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Numerical Study on Evaporation Characteristics of LH_2 Tank During Transportation under Typical Driving Conditions

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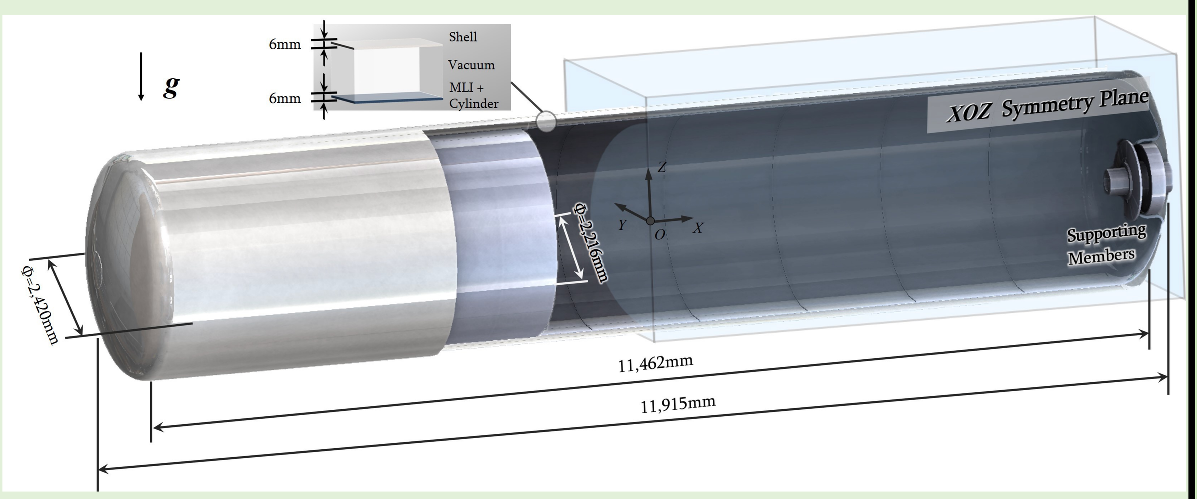
Abstract

This work employed a validated computational fluid dynamics model to investigate the dynamic response and evaporation of LH2 in a 40-foot ISO tank.

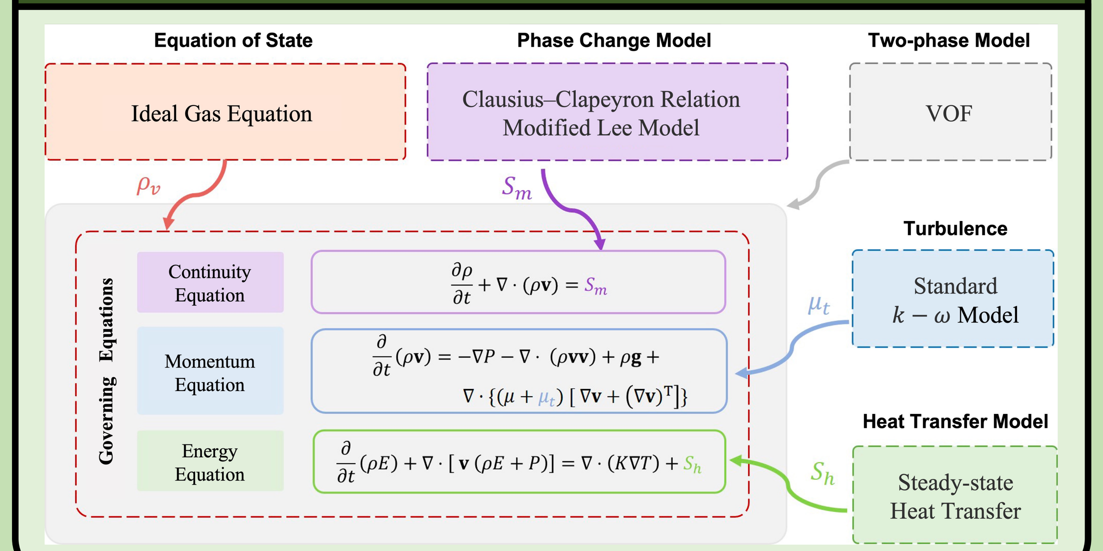
The research revealed the impact of varying speeds on ullage pressure during two transport scenarios, considering different fill levels and heat ingress.

