flow rate up to 11.5 g/s.
- Hydrogen release duration is 6 s from 4 mm diameter.
- Selection of 3 tests for CFD modelling.

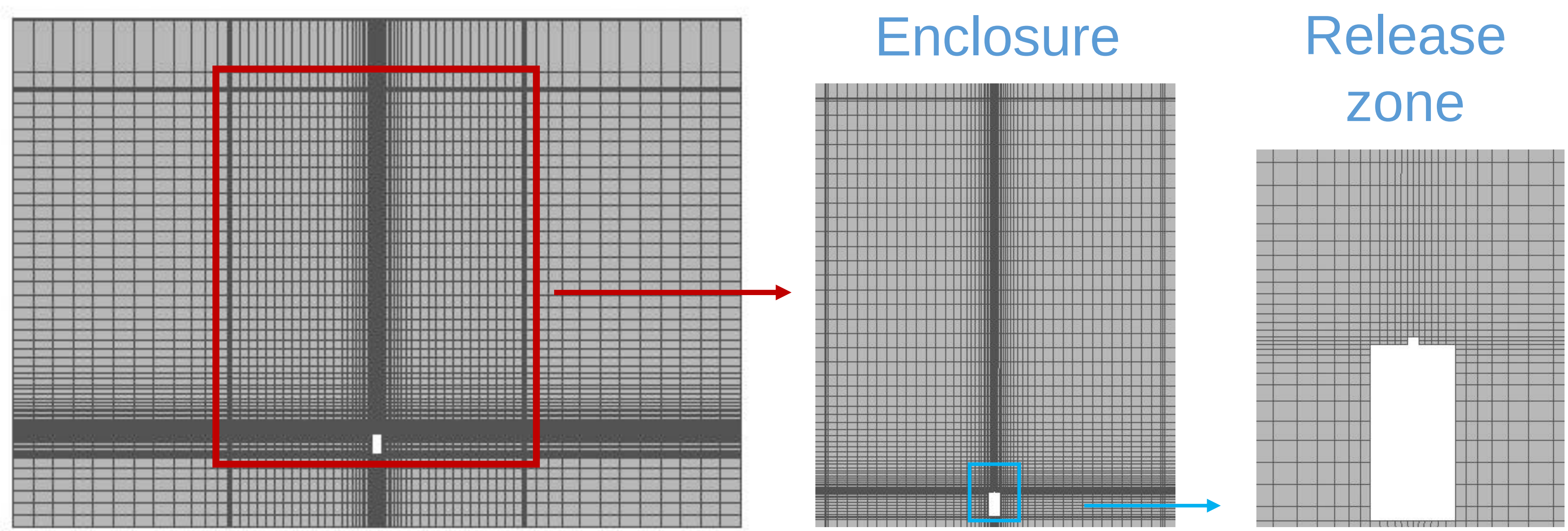
Test	Pressure, bar	Mass flow rate, g/s	N. of vents
14	117.8	11.37	3
18	124.6	11.47	2
19	89.3	8.62	1

- Pressure dynamics
- Temperature dynamics



CFD model
Numerical details

- ❖ ANSYS Fluent platform is used for simulations.
- ❖ Pressure-based solver with compressible ideal gas.
- ❖ RANS approach for turbulence modelling.
- ❖ Eddy Dissipation Concept for combustion modelling.
- ❖ Discrete Ordinates for radiation modelling.



