Ulster University

IA HySafe Research Priorities Workshop on Hydrogen Safety

26-27 September 2016, Petten, the Netherlands

The state-of-the-art and knowledge gaps in hydrogen safety physical effects

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Acknowledgements

The HySAFER team:

- Dr Sile Brennan
- Dr Volodymyr Shentsov
- Dr James Keenan
- Dr Sergii Kashkarov
- Dr Yangkyun Kim
- Dr Wookyung Kim

Funders and colleagues in research projects:

- FP7 H2FC Research Infrastructure
- FCH-JU HyIndoor
- FCH-JU HyResponse
- UK EPSRC H2FC SUPERGEN Hub
- UK EPSRC H2FC SUPERGEN Challenge

Progress

Blast waves from tank rupture in a fire

- Original analytical blast wave decay theory
  - Use of real gas EOS
  - Contribution of combustion to the blast wave strength
  - Validation against stand-alone and under-vehicle tank location
  - (Weyandt, 2005)
- CFD of blast wave and fireball dynamics in the open atmosphere
  - Blast wave and fireball parameters dynamics (ideal gas)
  - Simulation of radiation to assess a thermal doze

Deflagrations

- Localised mixture
  - A thermodynamics model for hydrogen inventory limit in closed room, e.g. warehouse
  - Engineering correlation for venting localised mixtures
- CFD model accounting for Rayleigh-Taylor instability

Progress

Storage safety (GTR#13, thermal protection)

GTR#13 regulation update of fire test:

- CFD prediction and experimental validation of the effect of heat release rate on fire resistance rating (change of GTR#13).

Design of tank thermal protection and fire resistance:

- CFD model of conjugate heat transfer to a tank from a fire, including the original failure criterion for loss of tank load bearing ability and validation against test in USA (2006), and KIT (2015).
- Effect of thermal protection on fire resistance rating (achieved fire resistance of 1h 50m is beyond longest car fire duration 1h 40 m)
- The model and parametric CFD study of tank protection by intumescent paint (increase fire resistance by an order of magnitude)

Working topics

Releases and jet fires

- Transient solution for under-expanded jet fire lift-off and blow-off
- Delayed ignition of high-pressure releases
- CGH2 and LH2 jet fire flame length and radiation
- Effect of impinging and attached jets on hazard distances

Blast waves and fireballs

- Blast wave and fireball dynamics from high-pressure tank rupture accounting real gas properties and effect of radiation effect on blast wave decay
- Thermal radiation from fireballs

Deflagrations and detonations

- Non-uniform vented deflagration (further model validation)
- DDT modelling and simulations in large industrial scales

Working topics

Storage safety

- Breakthrough explosion-free (leak-no-burst) technology for CGH2 storage in composite tanks (patent application GB1602069.5 Composite pressure vessel, 05.02.2016)
  - Following outcomes of the UK EPSRC H2FC SUPERGEN Hub and SUPERGEN Challenge projects
- Parametric study to underpin proposal for update of GTR#13 fire test protocol
  - Effect of HRR
  - Effect of burner design and type

New directions

- Update of GTR#13 fire test protocol to harmonise test procedure and eliminate test results discrepancy in different laboratories:
  - Definition of representative value of heat release rate of test fire to reflect parameters of real car fires
  - Establish requirements to “standard” burner design
- Radiation heat transfer modelling and numerical simulations to characterise hazards related to high-pressure storage and components at refuelling stations.
- Breakthrough safety technologies development and validation, e.g. exclusion of catastrophic tank rupture in a fire.

New directions

- Prevention and mitigation of blast wave in confined space such as tunnels, garages, car parks, HRS, etc.
- Time to rupture of high-pressure vessel, e.g. tube at road accident, subject to jet fire from high-pressure equipment, e.g. another tube.
- Efficiency of blast barrier designs.
- Harmful pressure and thermal effects on first responders (with protection).
- Pressure peaking phenomena for ignited releases.
- Thermal loads of indoor fires and effect of water condensation.
- Attached and impinging jets: CFD modelling and engineering correlations.
- LH2 tank rupture and rapid phase transition pressure loads.

New directions

- Liquefied hydrogen release, dispersion and ventilation, including under wind conditions.
- Combustion of cold hydrogen jets and clouds during and after LH2 release.
- Passive ventilation for multiple vents under realistic wind conditions.
- Validation experiments for: under-vehicle tank rupture, tanks of different volume and pressure, etc.