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HYDROGEN TECHNOLOGY IN FUEL CELL & IC ENGINE VEHICLES

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Abstract - *As the world moves towards clean mobility, there is a demand for low-emission vehicles. Vehicles running on gasoline and diesel cause a lot of pollution, and switching the fuel to hydrogen might bring a major revolution. Hydrogen when used in fuel cells and IC engines is the most viable solution to clean mobility. But the real challenge to this vehicle system is the integrated efficient storage. Hydrogen tanks store hydrogen in all vehicle types under high pressure and supply it to the fuel cells or IC engine. The major concern is regarding safety, so the tanks are built using various layers of materials and the tank goes through a series of tests which build up the resistance in such a way that they can sustain any high speed crash.*

Hydrogen when used in fuel cells causes zero emission, so the vehicles running on hydrogen fuel cells are very quiet, highly efficient, reliable, and provide the best fuel economy. Hydrogen in IC engines helps to reduce the emissions drastically while having parts modular with IC and SI engines which provides a great advantage for cost reduction and delivering the required reliability. Also, that this engine can run on lean mixtures.

So switching from conventional gasoline and diesel vehicles to hydrogen powered vehicles would be the most sustainable option for future automotive industry to reach zero emission vehicles.

Key Words: Hydrogen, Hydrogen Storage System, Hydrogen Fuel Cells, Hydrogen Internal Combustion Engine

1.INTRODUCTION

Integration of hydrogen technology in automobiles is a promising avenue for cleaner energy alternative and environmental sustainability. Hydrogen is a clean, abundant element which has taken the market attention in the race of sustainable transportation solutions. Hydrogen when integrated with fuel cells and internal combustion engine could make one of the best emission free solutions.

The fuel cells in FCEVs function as an electrochemical device which converts the chemical energy of the fuel to electric energy. The paper will delve into the architecture of how fuel cells are integrated vehicles and its power train. The fuel cell technology provides a lot of advantages of energy efficiency, fuel economy, fast refueling, extended range as compared to batterie electric vehicles, etc. Also, this technology faces a few challenges, the hurdles of infrastructure, cost, and the production of hydrogen are a part of concern which we could deal with in the near future when this technology would come in mass production.

Hydrogen when used in internal combustion engine aligns the goals of reducing the emissions and providing a reliable and efficient alternative. Hydrogen internal combustion engine run on lean mixtures having an air to fuel ratio of 34:1.
Hydrogen has a high energy content, making it reliable and potential fuel for internal combustion and serving improved efficiency and power output.
This paper would give a review about the integration of hydrogen technology in fuel cells and internal combustion engines with its features, opportunities and challenges.

2. HYDROGEN FUEL CELLS

Hydrogen fuel cells are driven by an electrochemical reaction in which hydrogen and oxygen produce electricity with heat and water as the only by-product. Fuel cell is a combination of an anode, cathode and electrolyte membrane where hydrogen splits at anode to hydrogen ions and oxygen is reduced at cathode that generates current.

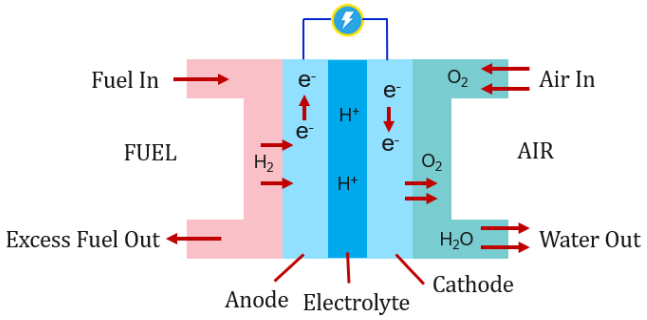

Fig -1: Hydrogen Fuel Cell

The electrochemical reaction conducted as follow:
Hydrogen splits into positive ions and negative ions,
$H_2 \rightarrow 2H+ + 2e-$
Positive ions pass through the electrolyte exchange membrane whereas the negative ions follow a different path through a circuit generating electricity and heat.
At the Cathode,
The positive ions cross the membrane and the oxygen from the air combine to form water,
$2H+ + 2e- + ½\ O_2 \rightarrow H_2O$

Net Redox Reaction,
$H_2 + ½ O_2 \rightarrow H_2O$
In a fuel cell the hydrogen that remains unused gets recycled.

3. HYDROGEN STORAGE SYSTEM

The most important component of the Hydrogen Storage System is the hydrogen tank. Hydrogen tank is used to store hydrogen at a high pressure of 700bar and 350bar. For automotive applications type III and type IV tanks are preferred for there light weight and capacity to store enough hydrogen.

