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WP5 - Characterization of service life

HyCOMP dissemination workshop

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WP objectives

The objective of this work package is to determine the gas pressure related loads and temperature conditions for which the cylinder needs to be designed. The second goal is then to identify and define the most relevant parameters characterizing service life and the extreme values of these parameters.

Field incidents

- Main causes for incidents (bursts) in composite cylinders in service have been identified to be:
  - Isolation or bad functioning Pressure Relief Devices in fire conditions
  - Degradation of load carrying materials, such as:
    - Acid exposure on glas fibres
    - Stress rupture in glas fibre,
    - Corrosion of metallic liners

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Composite cylinder safety - field experience with 20-25MPa CF cylinders

- **Under vehicle installation**

Curb hit

visible damage to dome
cylinder still met burst requirements

Tank dropped

from, dragged and overrun by heavy duty vehicle tank still met burst requirements

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Composite cylinder safety - field experience with 20-25MPa CF cylinders

Bridge Impact

- bus speed approx. 70 km/h
- Cylinders mounted transversal on roof
- interference with bridge was 150 mm
- front tank was most severely damaged - no rupture and no gas leak
- tank was burst tested after incident
- regulatory requirement is min. burst of 559 bar
- burst pressure after accident still was **597 bar**

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Summary – Field experiences

- Study carried out by Powertech Labs in Canada in 2008 identified the same main causes for the incidents as HyComp
- Both investigations support the view that RCS for Composite Cylinders made of Carbon Fibres have produced safe cylinders and might call for controlled reduction of safety factors (SF), in particular for transportable cylinder under controlled operating conditions
- Hydrogen cylinders, 35MPa and above produce thicker composite structures which
  - Create a more robust cylinder with respect to external impacts/loads.
  - Create more margin on internal gas pressure measured in absolute values
    - SF 2,25 over 20MPa represents 25 MPa higher pressure than nominal working pressure
    - SF 2,25 over 70MPa represents 87.5 MPa higher pressure than Nominal working pressure

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Transportable cylinders – smaller single portable cylinders

- Can be carried by a human beings or be exposed uncontrollable handling.
- Fill time can be as for passenger car cylinders or quicker.
- Moderate depressurization rate (hours) , unless dumping hydrogen to a larger low pressure onsite tank. In such cases the depressurization rate can be as quick or even quicker as the fill rate of the cylinders
- Temperature during and just after fill must be expected to be higher than the ambient conditions unless the fill gas is preconditioned to a lower temperature.

Transportable – Larger cylinders/bundles permanently mounted in frames

- Moderate fill time (hours) limited by the operational performance of the production/delivery system.
- If the gas is dumped of to a larger low pressure onsite tank or pipeline, the depressurization rate can be as quick or even quicker as the fill rate of the cylinders.
- One fill equals one pressure cycle (one fill per day over 20 years equals 7.300 cycles). For short transport distances 2-4 deliveries might happen representing up to 30.000 pressure cycles over 20 year.

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Transportable – Larger cylinders/bundles permanently mounted in frames

- Pressure is expected to be at higher than 100% service pressure (gradually reduced to settled service pressure) during the transport for ½ of the rated service life and at low pressure during the return to the production site or waiting for next fill.

- Temperature during and just after fill must be expected to be higher than the ambient conditions, while under return after the delivery of the hydrogen, the temperature can be expected to be lower than the ambient, but convert to ambient temperature conditions in particular for a long transport distances.

Stationary (hydrogen refueling stations)

- Pressure range determined by station size/capacity for back-to-back refuelling of vehicles (buses or passenger cars)
  - Back-to-back fill performance and fill rate will determine the pressure amplitude the cylinders will be exposed to
  - Maximum cycle rate will be driven by customer satisfaction in the form of the maximum acceptable refuel time. As number of vehicles grows the storage capacity or compressor capacity at the refuelling station will have to be increased to maintain acceptable fill times (customer satisfaction).
  - Pressure cycles will increase based on number of vehicles, and the high end of the pressure amplitude must be maintained to be able to fill within 3 minutes.

Stationary (hydrogen refueling stations)

- Moderate fill (determined by on site compressor and storage capacity)
- Quick depressurization within the pressure amplitude range the cylinders are designed to operate within.
- Each vehicle to be filled represents one pressure cycle
  - 20 refuelling per day over 20 years equal 146.000 cycles – (low estimate for the future)
  - 100 vehicles every day over 30 years equals about 1.000.000 cycles.
- Cylinders in the a hydrogen refuelling station will stay most of the lifetime at high pressure level (average pressure just below the service pressure).

Automotive applications

- Quick fill (pressure increase) from 3% to a maximum of 125% of service pressure.

- Fill gas temperature can be expected to be as low as -40°C at the start of fill, with end of fill temperature to exceed 85°C if the gas from the hydrogen refuelling station is not preconditioned or fill rate is restricted.
- Desired fill time from start of fill to 125% of service pressure should be as short as 3 minutes.
- Hydrogen consumption (depressurization), at all environmental temperature conditions, will start as soon as the on board FC start to produce electricity,
  - In average the cylinder pressure will be slightly above ½ the service pressure of the cylinder during its service life
  - Depressurization time can be as short as 1 hour under extreme driving conditions.

Automotive applications

- one fill per day over 20 years equals 7.300 cycles
- A FC passenger car with 4-5kg hydrogen storage capacity, will drive about 3 mill km over 20 years based on full utilization of the on board storage capacity (lifetime), which is an extreme range even for a conventional passenger car, and an unrealistic range (or operation hours) for a FC both today and in the future.
- If the car is in a local fleet-service operation 24h a day, we can assume that the vehicle will be filled once in each shift (3 times a day), which will equal to 21.900 partial fills (pressure amplitudes in the upper part of the pressure range of the composite cylinder). This will bring the average cylinder pressure over time to a higher level, while the pressure cycle amplitudes will be reduced.

Automotive applications

- Cylinders can also be expected to be exposed for long periods at the maximum developed pressure, if the passenger car is filled a cold night, and just thereafter go to a hot garage or hot/sunny outdoor location without any further use of the vehicle over a longer period.
- The cylinder should be robust enough to take some pressure cycles higher than rated maximum developed pressure at end of life, simply due to a refuelling stations/dispensers that is not working as intended.
- The probability for all worst cases to happen at same time is low. This can only be figured out by using a probabilistic qualification methodology and by determining an acceptable risk.

Automotive applications

- A dedicated specification/requirement, for one specific type of vehicle, with a specific performance requirement, controlled by a qualified on board data accusation system, might qualify for lower safety margin. Also relevant for permanently mounted transportable cylinders.

- This will in case require a weighting of the different loads the composite cylinder can be exposed for in service, and there must be a qualified algorithm that calculate the remaining lifetime of cylinders.

- Will require substantial baseline testing on the specific cylinder with a high number of combined loads, but might become beneficiary when a specific platform of FC vehicle (and thereby the number of composite cylinders) is going to be produce in a higher quantities (more than 100k).

Thanks for your attention