HySafe Research Priorities Workshop

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Delayed ignition deflagrations: initial trials with Ulster model

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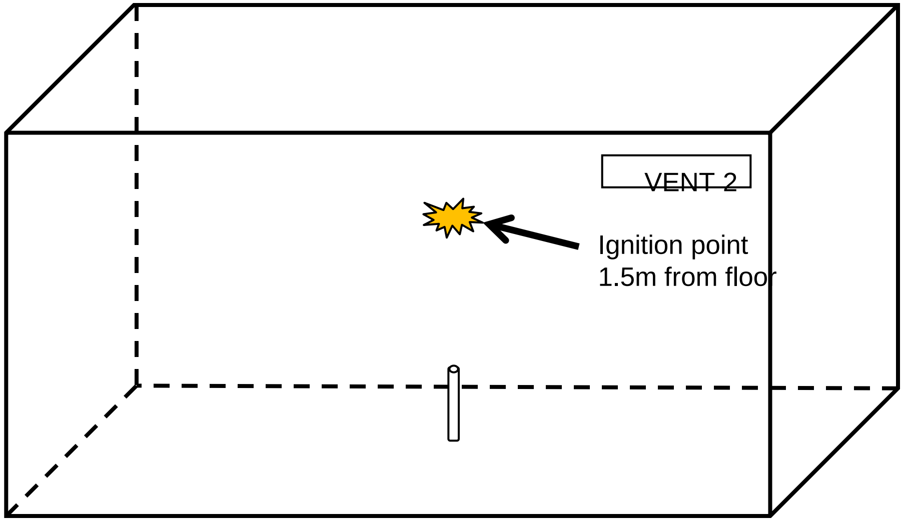
Justification and drivers

- To be able to correctly design an effective vent for deflagration mitigation is an essential safety feature of emerging hydrogen infrastructure
- Real-life industrial accident scenarios include formation of gradient mixtures, delayed ignition of turbulent hydrogen jet inside containers and enclosures, and combustion of non-homogeneous flammable composition.
- Delayed ignition is a knowledge gap for both CFD and analytical models
- Modelling and correlations for delayed ignition of hydrogen jets in vented enclosures is a subject of FCH JU Call for proposals FCH-04.3-2014 “Pre-normative research on vented deflagrations in containers and enclosures for hydrogen energy applications”

HSL experiment WP3/25 (HyIndoor project)

- Explosion box 2.5 × 2.5 × 5.0 m (31 m^3)
- Release rate 600 NL/min for 69 sec (0.69 m^3 H_2), ∅10 mm
- Ignition 1.5 m above the release point
- Single vent opening 0.224 m^2. Vent opens @2.8kPa.