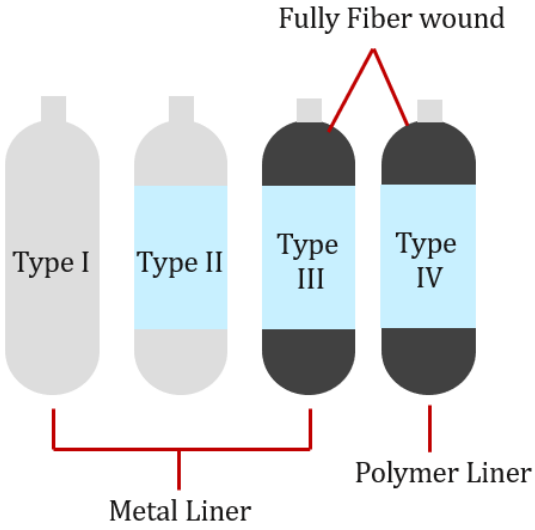

Fig -2: Hydrogen Tanks

These tanks have a cylindrical section, boundary section, dome section and a boss. There are various layers which build up the safety of the tank:

Layer 1: LINER
The liner is the innermost layer which seals in the hydrogen. The liner in the hydrogen storage system ensures permeability to hydrogen under gaseous form. A liner must have good mechanical properties (tensile, compressive, impact strength) as well as good thermo-mechanical behavior.

Layer 2: CARBON FIBER COMPOSITE
The carbon-fiber composite layer is the one which `ensures pressure resistance. The main motive of using composite materials in hydrogen storage system is to build strength. By mixing two materials (fibers & resins) with different mechanical characteristics will form a material with high performance characteristics. Fibers provide mechanical properties and resins maintain the reinforcement and help to give a final shape to the product.

Layer 3: GLASS FIBER
Glass-fiber reinforced layer protects the Carbon Fiber and acts as a shock revealer. The end section of the tank consists of Dome's and 2 Bosses one at the Inlet and one at the outlet. This makes the entire tank.
These tanks store hydrogen at a high pressure of 350-700bar.

4. HYDROGEN FUEL CELL ELECTRIC VEHICLES

Cars & commercial vehicles powered by the electricity produced by hydrogen fuel cells are known as Hydrogen Fuel Cell Electric Vehicles.
The main constituents of these type of vehicles are the Hydrogen tanks, Fuel cell stack, Battery, Motor, Motor controller and Power electronics system.
Hydrogen fuel is filled in the high-pressure hydrogen tanks from where it travels to the fuel cell generating electricity. This electricity is transferred to the motor to run the vehicle and the extra energy is stored in the battery which later provides energy to the motors wherever required.

4.1 Integration of Hydrogen Tanks in FCEV

Hydrogen Tanks can be accommodated in a vehicle by placing them on the roof, underfloor, behind the cabin or on the chassis.
It can be possible to place a small hydrogen reservoir on the front deck of the vehicle as there is no engine in this case, the empty space could be utilized for a small reservoir in case the main tank goes empty, and the battery does not support.

4.2 Power Train Modes

There are 3 modes of battery and fuel cell hybridization architecture.

1. Range Extender Fuel Cell: Has a large battery support & small hydrogen system. This is used to increase the Battery Only Vehicles insufficient range and improve usage flexibility.
2. Dual Power Fuel Cell: Has 50% support by the hydrogen system and 50% support by the battery. Generally suitable for vehicles with a balance of urban & highway usage, in context of limited H2 refueling stations.
3. Full Power Fuel Cell: Has a major Fuel Cell support and a minor battery support. This is a considerable solution for high range vehicles. Full Power fuel cells provide the best range and efficiency but lag with durability and are high cost.

4.3 Working of Full Power Fuel Cell Electric Vehicle

Considering 4 driving variations.
1] Starting of the Vehicle: Battery Only

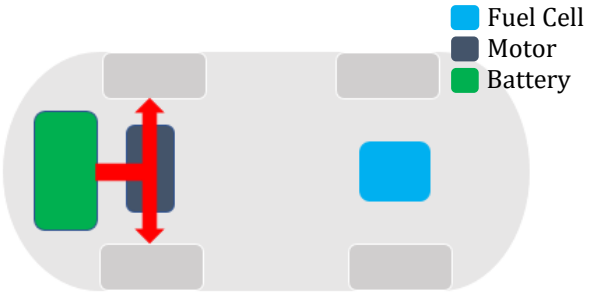

Fig -3: Powered by Battery Only

The motor operates spontaneously using the battery power for a smooth start.

2] Normal Driving: Power is provided to the motor from the fuel cells only.

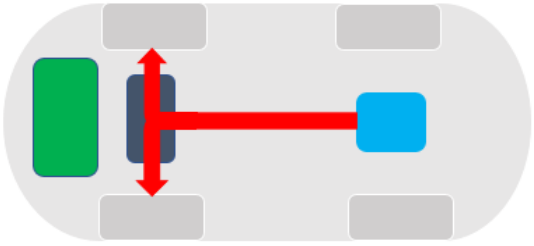

Fig -4: Powered by Fuel Cell Only

3] Accelerating: Power is provided from the fuel cells & battery to the motor to give a power boost.