Release source modelling

Notional nozzle approach

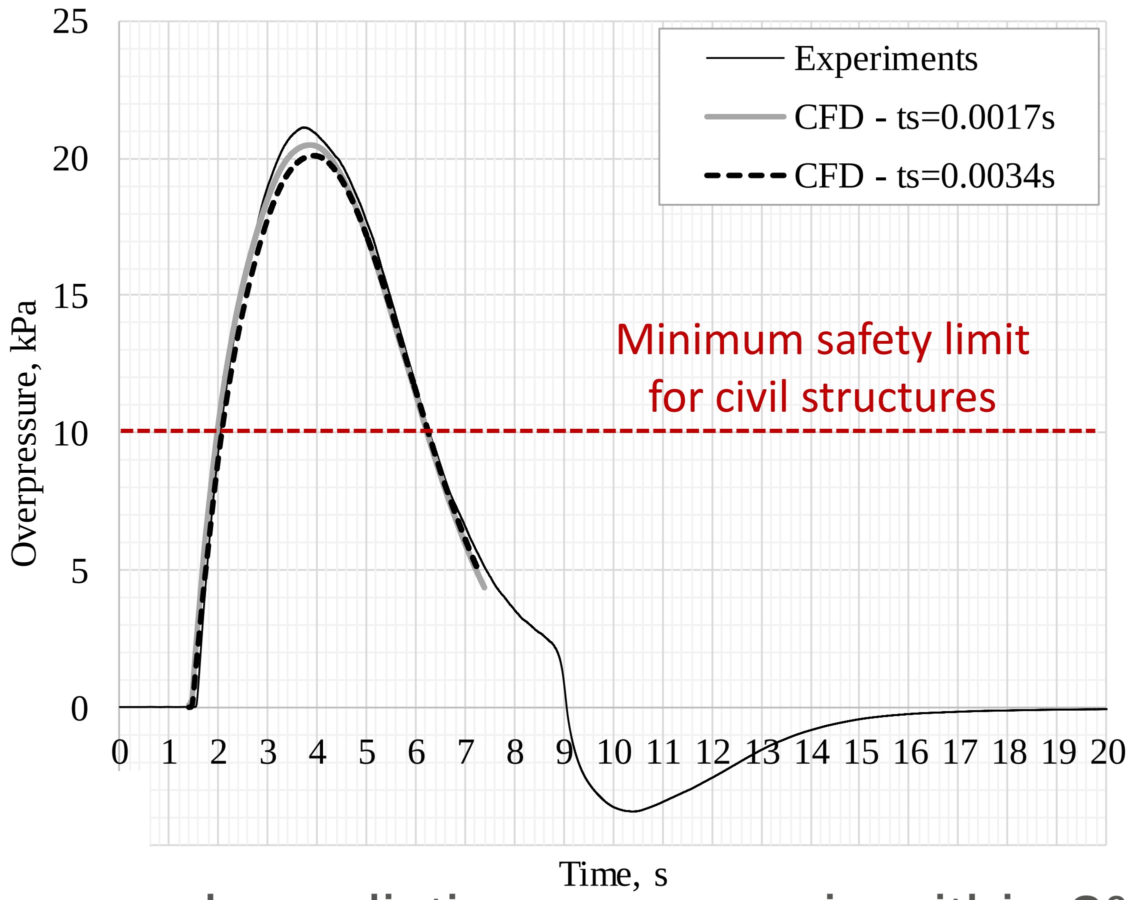
- Storage pressure >1.9 bar, thus an under-expanded jet is expected.
- Release source is modelled using the Ulster's notional nozzle theory.
- A discharge coefficient is introduced to reproduce the experimental mass flow rate and define notional nozzle parameters.

Test	Mass flow rate, g/s	C_d	D_{not}, mm	U_{not}, m/s
14	11.37	0.13	11	1154.5
18	11.47	0.12	11	1156.6
19	8.62	0.12	9.5	1156.6

Pressure dynamics

Simulation results

❖ **Test 14.** Pressure = 117.8 bar, mass flow rate = 11.37 g/s



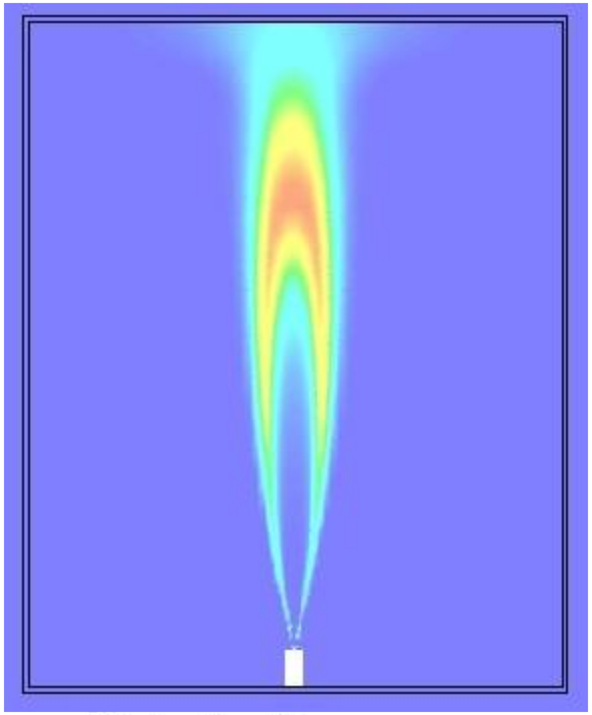
❖ Pressure peak prediction accuracy is within 3% (ts=0.0017s)

