Development of new containment systems for alternative fuels in marine applications

Università di Pisa
Department of Energy, Systems, Territoy and Construction Engineering (DESTEC)

GAS and HEAT

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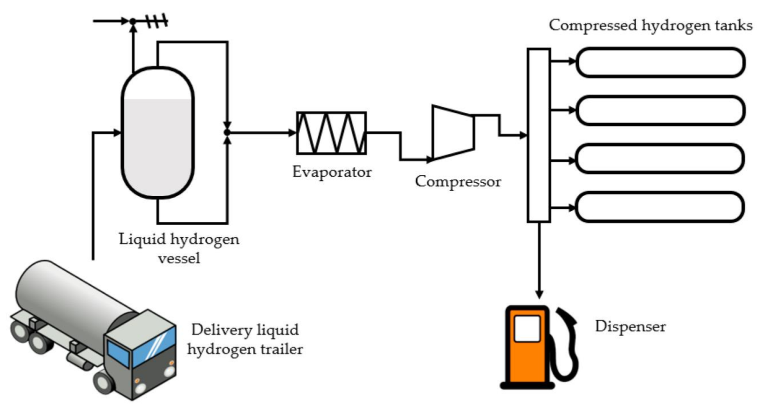
1) Abstract

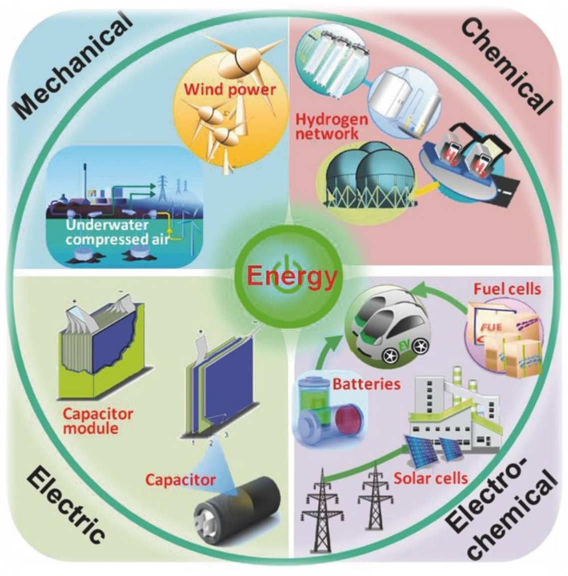
Main Issue

- The significant **low efficiencies** of the current techniques of **energy storage systems** specially the intensive energies.
- The challenge to store hydrogen in its liquid phase as an intensive and effective energy.
- The shortage of the current studies on liquid hydrogen storage and transportation.

Main Target

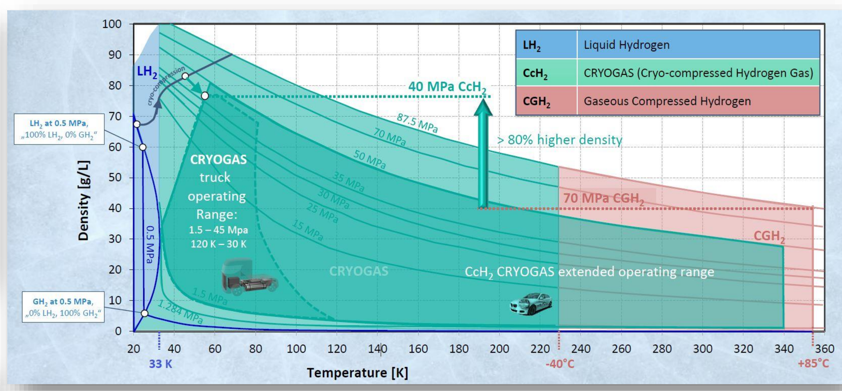
- Analysis of the **filling process** of liquid hydrogen into a cryogenic tank.
- Effective storage and transportation of **liquid hydrogen.**