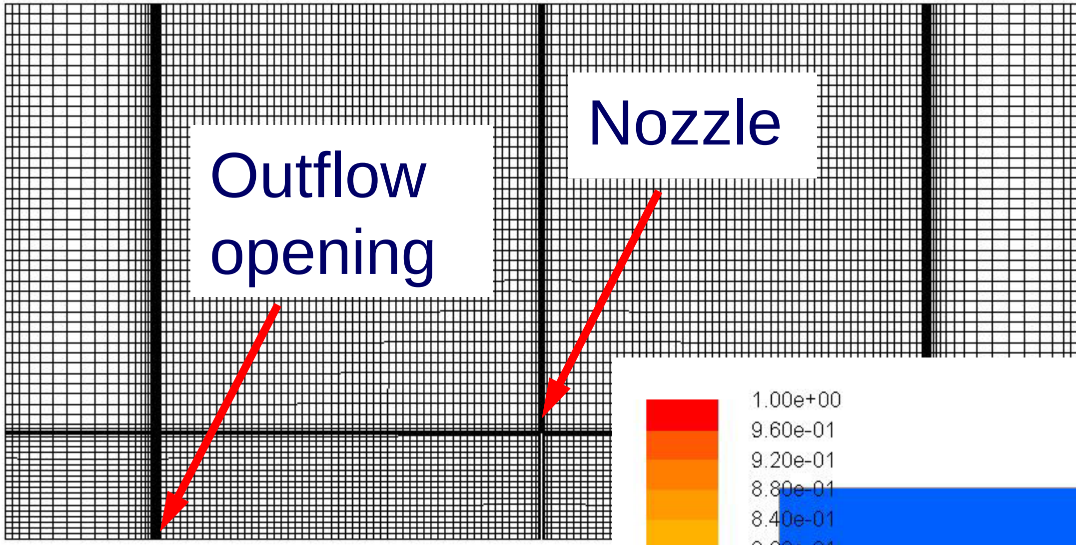


Release CFD model

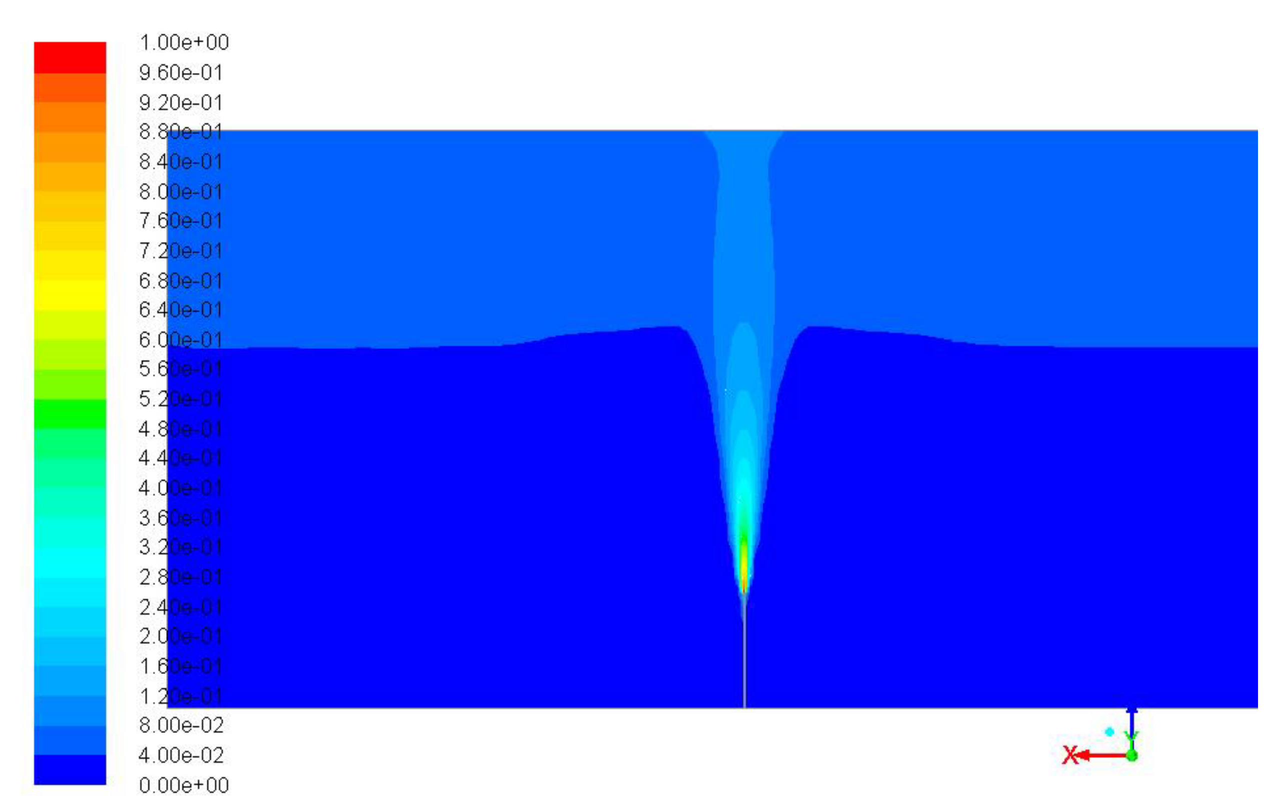
- Solver:
  - incompressible, pressure-based segregated
  - SIMPLE pressure-velocity coupling
  - 3rd order discretisation scheme MUSCLE
- Domain:
  - HSL enclosure only, 2 small outflow openings
  - 721,100 hexahedral CVs mesh
  - Inflow pipe resolution 3×3 CVs
- Model:
  - mass, momentum, energy, non-reacting H_2 transport
  - realisable k-ε model turbulence model
  - time step Δt=0.01s, 50 iter/time step
- CFD engine: FLUENT