Key findings include insights into the temperature and pressure variations in periodical cycles, an energy flow chain analysis.

Tank Model



Phase Change Model

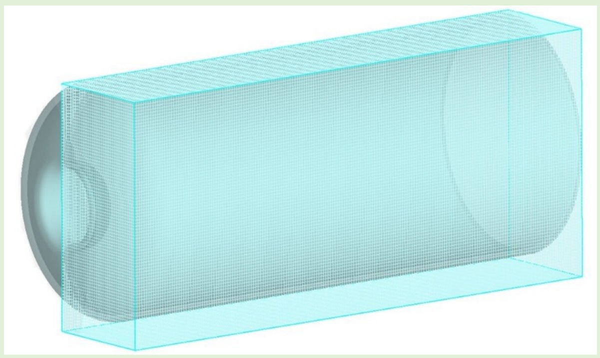


Boundary and Mesh

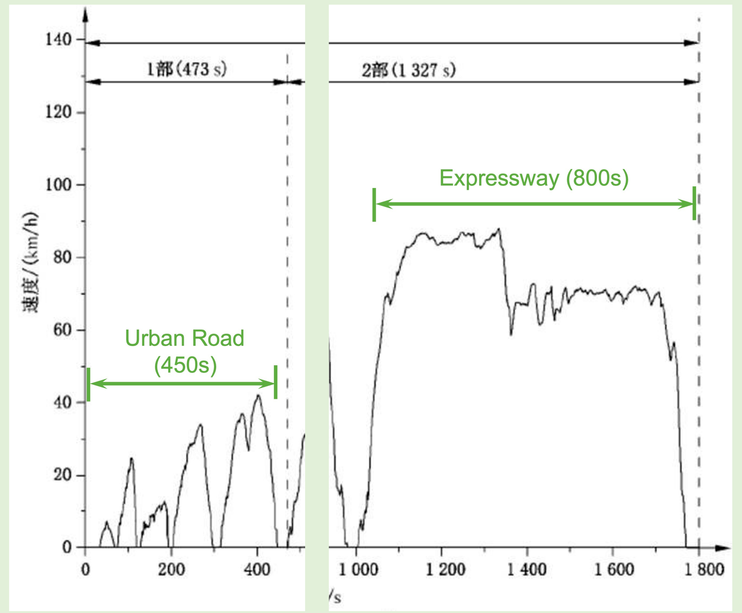
- Heat flux induced by supporting members, pipes and valves were determined by steady heat transfer calculations.

Boundary Conditions			
T_{LH_2}	20.36 K	P_{ullage}	1 atm
T_{GH_2}	20.369 K	Q_{total}	42.551 W

- A quarter of the inner tank was chosen as the CFD calculation domain due to its symmetry.