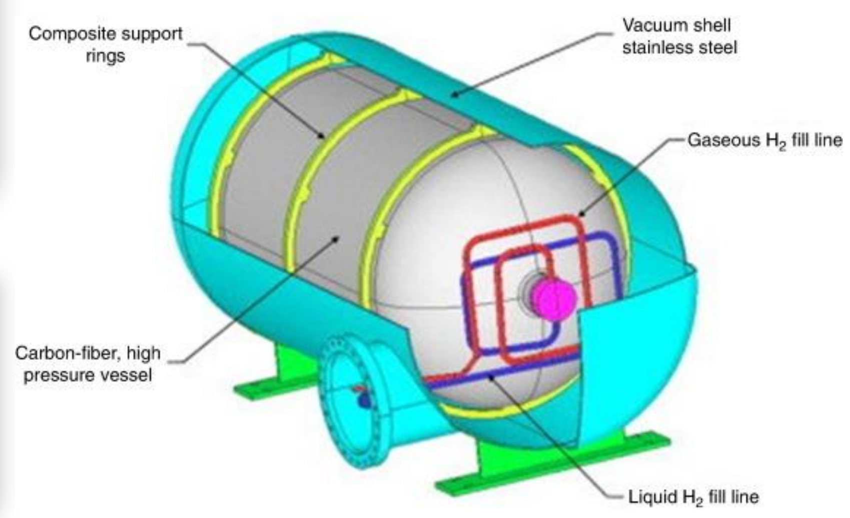


2) Introduction

- Great challenge to store **liquid hydrogen** at extremely low temperature at **20 K** and **4 bars**.



- Liquid hydrogen tank material should resist **embrittlement** and the structural **stresses** at cryogenic temperatures.
- Such tanks should be **double-walled** with a **vacuum** between the walls to minimize heat transfer.

