Onboard Compressed Hydrogen Storage: fast filling

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Storage Technology

Theoretical cylindrical tanks (increasing pressure)

Steel tank

Type IV tank

Target

Liquid H2

Volumetric Density [kg_Hydrogen/m^3 system]

Gravimetric density [%] [100*kg_Hydrogen/kg_system]

commercial tanks
The RCS Status

Requirements to qualify hydrogen storage systems for on-road passenger vehicles

- International standards

- Regulations
  - Commission Regulation (EU) No 406/2010
  - JARI is updating the Japanese regulation

- International effort for regulations (UN-ECE)
  - Global Technical Regulation for Hydrogen Fuelled Vehicles (GTR HFV) 2012 – under approval

- It considers different types of refuelling stations:
  - Type “A”- Station has -40° C pre-cooling
  - Type “B”- Station has -20° C pre-cooling
  - Type “C”- Station has 0° C pre-cooling
  - Type “D”- Station has no pre-cooling

- ...and 2 different type of re-fuelling protocols:
  - Non-communication between the vehicle and the re-fuelling station (only pressure and ambient/external T)
  - Communication e.g. including also T inside the tank
The refuelling of a hydrogen car/bus with compressed hydrogen tank has to take place in approximately 3 minutes to 5 to 20 g/s!

This industrial requirement has been defined by comparison with fillings times for other fuels. *(In other words, on assumption on the average patience of a driver at a filling station).*

From material and safety considerations point of view however, the maximal temperature in the tank cannot exceed 85°C, so that pre-cooling of hydrogen is required in many cases.
Fast Filling

Refuelling: technological – fundamental questions to improve process

How to measure the mass flow rate with the required accuracy in the re-fuelling station? (metering issue: the bill for consumers!)

The requirement to pre-cool hydrogen is lowering process efficiency and it increases system costs: are there alternatives?

The criterion of < 85°C: is it valid for local, short time events? How is the degradation of the properties material under these conditions? How conservative is the criterion?
Pneumatic test

Pressure

$P_{\text{max}}$
Typically nominal pressure

$P_{\text{min}}$
Typically 20 bars

Holding time
typically 0 - 30 min

Fuelling time
max 3 or 5 minutes

Defuelling time
typically 0.5 – 1 hr

Gap between cycles

Time
Experiments Full cycle

- Pressure
- Internal T5
- T Boss
- T Bottom

Bar

Time (min)

0 10 20 30 40 50 60

0 10 20 30 40 50 60 70 80

0 10 20 30 40 50 60 70 80
Experiments

The filling phase with and without pre-cooling (Hydrogen)

[Graph showing the pressure and temperature changes over time with and without pre-cooling.]
Experiment:

1.2-722 bar

filling time 245s and 330 s

\( T_{gas}=T_{amb}=294K \) (21°C)
CFD Validation

Comparison between simulation and experiment

Temperature Distribution - top

Temperature Distribution - bottom
CFD Validation

Results: Maximum temperatures at the end of the filling procedure

Test H2 25022010

Test H2 10122010

Joint Research Centre
Simulations

Mass flow rate effect

Inlet Pressure Profiles

H2 Temperature inside the tank

Calculation with pre-cooling
Some Fast Filling Gaps

CFD validation with broader range of conditions e.g. initial conditions, pre-cooling, different tank size and geometry.

Development and validation of accurate engineering correlations that can be applied in re-fuelling stations.

Accurate measurement of mass flow rate.

Filling strategy that can work without pre-cooling or with minimum use of pre-cooling.

Are 85°C too conservative?
References


