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Overview of research programme on jet fires

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Publication date:
2020

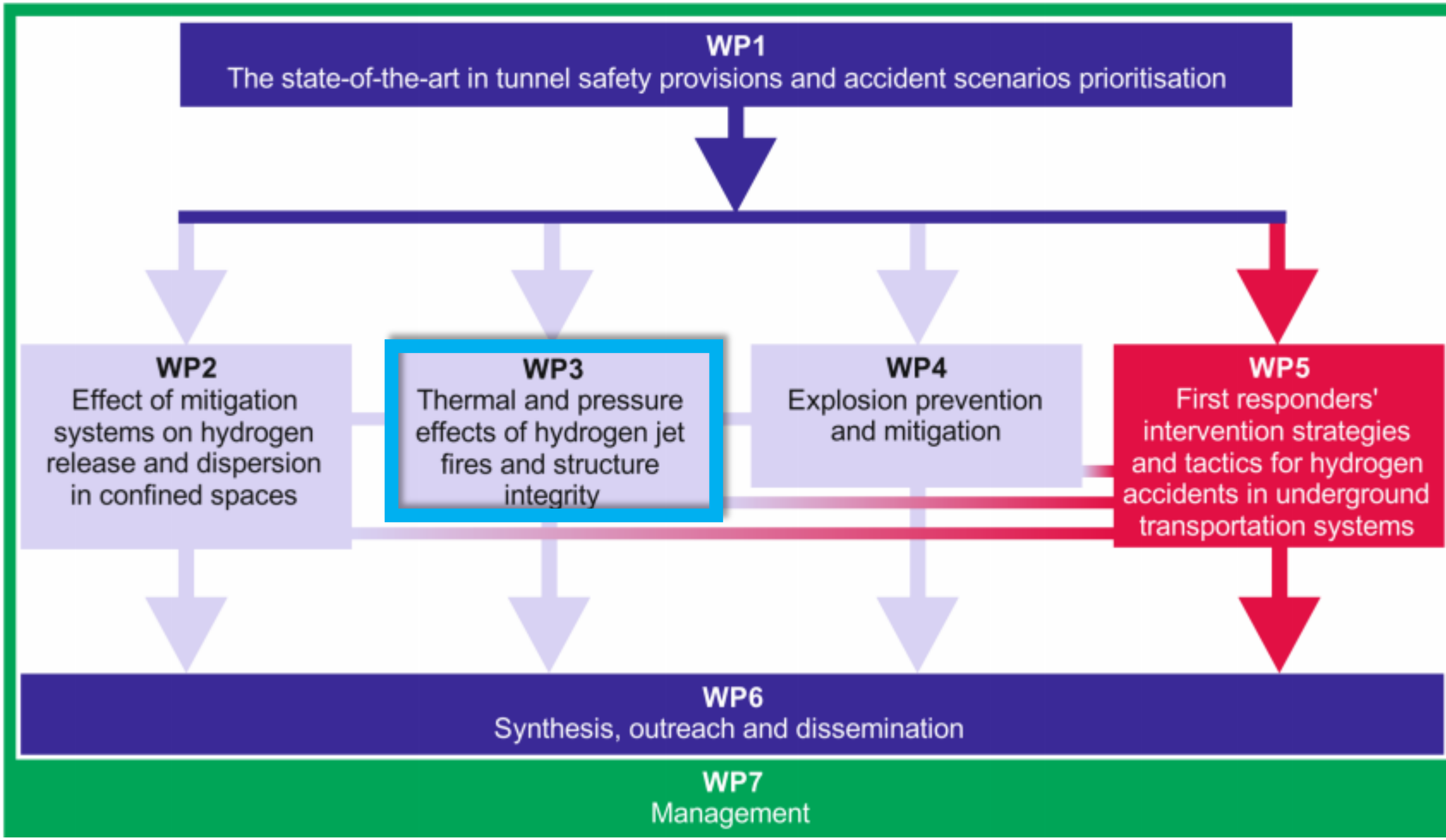
Document Version
Publisher's PDF, also known as Version of record