Driving Conditions

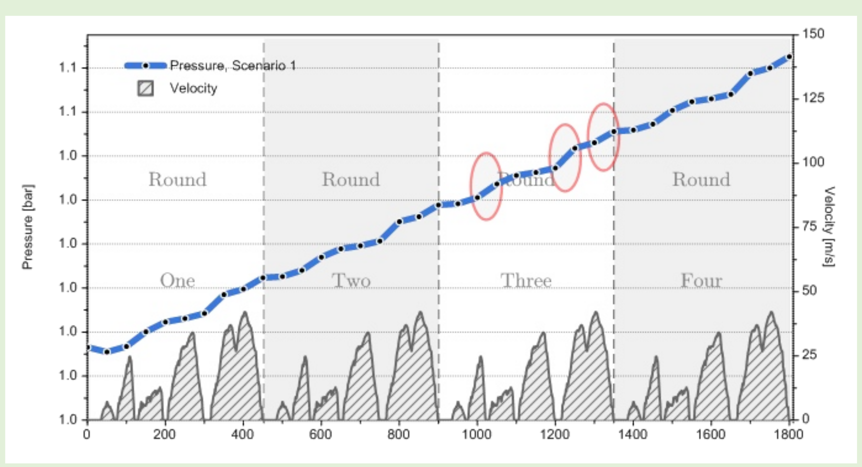


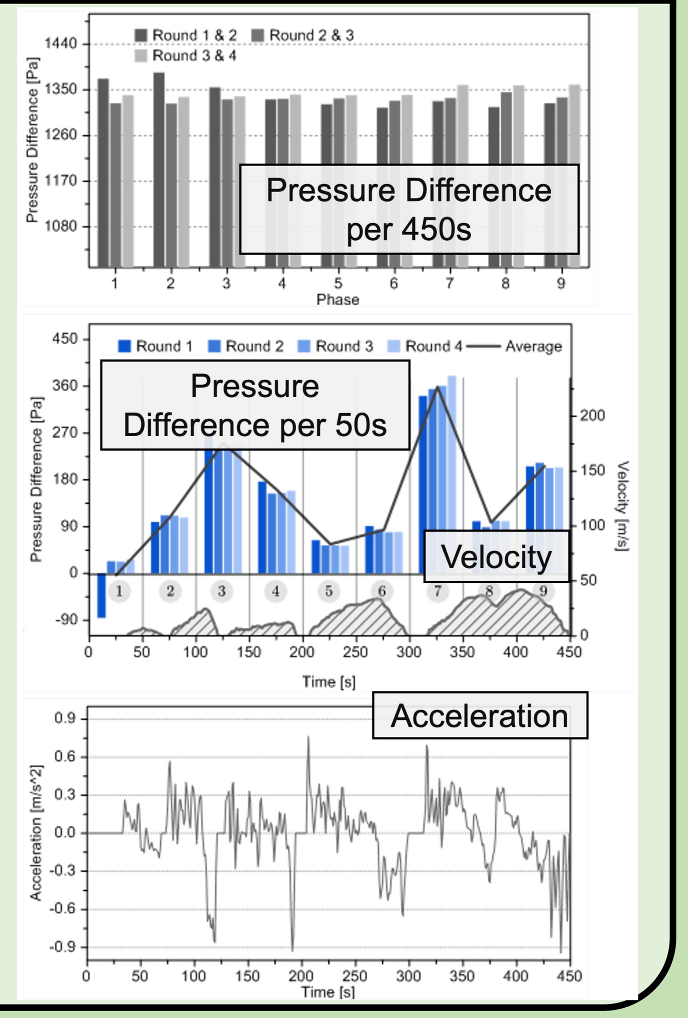
- Two driving cycles, ***urban*** & ***expressway*** cycle, were extracted from GB/T 38146.2.

Scenario	Filling Rate	Transient Cycle	Normal Leakage	Duration [s]
1	0.5	Urban Cycle × 4	1×	$4 \times T_u = 1800$
2	0.5	Expressway Cycle × 2	1×	$2 \times T_e = 1600$
3	0.9	Urban Cycle × 4	1000×	$4 \times T_u = 1800$
4	0.9	Expressway Cycle × 2	1000×	$2 \times T_e = 1600$

- Based on those cycles, scenarios were designed with two series of ***half-full + normal heat leakage***, and ***full + massive heat leakage***.

