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# Overview: Hydrogen Storage System in Fuel Cell Vehicle

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**ABSTRACT**

This paper provides a comprehensive exploration of hydrogen storage systems within Fuel Cell Electric Vehicles (FCEVs). FCEVs utilize compressed hydrogen to generate electricity, promoting zero-emissions transportation. A critical component of these vehicles is the hydrogen storage tank, which plays a pivotal role in ensuring the safe and efficient utilization of hydrogen fuel. The literature review delves into the types of hydrogen storage systems, distinguishing between physical-based and material-based methods. While material-based systems are in early development, the focus is on compressed hydrogen storage systems (CHSS), particularly Composite Overwrapped Pressure Vessels (COPVs), which are commonly used in FCEVs. The study outlines the key features of COPVs, highlighting materials, construction, operating pressures, and spatial considerations. Additionally, it discusses less common alternatives, such as metal hydride tanks and liquid hydrogen tanks, emphasizing their operational characteristics. The paper addresses safety concerns associated with storing highly flammable hydrogen at high pressures and cryogenic conditions. It discusses challenges related to cryogenic storage, efficiency, cost-effectiveness, manufacturing complexity, and hydrogen embrittlement. Safety measures, ad- vanced materials, and manufacturing innovations are proposed to mitigate these challenges.

**Key words:** HSS, CHSS, COPV, FCEV, Hydrogen Embrit- tlement

## INTRODUCTION

Fuel cells in vehicles generate electricity generally using oxygen from the air and compressed hydrogen. Most fuel cell vehicles are classified as zero-emissions vehicles that emit only water and heat. The key component of any Fuel Cell Vehicles are the Hydrogen tanks that store compressed hydrogen. A hydrogen storage tank in the system is designed to safely store hydrogen fuel.

## LITERATURE REVIEW

### Types of Hydrogen Storage Systems and their application of use

Depending on the way in which hydrogen is stored, hy- drogen storage system can be categorized into Physical based, and material based. Physical based has three types: compressed hydrogen tanks also known as Compressed Hydrogen Storage System(CHSS), liquid nitrogen tanks, and solid-state hydrogen storage containers.

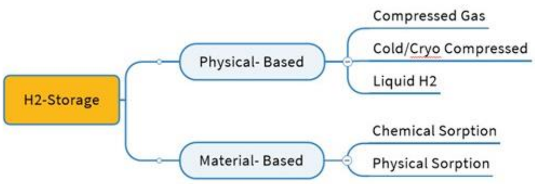


**Fig. 1** Types of Hydrogen Storage Systems

Material-based storage methods are still in their early de- velopment stage and need more time to prove themselves as viable long-term solutions. This is not the current focus of the paper.

| Category | Schematic | Material | Applications | Typical Pressure | Strength/Risk |
|---|---|---|---|---|---|
| Type I |  | **Fully metallic** (Steel/Aluminum) | Industrial | Aluminum: 175 bar<br>Steel: 200 bar | High strength, moderate risk |
| Type II |  | **Metallic Enclosure**<br>Steel pressure vessel with a glass fiber composite overwrap | Stationary: Fueling stations | Aluminum/glass: 263 bars<br>Steel/carbon or aramide 300 bars | Moderate strength, moderate risk |
| Type III | | **Metallic Liner**<br>Full composite wrap with metal liner | Mobile: Drones, FCEVs | Aluminum/glass 305 bars<br>Aluminum/aramid 438 bars<br>Aluminum/carbon 700 bars | High strength, low risk |
| Type IV |  | **Fully Composite** Composite tanks such of carbon fiber with a polymer liner (thermoplastic) | Mobile: FCEVs, aircraft | 700 bars | Highest strength, lowest risk |

**Fig. 2** Categories of Compressed Hydrogen Storage Systems

## COMMONLY USED HYDROGEN STORAGE SYSTEM IN FCEVS

Among the different types of tanks, FCEVs typically use compressed hydrogen storage systems (CHSS). Among different types that are available, Type is more common which are also knows as Composite Overwrapped Pressure Vessels (COPVs). Fuel Cell Electric Vehicles (FCEVs) commonly use high-pressure composite overwrapped pressure vessels (COPVs) as hydrogen storage tanks. These tanks are designed to store hydrogen gas at high pressures, allowing for efficient storage and delivery of hydrogen to the fuel cell stack for electricity generation. Here are some key features of the hydrogen tanks used in FCEVs:

**1) Composite Overwrapped Pressure Vessels (More Com- mon):**

Material: COPVs are typically made from lightweight materials such as carbon fiber- reinforced composites. These materials provide strength while keeping the overall weight of the tank relatively low.

**Construction:** The tanks consist of a pressure- resistant inner liner, often made of metal, sur- rounded by layers of carbon fiber or other high- strength composite materials. The composite lay- ers provide additional strength and help withstand high-pressure conditions.

**Operating Pressure:** Hydrogen tanks for FCEVs operate at high pressures, commonly in the range of 350 to 700 bar (5,000 to 10,000 psi). The high pressure allows for a higher storage density of hydrogen.

**2) Metal Hydride Tanks (Less Common):**

Some FCEVs may use metal hydride tanks for hydrogen storage. In metal hydride storage sys- tems, hydrogen is absorbed into a solid metal hydride material, providing a different approach to hydrogen storage.

**Material:** Metal hydride tanks use materials that can absorb and release hydrogen reversibly. Com- mon materials include various metal alloys.