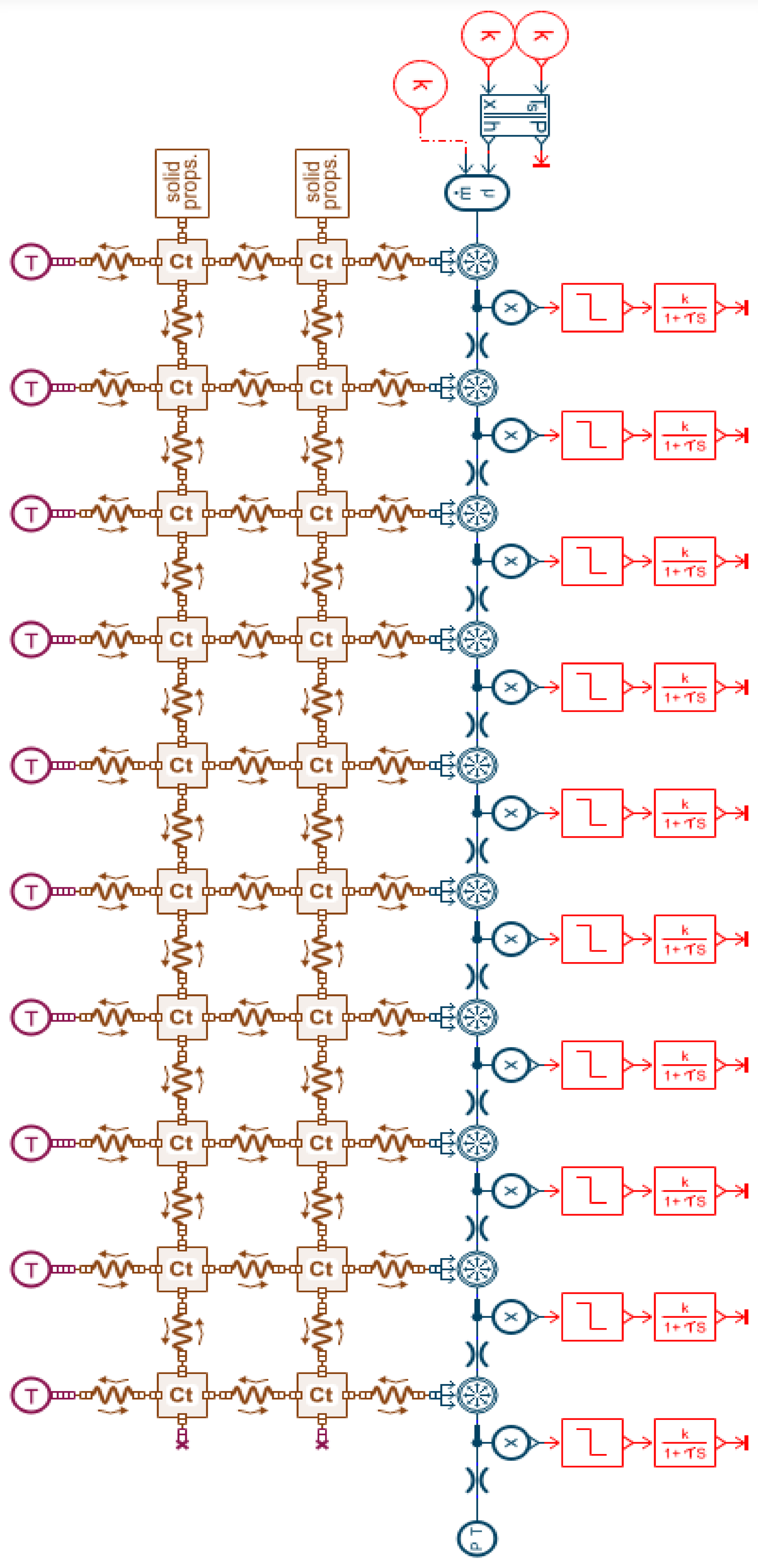


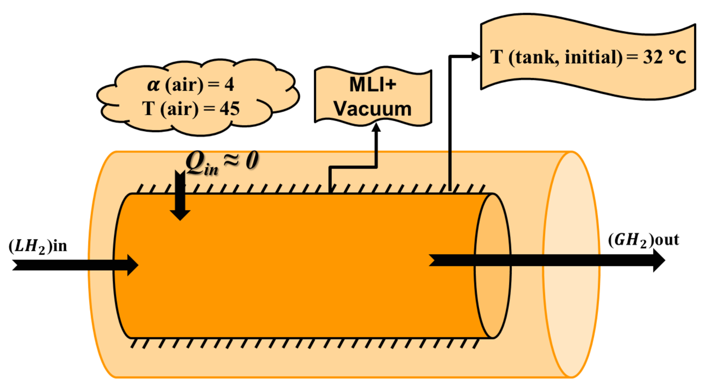
3) Methodology

- Particular double-walled will be used as a case study.
- Tank design takes the considerations recommended in the standard codes of **ISO 13985** and **ISO 21029-1**.
- Tank material is chosen to be **316L stainless-steel**.
- Both of multi-layer insulation **(MLI)** and **high degree of vacuum** are used between the two walls.
- Safety of the design will follow the instructions mentioned in **NFPA 55, EIGA-DOC 6/19**.

- Lumped system analysis and its assumptions is applied on the tank case study.
- Time estimation of the tank cooling down and the filling process of LH2 inside the tank is analyzed.
- Energy balance:

$$\textit{the heat lost by the tank material} = \textit{the heat gained by liquid hydrogen by convection} = \textit{the change in liquid hydrogen enthalpy}$$