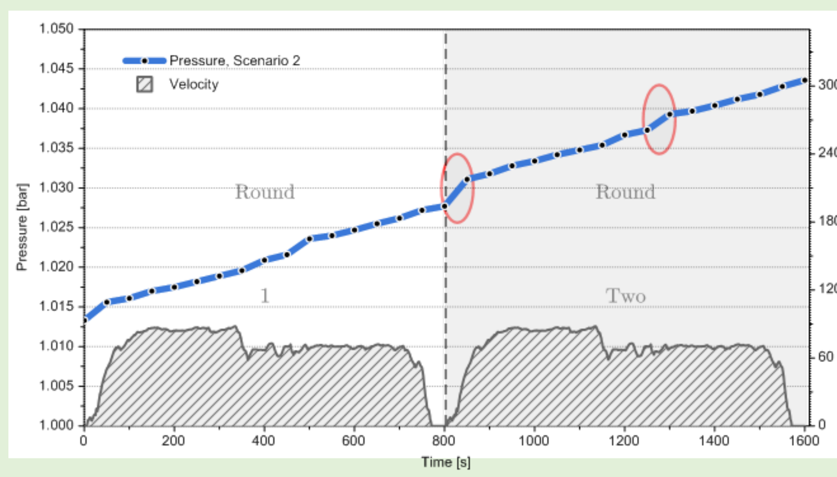
Scenario 1: Normal Heat Leakage, Urban

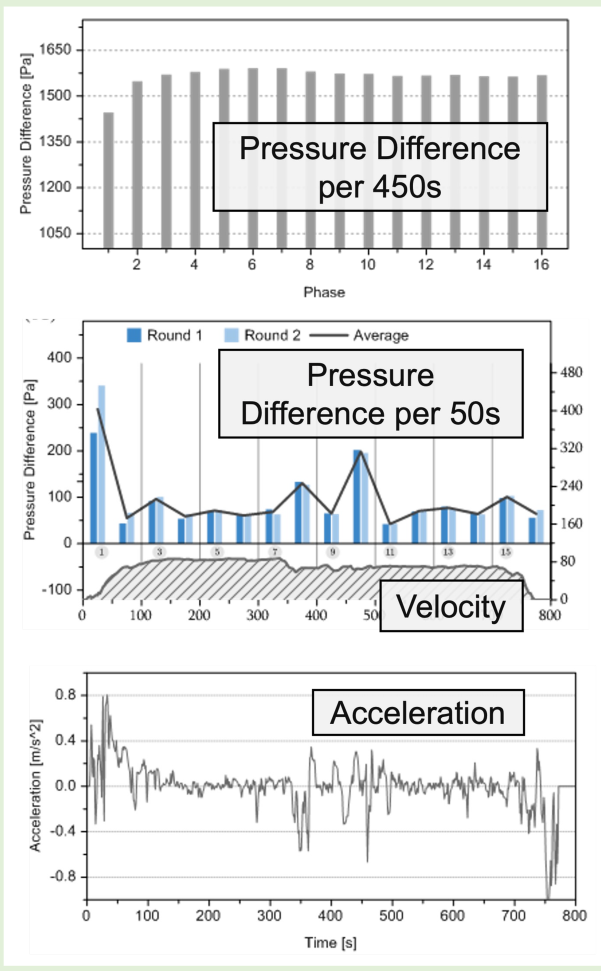




- For normal heat leakage scenarios, the tank pressure rised ***linearly*** with time.
- In cases where both velocity and acceleration were high, ***a sudden pressue increase*** occurred periodically.

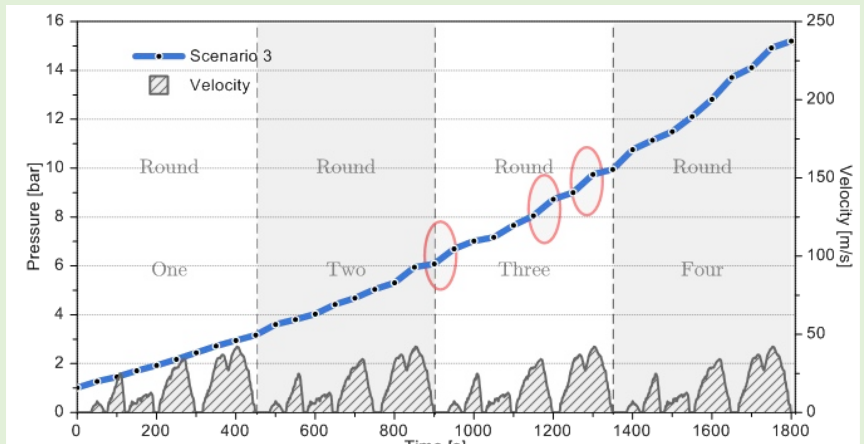
Scenario 2: Normal Heat Leakage, Expressway