**Operating Pressure:** Metal hydride storage systems typically operate at lower pressures compared to high-pressure gaseous storage, ranging from 20 to 100 bar (290 to 1,450 psi).

**3) Liquid Hydrogen Tanks (Less Common):**

Some FCEVs use liquid hydrogen storage, where hydrogen is stored in a cryogenic state as a liquid.

**Operating Temperature:** Liquid hydrogen tanks op- erate at extremely low temperatures, close to the boiling point of hydrogen, which is -252.87°C (- 423.17°F).

**Operating Pressure:** The pressure of liquid hydro- gen is relatively low, typically around 1 bar (14.5 psi) at atmospheric pressure.

The spatial constraints of vehicles are being considered while optimizing hydrogen storage capacity. Vehicle manufac- turers have made compressed hydrogen tanks a popular choice for their reliability and maintenance, as well as the ability to be used in cars with low mileage.

## ISSUES FACED AND CHALLENGES

By utilizing hydrogen storage tanks, FCEVs can facilitate the development of cleaner energy sources. Still, this technol- ogy is confronted with several difficulties that are primarily related to safety, efficiency, and cost-effectiveness.

### A. Safety Concerns

The issue with FCEVs involving hydrogen storage systems is the safety aspect, according to Walker (2008). The use of highly flammable hydrogen poses significant risks when stored at high pressures or in cryogenic conditions, which are commonly used in contemporary FCEVs. In order to store liquid at 350-700 bar pressure, tanks must be designed to handle extreme conditions without compromising structural integrity. Leaks and an ignition source can lead to catastrophic explosions, which are always a risk. To address this situation, it is necessary to incorporate robust safety measures (Muthukudi- mar et al., 2023). The list comprises advanced valve systems that detect hydrogen leaks and emergency shutdown systems designed to prevent and mitigate accidents.

### B. Cryogenic Storage Challenges

Nevertheless, the alternative method of freezing hydrogen in liquid form at very low temperatures presents its own problems. To preserve hydrogen as a liquid, it is necessary to maintain temperatures around -253°C and therefore require extensive insulation and cooling mechanisms. Despite the energy efficiency benefits of hydrogen as a fuel, the effort required to maintain such low temperatures can be negated by some additional energy. Additionally cryogenic tanks are the subject to faster temperature variations than standard tanks that impairing their structural integrity over time.

**C. Efficiency and Cost-Effectiveness**

The study of Balali and Stegen (2021) indicated that the adoption of FCEV hinders the implementation of efficiency- reducing storage systems that has been achieved by reducing their cost. By designing tanks that are made of lighter and stronger materials, the overall weight of the vehicle can be significantly reduced while enhancing efficiency and range. Therefore, the cost of composites and metal materials that are suitable for these applications is still high. Regardless of the ability to be accessible FCEVs are significantly limited by economic factor that is significant for manufacturers and consumers.

**D. Manufacturing Complexity**

The complexity of manufacturing in these advanced hy- drogen storage tanks is another problem. As, high-quality materials and precision engineering are necessary to create tanks that can withstand high pressures or extremely low temperatures. The manufacturing procedure requires intricate design considerations testing and strict adherence to high safety standards (Rasul et al. 2021). Due to the increased complexity the production costs lead to logistical challenges while scaling up for mass manufacturing.

**E. Hydrogen Embrittlement**

Additionally, the issue of hydrogen rust accumulation in tank metals is a pressing matter in material science. Hydrogen molecules can penetrate metal structures that result in fragility and susceptibility to fractures. Although the advancements in engineering and stricter regulations in safety remains a top priority, to achieve efficiency and cost-effectiveness there is a growing demand for innovation in materials science and manufacturing processes (Elberry et al., 2021). New mate- rials or coatings are created to resist deterioration that is problematic in high-pressure settings. Even though hydrogen storage systems in FCEVs are dignified towards a future of automotive efficiency this requires comprehensive solutions. By overcoming these obstacles, FCEVs can be practically implemented and widely used, signifying collaboration across various scientific and industrial sectors to develop a more sustainable mode of transportation.

**Table 1:** Hydrogen Storage System In Fcev Overview

| Feature | Description |
|---|---|
| Type of Tank | Compressed hydrogen tank / Liquid hydrogen tank / Solid-state hydrogen storage |
| Material Used | Advanced composites / Metal alloys |
| Pressure Rating | Typically 350-700 bar for compressed hydrogen tanks |
| Capacity | Varies based on tank design and vehi- cle requirements |
| Safety Features | Pressure relief valves, leak detection sensors |
| Temperature Management | Insulation for liquid tanks, temperature sensors |
| Efficiency | Related to the method of hydrogen storage and release |
| Cost | Influenced by materials, manufacturing complexity |
| Manufacturing Complexity | High, due to precision engineering and safety standards |
| Challenges | Hydrogen embrittlement, cost, safety concerns |

## CONCLUSION

Hydrogen storage systems are fundamental design of Fuel Cell Electric Vehicles as they offer a clean and efficient substitute for fossil fuels. As compressed hydrogen, tanks are currently the most popular due to their ability to provide ef- ficiency and practicality. However, advancements in materials science have made them a crucial solution to existing issues. To achieve more efficient and dependable hydrogen storage options, we must address safety, cost-effectiveness, and mate- rial durability. Thus, the ongoing research and development of HSS in FCEVs is poised to become a significant advancement for the automotive industry that contribute to societal progress. The advancement is expected to lead to novel approaches that can improve the viability and appeal of FCEVs as a sustainable transportation option.

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