Hydrogen liquefaction: A fundamental approach for a clean and renewable energy carrier for various applications.

by ADARSH DAS

2nd Year, DEPARTMENT OF METALLURGY AND MATERIALS ENGINEERING

Hydrogen liquefaction

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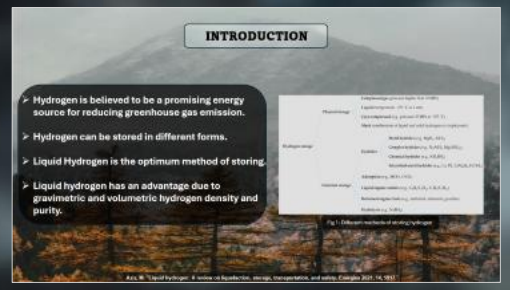

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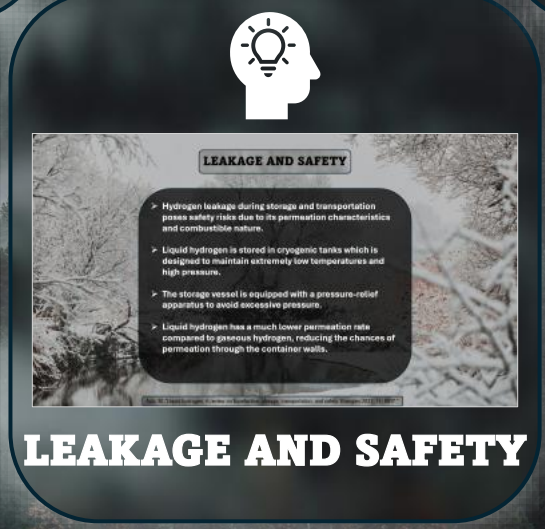

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INTRODUCTION

- Hydrogen is believed to be a promising energy source for reducing greenhouse gas emission.
- Hydrogen can be stored in different forms.
- Liquid Hydrogen is the optimum method of storing.
- Liquid hydrogen has an advantage due to gravimetric and volumetric hydrogen density and purity.

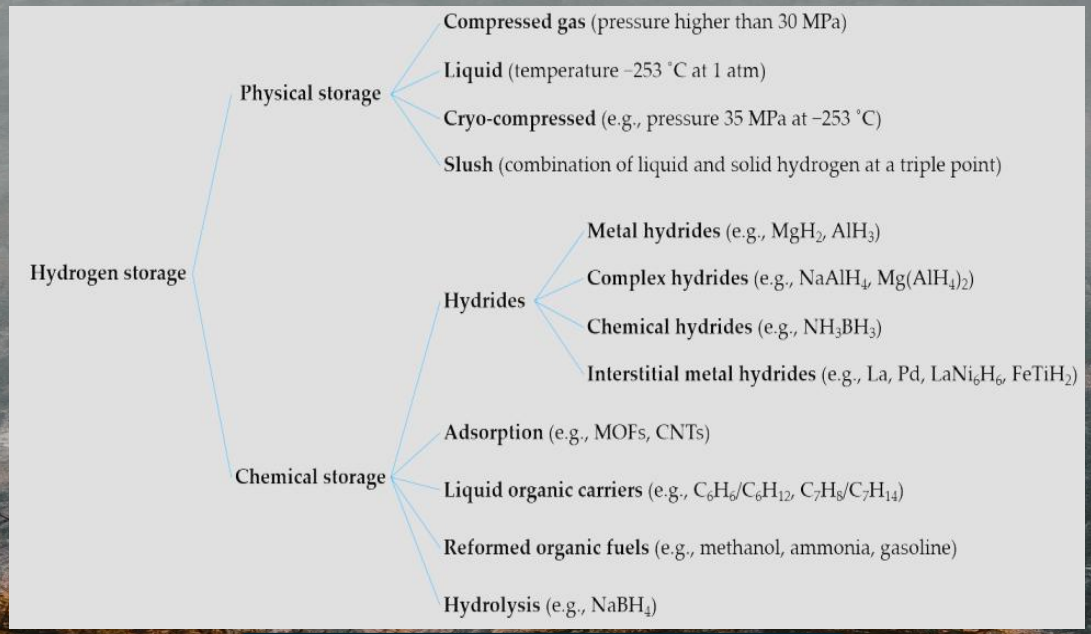

Fig 1: Different methods of storing hydrogen

Aziz, M. "Liquid hydrogen: A review on liquefaction, storage, transportation, and safety. Energies 2021, 14, 5917."