OH mole fraction dynamics

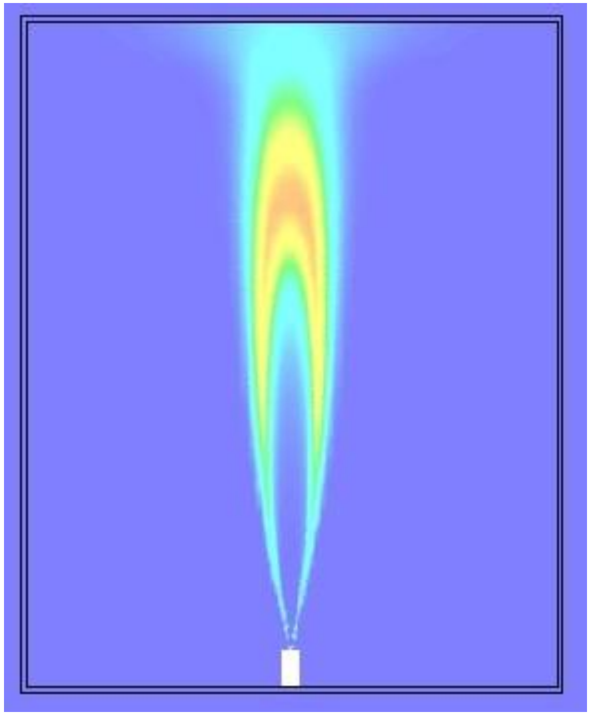
Simulation results

❖ **Test 14.** Pressure = 117.8 bar, mass flow rate = 11.37 g/s

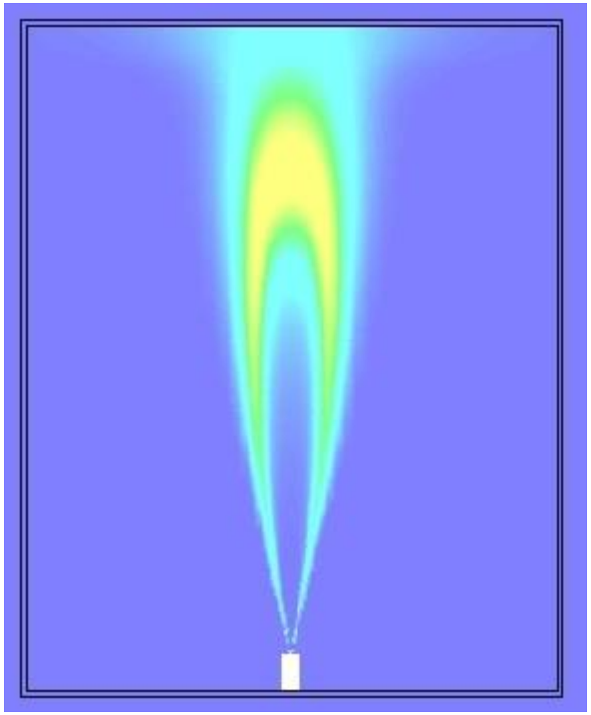
Time = 2.4 s



Time = 3.4 s

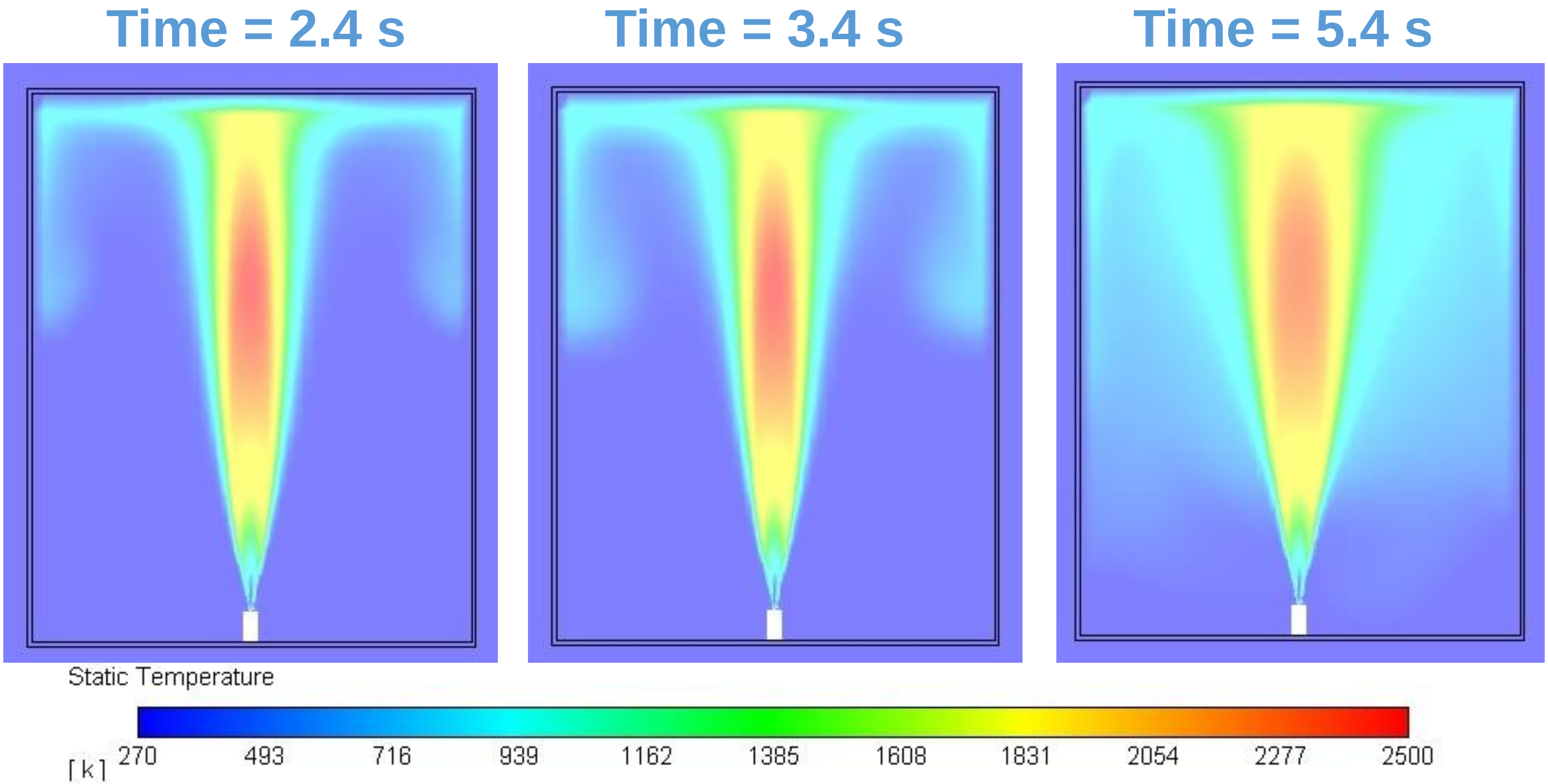


Time = 5.4 s



Temperature dynamics
Simulation results

❖ **Test 14.** Pressure = 117.8 bar, mass flow rate = 11.37 g/s



Concluding remarks
… and future works

- A CFD model is being validated against large scale experiments performed by USN within HyTunnel-CS.
- The CFD model agrees well with the experimentally measured pressure peak and dynamics in the enclosure.
- CFD modelling can be used to model the flame dynamics and thermal load on the enclosure structure.
- The validation range of a CFD model is envisaged to be further expanded to tests with pressure up to 700 bar.
- The CFD model can be employed in hydrogen safety engineering to determine the maximum TPRD size to prevent damage of a structure due to PPP.

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