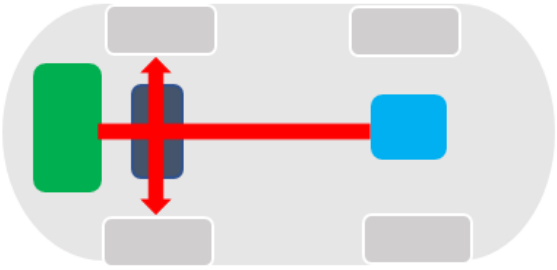

Fig -5: Powered by Fuel Cell & Battery

4] Braking & Deceleration: During braking & deceleration the Kinetic energy is converted to Potential energy and stored in the battery.

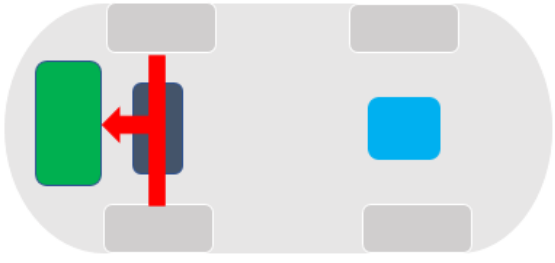

Fig -6: Energy storing in the Battery

5. SAFETY CONCERNS OF FCEV

FCEV are not as threatening as they look to be.
Hydrogen tanks serve the majority safety concerns of these vehicles. These tanks are designed in such a way that they can survive any high-speed crash without cracking or breaking. The main source of protection is provided by the carbon fiber and the Glass wool in the tank. 20-30 tests are carried out to check the safety of the tanks and sensitive sensors are installed that detect even a minute amount of hydrogen. Hence, we can say that they are as safe as a conventional car.

6. FCEV STRENGTHS

- Quite Operation - as there are no moving parts involved it is a quite system.
- Pollution Free - No harmful pollutants are emitted from these vehicles.
- Fast refueling - The refueling time is just 3 to 5 mins which is faster than charging battery electric vehicles.
- Mileage - These vehicles provide 3 times more mileage than conventional gasoline & diesel vehicles.
- Scalability and flexibility – Hydrogen fuel cell technology is very scalable and flexible, as hydrogen can be produced from a wide range of resources and is used over a huge range of applications from small scale to high power generation.

7. FCEV CHALLENGES

- High Cost - The price of fuel cell vehicles is high as the overall cost of production, Storage and delivery of hydrogen is high. Its cost would reduce once it comes into mass production.
- Extraction of Hydrogen - Immense amount of energy is required to extract it from water or other molecules.
- Storing of Hydrogen - Hydrogen is light so it needs to be heavily compressed which require expensive tanks.
- Fuel Purity - Pure hydrogen is required which should be free from contaminants.
- Fueling Infrastructure - The fueling infrastructure is not yet developed in many countries.

8. HYDROGEN INTERNAL COMBUSTION ENGINE VEHICLES (HICEV)

Hydrogen Internal Combustion Engine Vehicles use an internal combustion engine with Hydrogen as a fuel. HICEV are different from Hydrogen fuel cell electric vehicles as they use Hydrogen electrochemically whereas HICEV use it through combustion.

Hydrogen Internal Combustion Engine operate on the same cycle as SI engine or CI engine and almost have the same components. This modularity in engine parts gives us a good cost advantage and also delivers the needed reliability and efficiency.

HICEV operates similar to a 4-stroke gasoline internal combustion engine but provides a better air to fuel ratio which helps the vehicles to operate on lean mixtures (more air less fuel).

As Hydrogen does not contain Carbon, there are no carbon - based pollutants formed such as CO, HC, CO2
which helps us achieve carbon neutrality. The combustion of hydrogen produces oxides of Nitrogen (NOx), due to this there might be a need of SCR (Selective Catalytic Reduction) in the vehicle to control the amount of NOx. Hence HICEV is not a zero emission.

Due to high cost of FCEV, HICEV could be a better alternative as it provides better range as compared to conventional vehicles and battery electric vehicles.

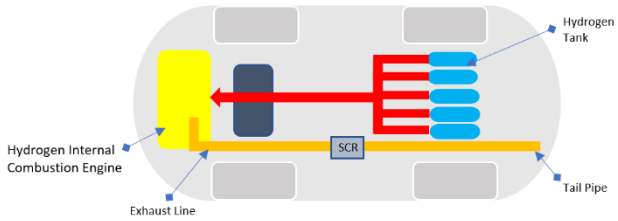

Fig -7: Hydrogen Internal Combustion Engine Vehicle

9. CONCLUSIONS

Hydrogen Technology looks to be a very promising technology for future innovative. The integration of hydrogen technology in fuel cells and internal combustion engine prove to be a very viable alternative to the nonrenewable fuels and have a significant potential along with its challenges which brings it to the center of innovation and demand. The efficiency, zero emission and fuel economy make it the most ideal option for the automotive future. With increasing innovation and widespread adoption can help to beat the challenges of infrastructure and cost. Hydrogen Internal Combustion Engine serves like a bridge between the fully electric and conventional IC engine vehicles. Which gives a good advantage in price, durability and robustness.

Looking ahead, the integration of hydrogen technology in fuel cells and internal combustion engine presents an evolving step towards environment friendly and sustainable transport solution. Understanding the opportunity and dealing with challenges hydrogen technology will surely make its way to the market center.

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