ENERGY DENSITY

- Hydorgen has a lower volumetric energy density as compared to natural gas.
- Liquid hydrogen can easily overcome it, as it provides a higher energy per unit mass as compared to gasoline.
- High energy density per mass suggests that it can store more energy in a smaller mass, so storage and transportation for the same amount of energy will be enhanced.
- High energy density extends operational durations and ranges across various applications, enhancing their practicality and reducing vehicle weight.

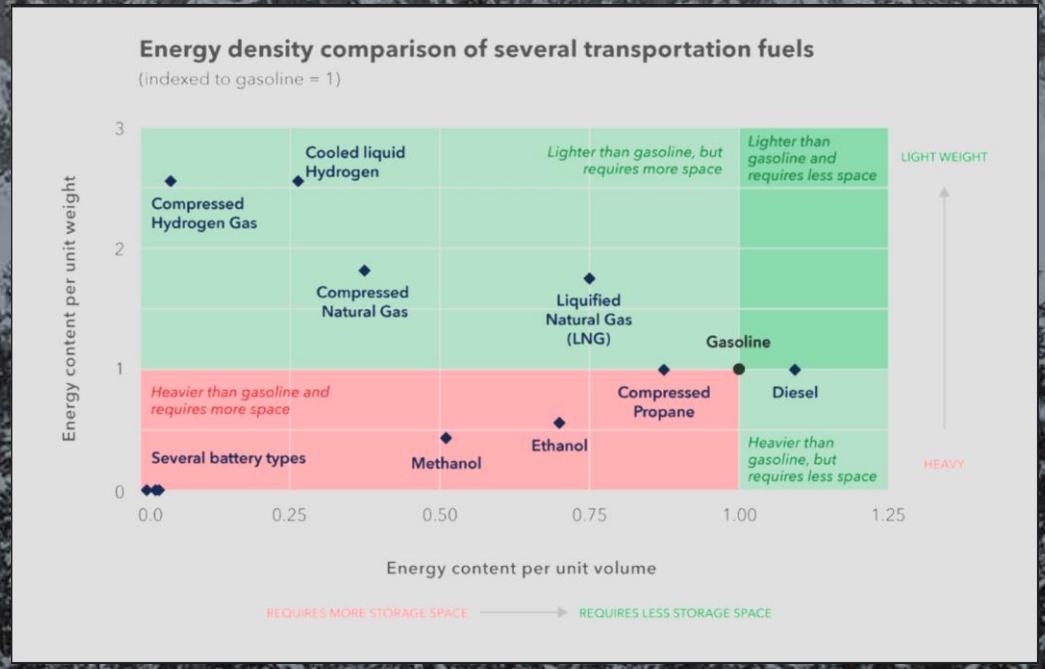

Fig 2: Energy Density Comparison

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MATERIAL COMPATIBILITY

- The storage of liquid hydrogen can be done after considering multiple factors including:
  - Hydrogen embrittlement.
  - Hydrogen permeability.
  - Capability to withstand very low temperatures.
- Cryo-compressed hydrogen method is used to store liquid hydrogen to reduce:
  - Convection heat transfer.
  - Conduction heat transfer.
  - Radiation heat transfer.
- Materials with low permeability to hydrogen is used to ensure the integrity of the storage and transportation systems.
- Liquid hydrogen storage vessels are majorly made up of Stainless steel and Aluminium.