Digital Stakeholders Workshop
HyTunnel-CS project
4-5 May 2020

Overview of research programme on jet fires

F. Markert, DTU

Implementation
Workpackages



WP 3- Thermal and pressure effects of hydrogen jet fires and structure Integrity

Research topics

- **<u>Improve the principal understanding</u> of hydrogen jet fires on life safety provisions in the underground and the transport systems structural integrity**
- **Generate <u>unique experimental data</u>**
  - To support development and validation of physical models , simulations, hazard and RA tools
- **Perform <u>numerical simulations</u>**
  - To support the experiments
  - To better understand hydrogen jet fire effects on
    - ✓ Life safety
    - ✓ Property
    - ✓ Environment protection

WP 3–Thermal and pressure effects of hydrogen jet fires and structure Integrity

Objectives

- **Develop novel engineering correlations for fire safety engineering**
  - Applicable to H2 vehicles in underground transport systems and similar confined spaces
- **Study thermal effects of hydrogen fires on**
  - The structural integrity
  - Erosion of road and lining materials
  - Spalling of concrete
- **Prevention and mitigation of H2 related accidents**
  - Identification and evaluation of innovative safety strategies and engineering solutions in underground transportation systems
- **Underpin key RCS outputs and recommendations for inherently safer use of hydrogen vehicles in such applications**
  - PNR on hydrogen fires

WP 3 - Thermal and pressure effects of hydrogen jet fires and structure Integrity

Resources

WP	WP Title	Lead	Person months	Start month	End month
WP1	The state-of-the-art in safety provisions for underground transportation systems and accident scenarios prioritisation	KIT	10.10	1	12
WP2	Effect of mitigation systems on hydrogen release and dispersion in confined spaces	NCSRD	53.70	1	36
WP3	**Thermal and pressure effects of hydrogen jet fires and structure Integrity**	**DTU**	**36.50**	**1**	**36**
WP4	Explosion prevention and mitigation	HSE	42.60	1	36
WP5	First responders' Intervention strategies and tactics for hydrogen accidents in underground transportation systems and risk assessment	IFA	18.50	1	36
WP6	Synthesis, outreach and dissemination	FHA	17.30	1	36
WP7	Management	Ulster	16.56	1	36
WP8	Ethics requirements	Ulster	N/A	1	36

WP 3 - Thermal and pressure effects of hydrogen jet fires and structure Integrity

Task list

3.2 Analytical studies, development and validation of engineering tools

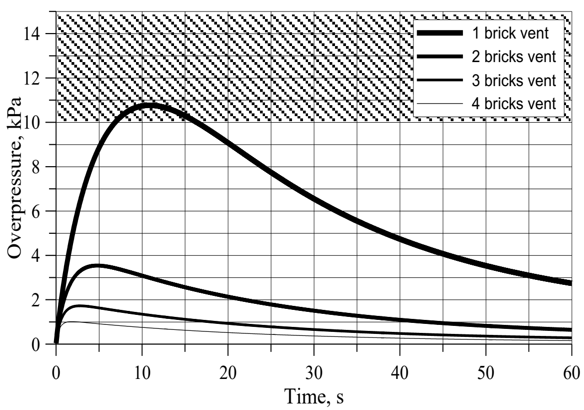
- 3.2.1 Correlation for pressure peaking phenomenon for jet fires in enclosures
- 3.2.2 Hydrogen fire suppression systems by water sprays and oxygen depletion
- 3.2.3 Mechanical ventilation of hydrogen non-premixed turbulent combustion in underground parking

Subtask 3.2.1 (UU)

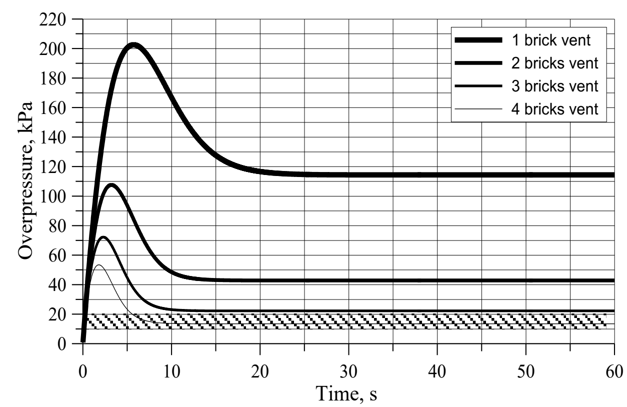
Example:

PPP correlation for jet fires in enclosure

- The peak can significantly exceed the steady-state overpressure, which is reached when the enclosure is fully occupied by leaking with a constant rate hydrogen.
- The amplitude and duration of the pressure peak vary depending on the enclosure volume, vent size and leak flow rate.