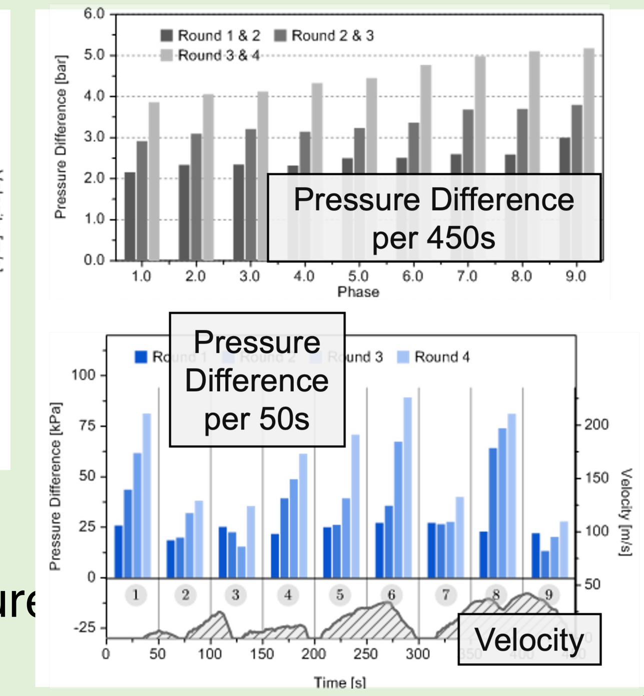




- The situation was the same for the expressway scenario.
- The sudden pressure increment was manifested by a amount of ***mechanical energy converted into internal one*** due to the velocity difference between fluids.