Release CFD results (1/2)

Mesh

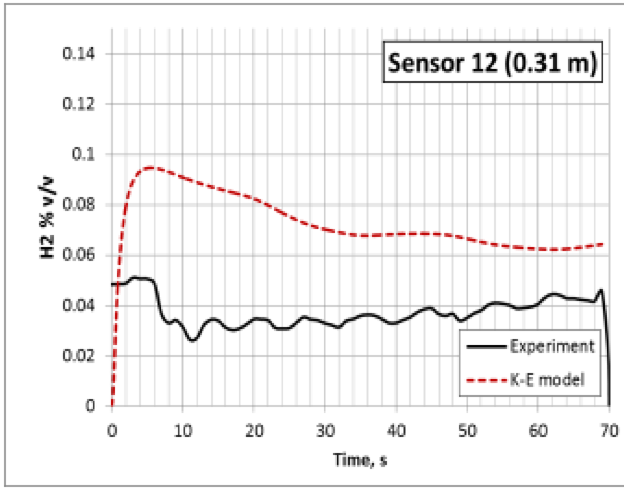


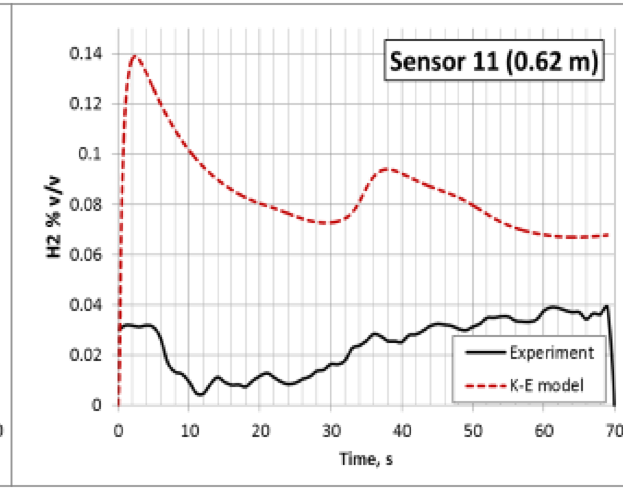
H_2 distribution

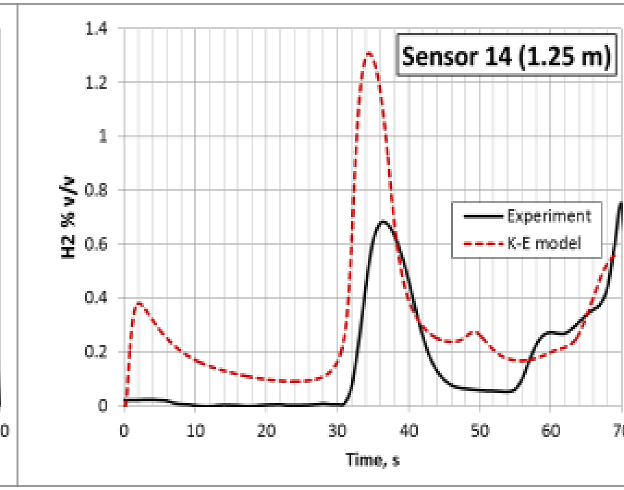


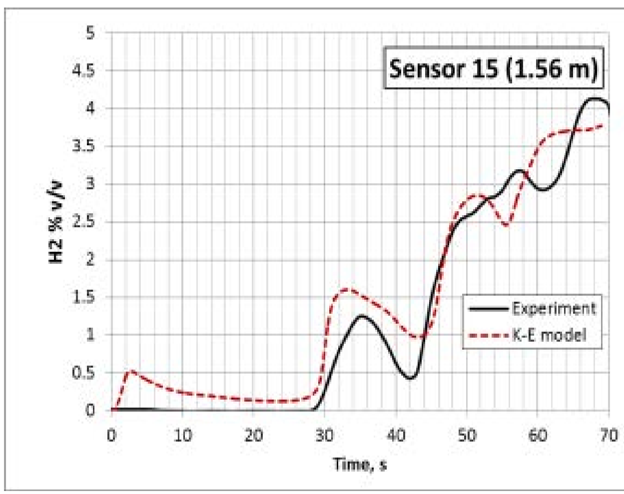
Release CFD results (1/2)