Unignited release in a garage:
TPRD D=2.0 mm, P=70 MPa (107 g/s).



Ignited release in a garage:
TPRD D=2.0 mm, P=70 MPa (107 g/s).

WP 3 - Task list

3.3 Numerical studies

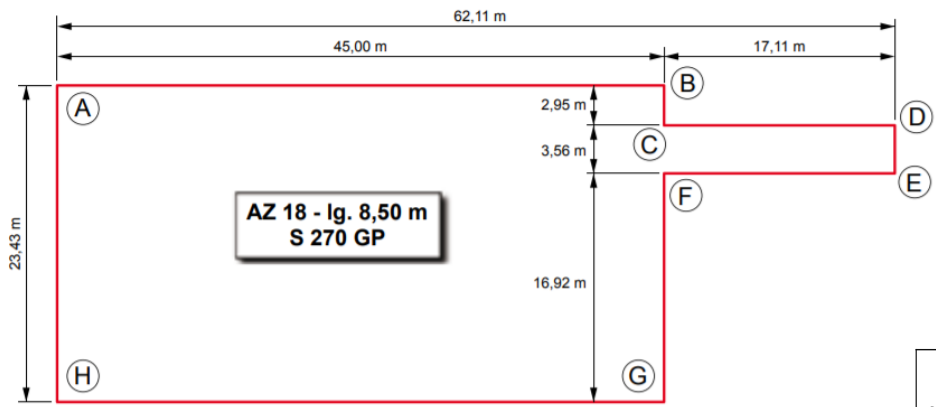
- 3.3.1 CFD model for predictive simulation of pressure peaking phenomenon for hydrogen jet fire in confined space
- 3.3.2 CFD model of hydrogen non-premixed turbulent combustion in scaled underground parking with mechanical ventilation
- 3.3.3 Coupled CFD/FEM modelling of the structures reaction to fire
- 3.3.4 CFD model on influence of hydrogen releases to fire spread scenarios in underground transportation systems

Subtask 3.3.2 (University of Ulster)

Example:

CFD model of hydrogen non-premixed turbulent combustion in scaled underground parking with mechanical ventilation

Real underground car park in St. Martnes Latem (Gent, Belgium)



Parameter	Value
Width, m	23.5
Length, m	45
Height, m	3

Result for case study A:

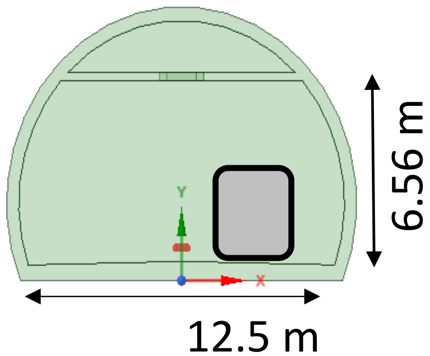
23x45x3 m park (one extraction vent)

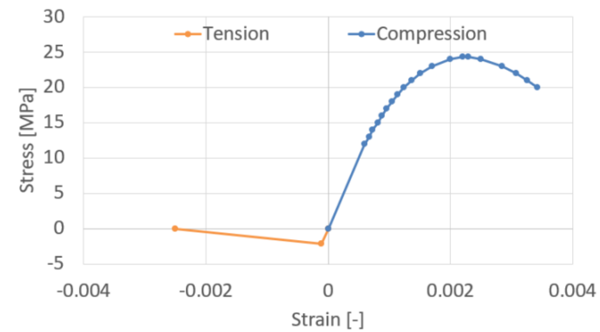
TPRD diameter, mm	Storage pressure, bar	Temperature level at the entrance of the extraction duct, °C			
		15 ACH	10 ACH	5 ACH	2 ACH
0.5	700	65.4	90.3	163.3	368
1	700	210.6	302	554.5	1156.2
2	700	706.4	977.3	1597.3	2594.2
5	700	Not acceptable			
5	700	Not acceptable			

Subtask 3.3.3 (Denmark's Technical University)

Example:

Tunnel design - modelling of the structures reaction to fire





- Interior bottom slab width 13.2m
- Height to ceiling 6.56 m
- Thickness of the ceiling: 30 cm
- Concrete fck=35 Mpa
- Circular cross-section
- Inner radius equal to 7.1m
- Wall thickness 0.5m.
- Exterior bottom slab width 13.2m

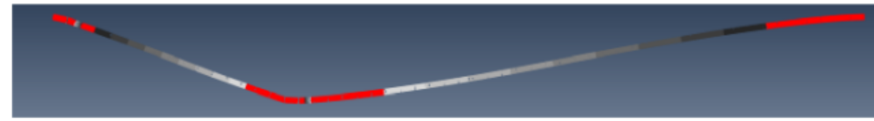
- MATERIAL
  - Concrete C30/35
  - Model: Reinforcement modelling excluded
- LOAD
  - External hydrostatic pressure
  - Internal pressure history field
  - Temperature history field

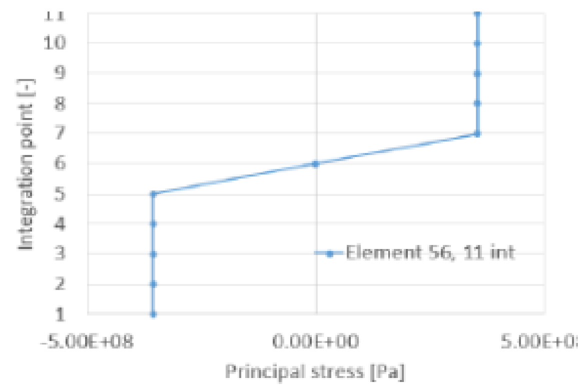
Subtask 3.3.3 (cont.)

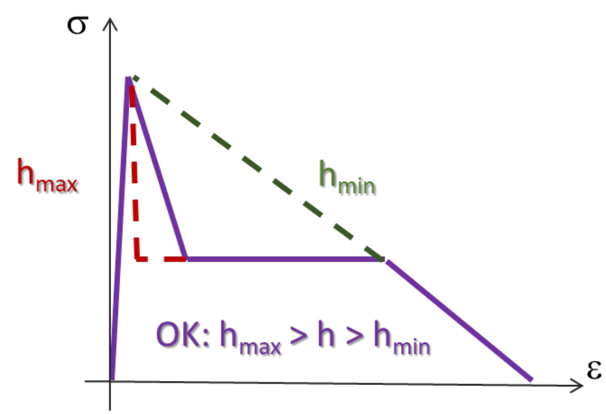
Example:

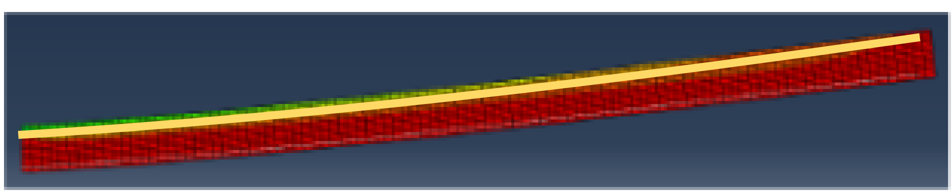
FEM of Concrete Tunnel Mesh calibration

- **Plastic hinge length**
  - Sufficient horizontal discretization to catch plastic redistribution along the element length
- **Plastic moment**
  - Sufficient vertical discretization to catch plastic redistribution along the element section
- **Ultimate strain dependency on element length**
  - Limits on element size to avoid numerical problems → ***varies with temperature!***
- **Geometry**
  - Sufficient discretization of the rebar cover to catch cracking *(no reinforcement included yet)*









Subtask 3.3.4 (Denmark’s Technical University)