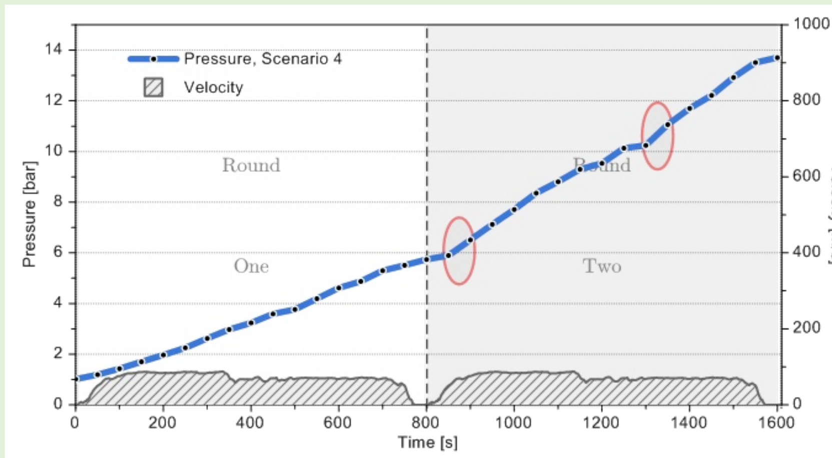
Scenario 3: Massive Heat Leakage, Urban

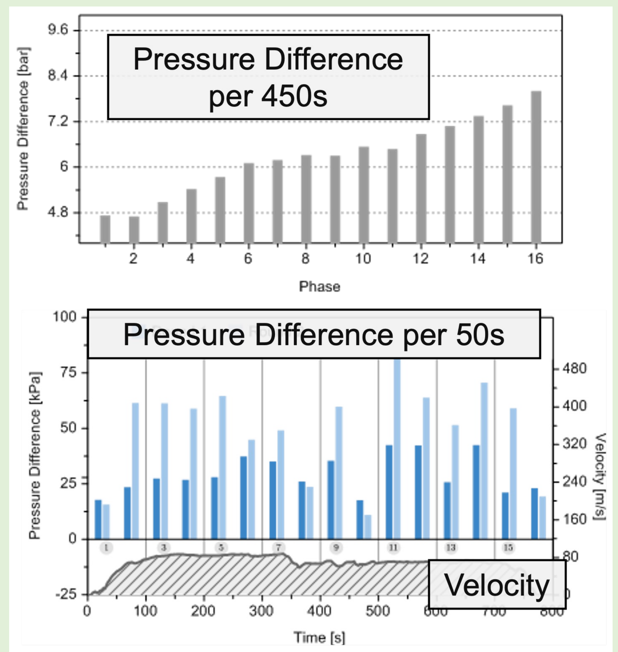




- Tank pressure rised ***non-linearly***.
- The numerical magnitude of pressure sudden changes increases linearly.

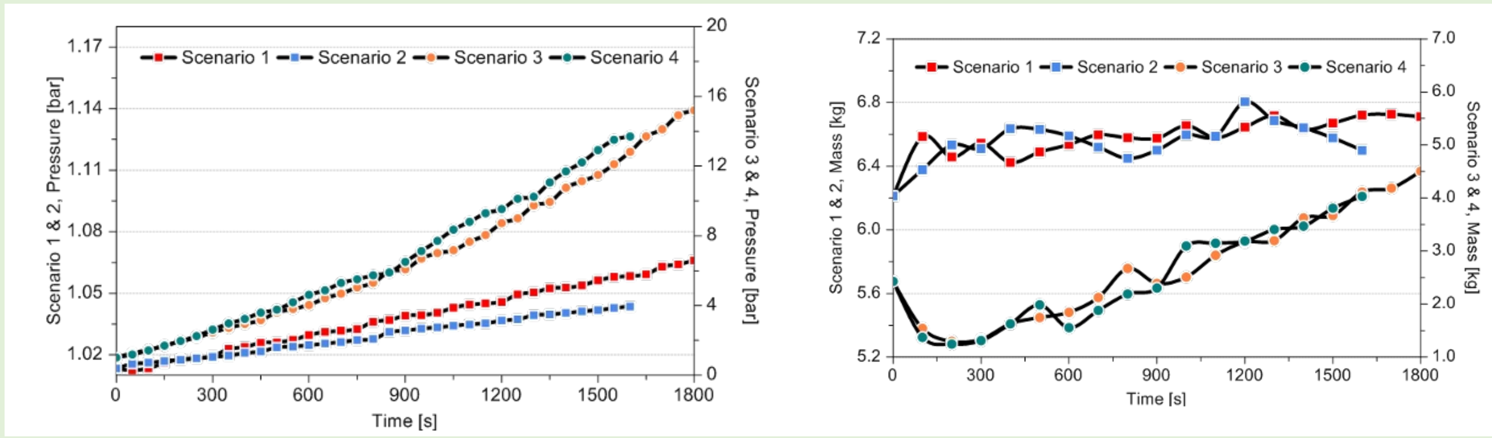
Scenario 4: Massive Heat Leakage, Expressway





- The situation was the same for the expressway scenario.

Pressure and Mass Comparison



According to the ideal gas theory, as the temperature and mass of GH2 increase approximately linearly, ***the pressure subsequently increases non-linearly***.

Further Considerations

- **Theoretical Explaination**: An elaborate theoretical explaination for sudden pressure inceases is our ongoing persuit.
- **Active Release Strategies**: We are designing an active release control for boiled-off GH2 to chose safe and economic transport and release strategy.