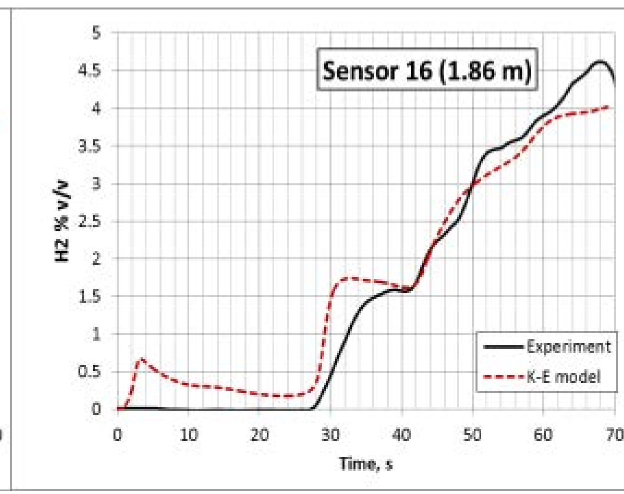
Good agreement with experimental data

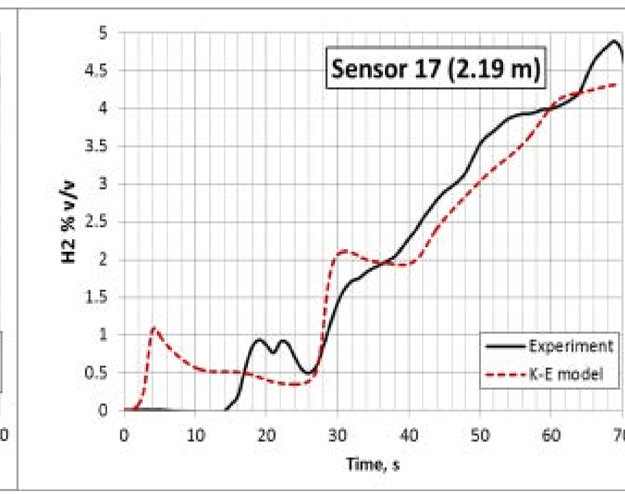








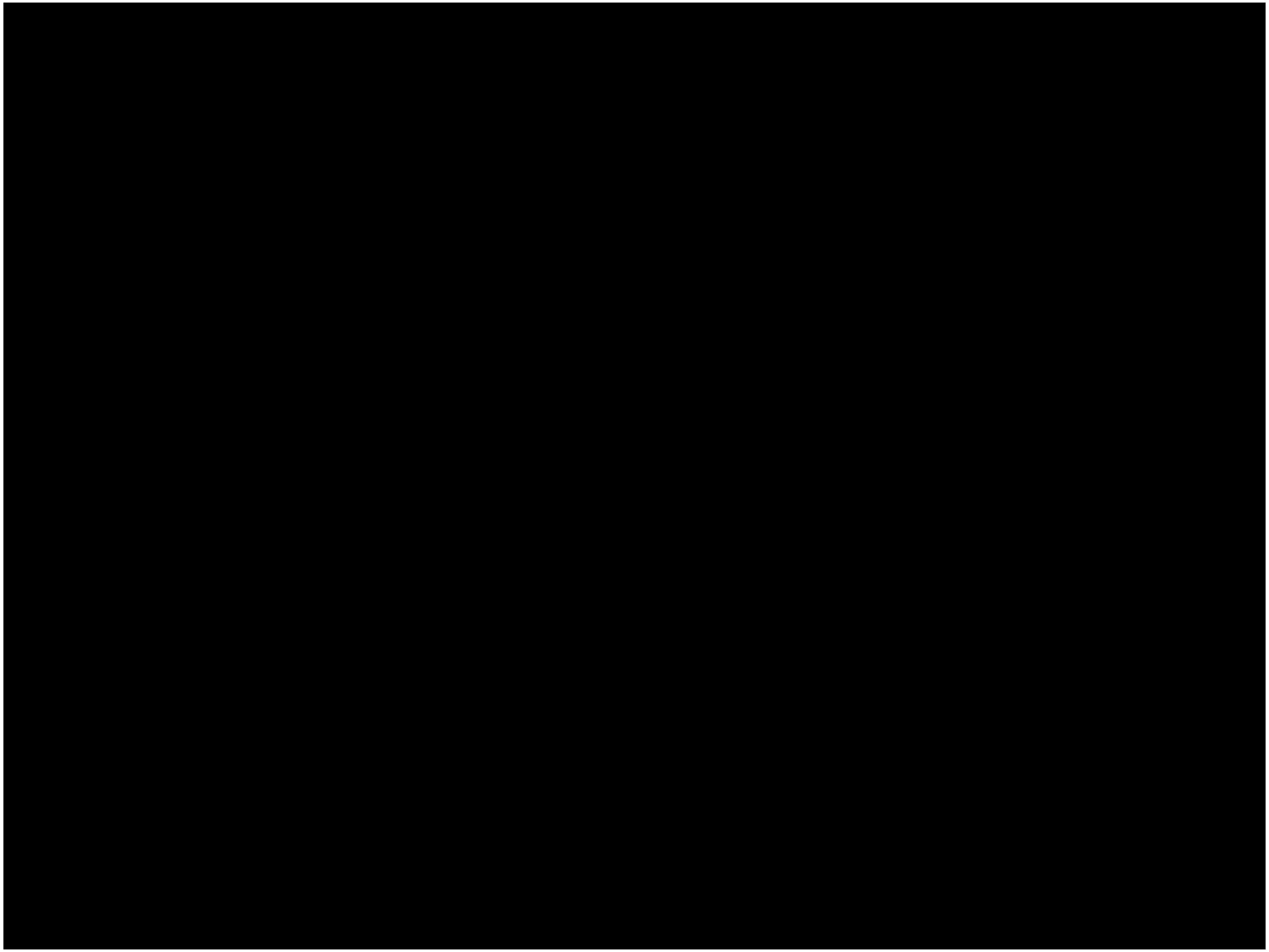




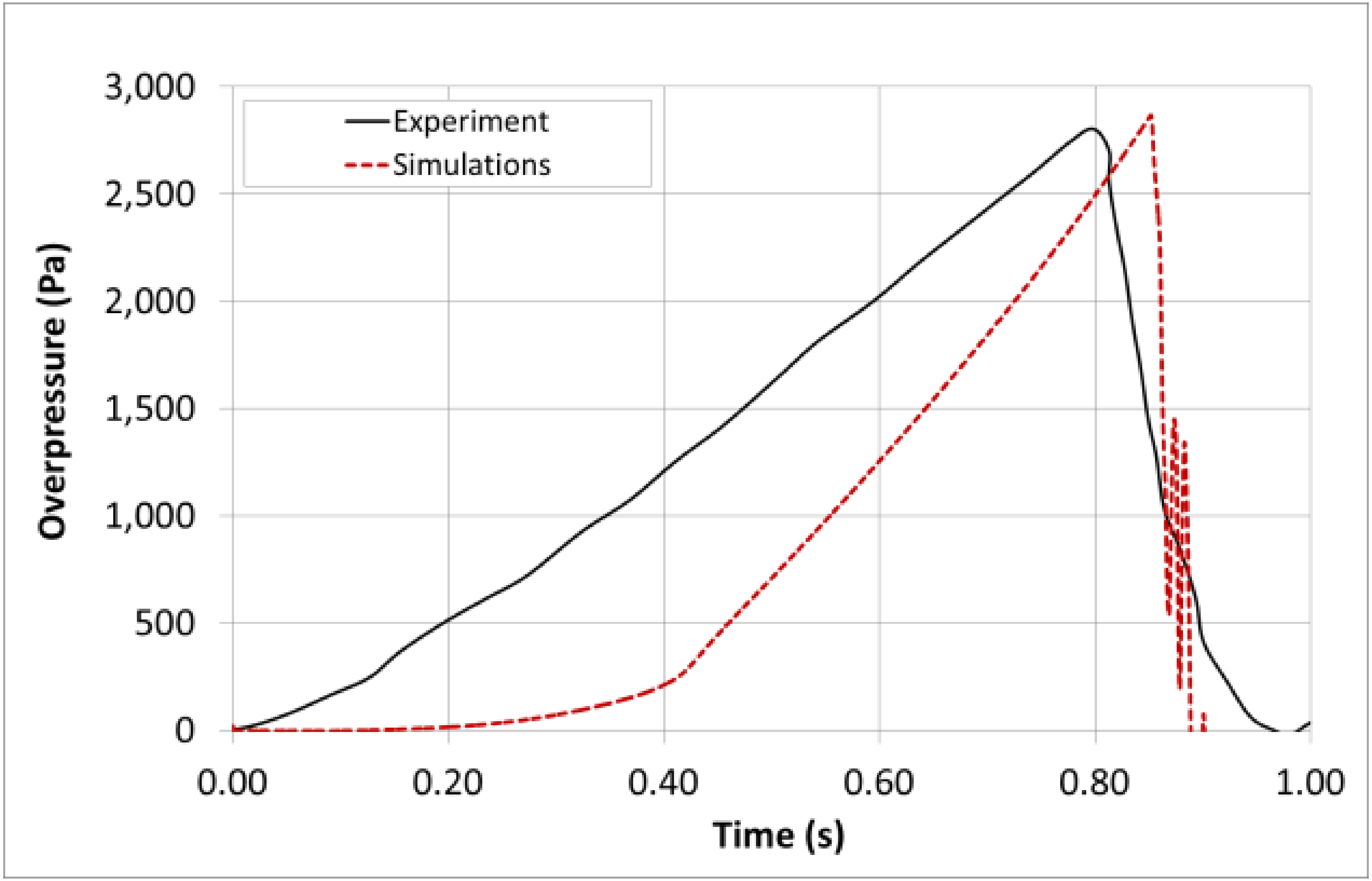
Deflagration CFD model

- Solver:
  - compressible, density based coupled
  - 2^{nd} order upwind scheme
  - Explicit time stepping, CFL=0.8
- Domain:
  - HSL enclosure + external area
  - 852,220 tetrahedral CVs mesh
- Initial H_2 distribution exported from release solution, volumetric release to reproduce continues H_2 jet
- University of Ulster LES combustion model:
  - RNG LES for turbulence modelling
  - UU multi-phenomena combustion model
  - Maximum Karlovitz and leading point factors from t=0 s
- Continues ignition source

Flame propagation dynamics



Pressure dynamics



Deflagration CFD results

- Captured flame propagation through
  - jet area
  - non-uniform H_2-air layer under cealing
- Qualitative agreement with experimental pressure dynamics
- Relatively slow pressure dynamics at initial moment
- More research effort is needed
  - to obtain detailed experimental data to allow insight into physical phenomena for model validation
  - to resolve turbulent flame propagation and deflagration dynamics in turbulent jet area

THANK YOU

Learn more!