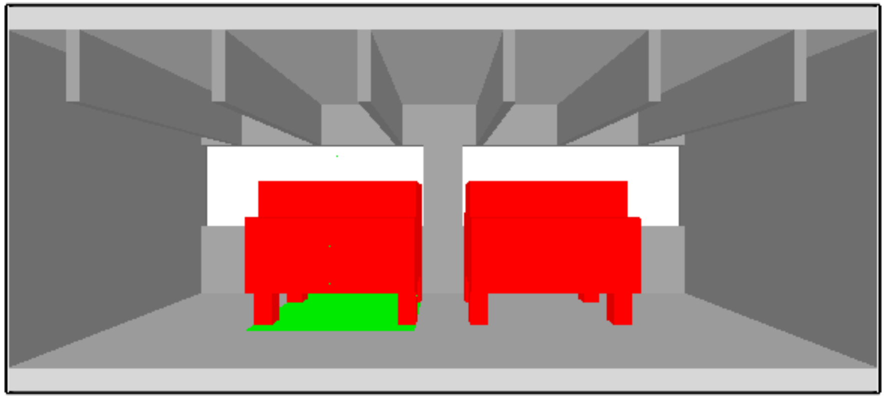
Example:

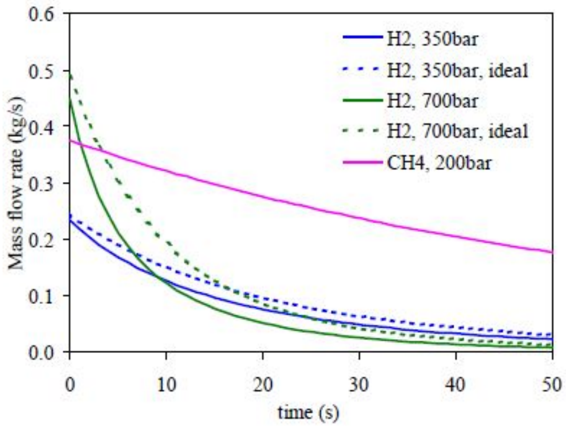
CFD model on influence of hydrogen releases to fire spread scenarios in underground transportation systems

Investigation of firespread from HVF to normal car using FDS.

Development of more detailed car model. Calculation of various scenarios in car parks and tunnels

Hydrogen release is modelled as a burner underneath the car assigned a mass flow rate curve and activated when the TPRD is 110°C





WP 3 - Task list

3.4 Experiments

- 3.4.1 Pressure peaking phenomenon for hydrogen jet fires in confined spaces (University of South East Norway)
- 3.4.2 Thermal effects of hydrogen non-premixed turbulent combustion on a vehicle fire behaviour, structure and evacuation conditions in underground parking (University of South East Norway)
- 3.4.3 Effect of hydrogen jet fire on structure integrity and concrete spalling (Denmark's Technical University)
- 3.4.4 Effect of hydrogen jet fires on the erosion of tunnel road materials and lining materials (Health and Safety Executive, United Kingdom)
- 3.4.5 Effect of hydrogen combustion from TPRD on vehicle fire dynamics in tunnel (CEA, France)
- 3.4.6 Effect of water sprays on mitigation of hydrogen jet fires (KIT, Germany)

Experiments and their status will be presented by TL 3.4 CEA in presentation 6

WP 3 -Thermal and pressure effects of hydrogen jet fires and structure integrity

More details on the research and present results

<u>Presentations in the following:</u>

1. Fire resistance rating of composite tank in a fire *(S, Kashkarov, UU)*
2. Pressure peaking phenomenon: Unignited and ignited releases *(V. Shentsov, UU)*
3. Effect on hydrogen jet fire on mechanical ventilation system in underground parking *(D. Cirrone, UU)*
4. CFD modelling of a hydrogen jet fire in a tunnel *(D Cirrone, UU)*
5. CFD model for Pressure Peaking Phenomenon for ignited hydrogen releases *(D. Cirrone, UU)*
6. Jet fires effects: experimental studies *(D. Bouix, CEA)*

WP 3 research

Summary

The WP 3 tasks support the decision process and supports PNR to facilitate hydrogen applications for tunnel and underground car park scenarious

- Improved validated engineering models
- Improved CFD models for various phenomena: PPP, hydrogen jets in car parks, flame spread, extinguishing
- Experiments (labscale to real scale) will provide a sound background and provide reference data for decision support

tunnel HP

Acknowledgements

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking (JU) under grant agreement No 826193. The JU receives support from the European Union's Horizon 2020 research and innovation programme and United Kingdom, Germany, Greece, Denmark, Spain, Italy, Netherlands, Belgium, France, Norway, Switzerland.

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USN Universitetet i Sørøst-Norge
HSE Health & Safety Executive
DTU Technical University of Denmark
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ifa International Fire Academy
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