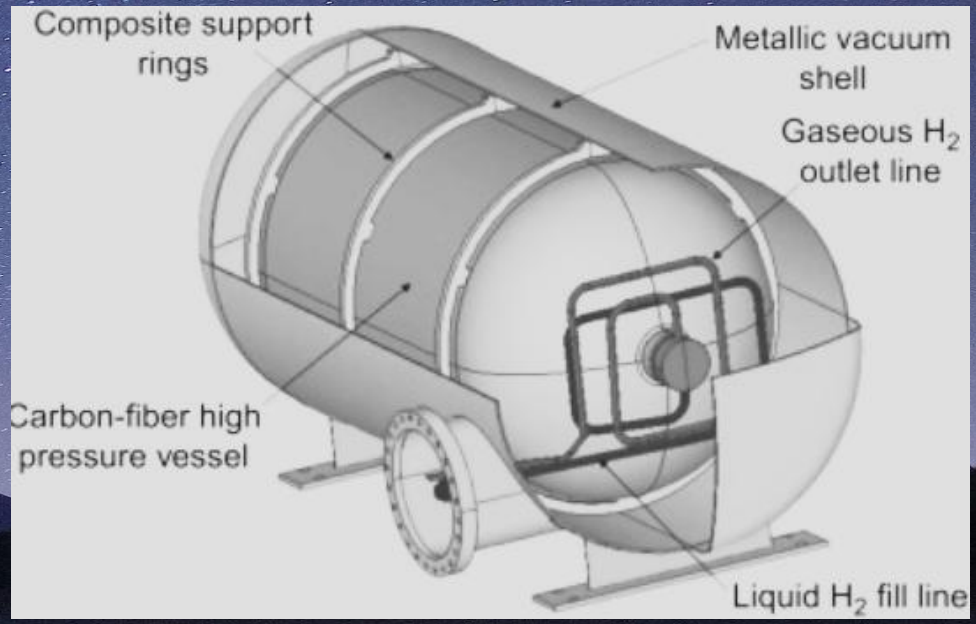

Fig 3: Cryo-compressed hydrogen

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LEAKAGE AND SAFETY

- Hydrogen leakage during storage and transportation poses safety risks due to its permeation characteristics and combustible nature.
- Liquid hydrogen is stored in cryogenic tanks which is designed to maintain extremely low temperatures and high pressure.
- The storage vessel is equipped with a pressure-relief apparatus to avoid excessive pressure.
- Liquid hydrogen has a much lower permeation rate compared to gaseous hydrogen, reducing the chances of permeation through the container walls.

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LEAKAGE AND SAFETY

- The Cryogenic vessels used for transportation are fitted with leak detection alarm, such as hydrogen sensor.
- Low temperature of liquid hydrogen reduces the rate of vaporization which hence minimizes the formation of explosive mixtures with air and reducing the chances of accidental ignition.
- Training programs should be arranged for personnel involved in handling and operating hydrogen systems, to provide knowledge and skills to react to emergencies and to avoid risks or accidents.
- The guidelines issued by The International Standardization Organisation(ISO) should be followed carefully regarding handling of hydrogen and liquid hydrogen.
- In consumer detection sites, safety in hydrogen filling stations should also be ensured by adopting hydrogen sensors.

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INFRASTRUCTURAL DEVELOPMENT & COST EFFECTIVE

- Liquid hydrogen infrastructure development can be incremental in nature, targeting the most important areas to invest at the early stages and minimize upfront investment.
- Liquid hydrogen infrastructure should collaborate with government, industry stakeholders and research institutes as:
  - It represents a frontier in technological innovations.
  - It offers significant environmental benefits over gaseous hydrogen, hence reducing carbon emissions and promoting clean energy.
- Due to the High energy density per unit mass, transportation and storage of more energy is possible for the same space, hence reducing the overall cost.

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CONCLUSION

- Hydrogen has been increasingly considered to be a clean and renewable energy carrier for several applications.
- There are several challenges researchers face for transporting and storing of hydrogen.
- A key finding for this issue is to use Liquid hydrogen, as a substituent to gaseous hydrogen.
- The following points are discussed to consider liquid hydrogen as an economically efficient method of storage and transport:
  - High Energy Density.
  - Leakage prevention and safety precautions.
  - Material Compatibility.
  - Infrastructure Development.

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Thank you!

Questions?