Tank Specifications

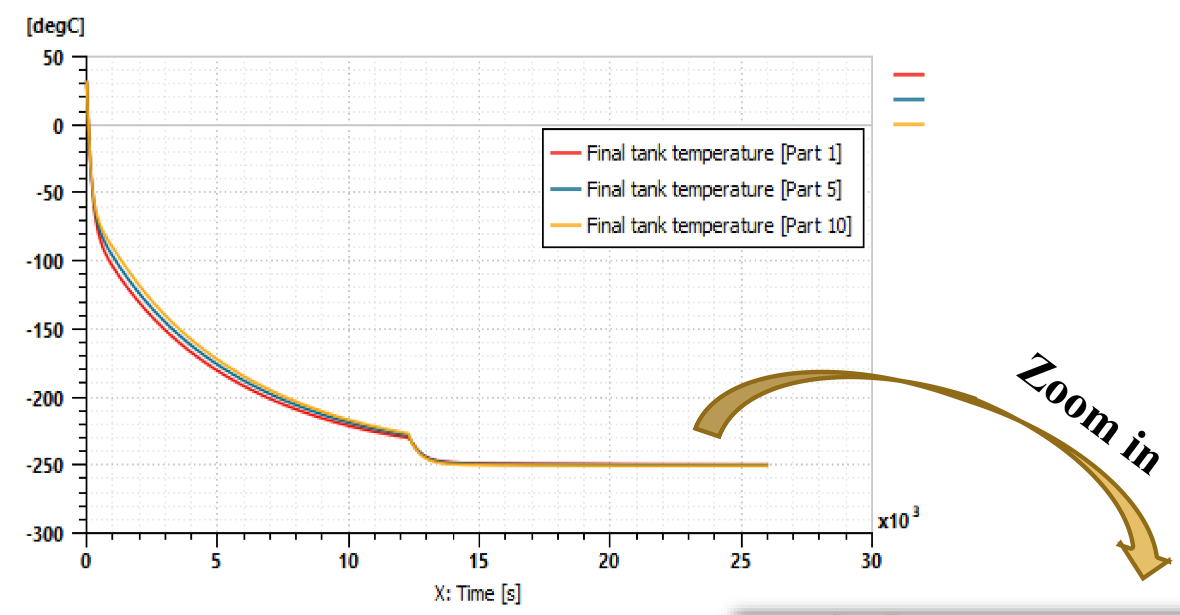
- ρ (tank) = 8030 (kg/m^3)
- C = 530 (J/ kg.K)
- A (out) = 1320 (m^2)
- A (in) = 1215 (m^2)
- V (out) = 3500 (m^3)
- V (in) = 3000 (m^3)
- V (diff.) = 500 (m^3)
- D (in) = 11.5 (m)
- Thickness (in) = 0.02 (m)
- Height (in) [H in] = 31 (m)
- D (out) = 12.76 (m)
- Thickness (out) = 0.015 (m)
- Height (out) [H out] = 33.505 (m)

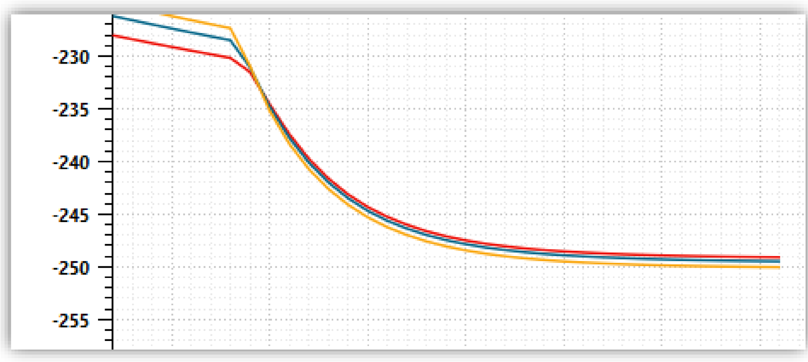
- The cooling and filling process are simulated on **Amesim** software.
- The tank is divided into **10 parts** to take into account the **two phase change** and the **temperature variation** of liquid hydrogen and the tank during the cooling and filling process.

- All the **thermal resistances** that exist in the direction of heat transfer are simulated.
- All values inserted in the model are related to the applied **material types** and the **tank specifications**.

4) Preliminary Results

- The results show the **estimated time of the tank cooling down** to achieve the designed temperature at -253 °C.
- Additional parameters of the liquid hydrogen and the tank are analyzed.





5) Preliminary outcomes

- **Phase change of hydrogen** has a great effect on the thermodynamic and heat transfer properties during cooling down and filling processes and in turn affect the overall filling time.
- The **conduction heat transfer** of the tank itself has a high effect on the cooling process of the tank.

6) Future Plan

- **Continuous deep study** on the filling process will be simulated in more details on Amesim.
- The change of **heat transfer coefficient** will be controlled and simulated.
- Studying the storage and transportation performance of liquid hydrogen in the cryogenic tank and will be simulated on **Ansys CFX**.

7) References

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