Renewable Hydrogen Fuel for Automobiles

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ABSTRACT

In the search for an alternative to today's petroleum powered vehicles, efficient hydrogen fueled vehicles are an attractive option. Hydrogen based vehicles can use advanced technology of electric vehicles to improve environmental quantity and energy security while providing the range, performance and utility of today's petroleum & gasoline vehicles.

Presently the significant hurdle for hydrogen vehicles is storing sufficient hydrogen onboard. Hydrogen storage choices determine fuel tank weight, refueling time, cost, infrastructure requirements energy efficiency, vehicles fuel economy, performance and utility.

Different viable storage technologies are at the research level worldwide. The U.S Department of Energy (DOE) along with transport industries has set targets to achieve to make hydrogen economy a reality in the near future atleast by 2020.

The availability of Hydrogen fuel can be a wonderful renewable solution against depleting fossil resources, concern over increasing pollution level, climate change and global warming.

The paper will deal with Hydrogen energy as a future fuel, current technology status and future challenges

Keywords : Hydrogen energy, fuel cell vehicles, storage, safety, Hydrogen economy.

Introduction

One of the answers to the imminent long time crisis is the renewable sources. The realization of pollution of our environment due to fossil fuels has given birth to environmental movement. Various environment experts through different forums are advocating reductions in green house gas emissions. Today's life styles with increased number of gadgets, and vehicles are the main contributors for pollution which are reaching alarming levels.**[1]**

Rapid changes are visible in manufacturing and service sectors which are going beyond their conventional outlook. There is a serious need for reduction in the usage of fossil fuels and explore renewable energy options which are environment friendly and non-exhaustible.

Scientists working in this field strongly feel that Hydrogen Energy System will be a permanent solution to the projected global crisis in energy supply. This is mainly because all the current fossil fuel resources are in their mid-depletion region and the pollution levels have already reached unsafe levels.

As Hydrogen is to be produced from water, it is supposed to be one of the lightest, most efficient, cost effective and cleanest fuel on the planet, if the matured technology is developed. This is realistic since over 72% of the globe is covered with water and byproduct again is water. In other words Hydrogen economy starts and ends with water. It can avoid all harmful gases, acid rains, pollutants, ozone depleting chemicals and oil spillages due to conventional fuels. Use of Hydrogen can afford the development of clean and adequate energy for sustainable growth.

Ever growing demand for energy and the rising concern caused by the use of conventional fossil fuels, call for new and clean fuels. Among all kinds of energy sources, hydrogen is the best choice as a clean fuel. The main advantage of hydrogen as energy source lies in the fact that its byproduct is water, and it can be easily regenerated.

Hydrogen is the simplest element; an atom of hydrogen consists of only one proton and one electron. It is also the most plentiful element in the universe. Despite its simplicity and abundance, hydrogen doesn't occur naturally as a gas on the Earth—it is always combined with other elements. Water, for example, is a combination of hydrogen and oxygen (H_2O). Hydrogen is also found in many organic compounds, notably the "hydrocarbons" that make up many of our fuels, such as gasoline, natural gas, methanol, and propane.

Production of hydrogen

Hybrid System With Intermittent Energy Source [2]

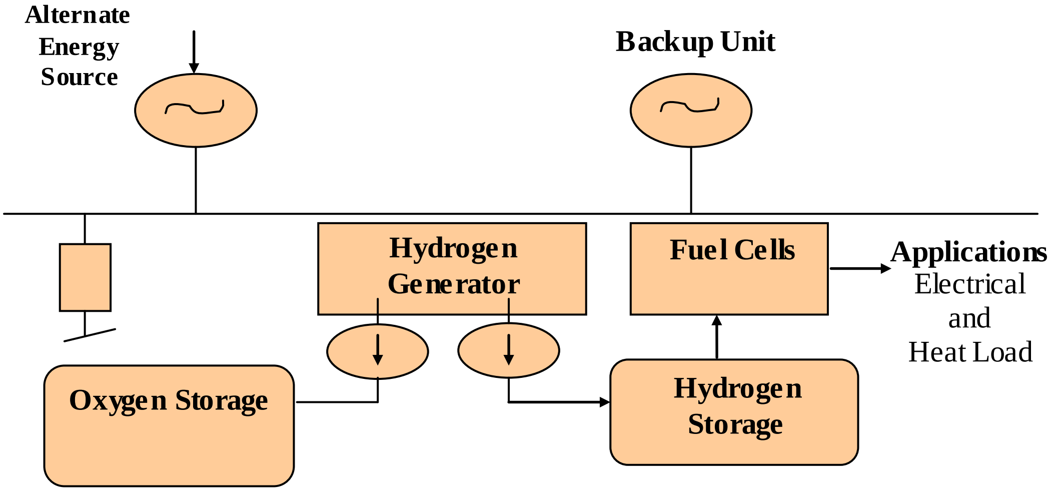

Figure 1 – Hybrid System

- The hydrogen storage in combination with other energy sources is a useful operational technique for optimization.
- The above scheme is useful for both stationary and mobile applications.
- Hydrogen storage using intermittent energy sources is a very interesting alternative for sustainable applications.

Hydrogen from fossil fuels

Industries which use hydrogen in large scale, chemical methods basically by steam reforming of natural gas, coal gasification and reforming of heavy oil feedstock's. The natural gas is very common and economic method using endothermic steam reforming process.

$$CH_4 + H_2O \longrightarrow CO + 3H_2 \uparrow$$

Further to maximize the hydrogen yield, externally heated bed reactor is used for water gas shift reaction.

$$CO + H_2O \longrightarrow CO_2 + H_2 \uparrow$$

It is required to have several gas purification stages. One of the important climate affecting factor is the release of carbon monoxide and carbon dioxide gases which are harmful. Coal is the largest releaser of toxic gases and natural gas is the least.

Solar Hydrogen

One of the important steps of hydrogen economy. Here hydrogen is produced using renewable means such as solar / wind power. Water is supplied with energy to separate hydrogen and oxygen.

$$H_2O + \text{Energy} \longrightarrow H_2 + \tfrac{1}{2} O_2 \uparrow$$

This is a direct method without any pollutants or harmful byproducts. This is generally electrochemical water splitting reaction. This method is still a subject of research and can be highly efficient.

Hydrogen storage

Various technologies are available for the storage of hydrogen.

- Compressed gas - High-pressure tanks: Hydrogen gas can be compressed and stored in storage tanks at high pressure. These tanks must be strong, durable, light weight and compact.
- Liquefied gas - It can be stored, as liquid but has to be kept at cold. Needs cryogenic tanks and one of the difficult processes.
- Stored in side pores in solid / porous materials - Hydrogen combines with some metals, which can result in higher storage capacity compared to high-pressure gas or liquid. Carbon Nanotubes can store hydrogen.

Department Of Energy(DOE) USA Hydrogen Storage Goals [4]

Storage Parameter	Units	2005	2010	2015
Specific Energy	K Wh/kg	1.5	2.0	3.0
Wt%	**Kg H_2/kg System**	**4.5**	**6.0**	**9.0**
Energy Density	K Wh/1	1.2	1.5	2.7
	gm H_2/1 System*	36	45	81
Storage System Cost	$/k Wh	6	4	2
	$/kg H_2 capacity	200	133	67
Refueling Rate	Kg H_2/min	0.5	1.5	2.0
Loss of usable H_2	(g/hr)kg stored	1	0.1	0.05
Cycle Life	Cycles(1/4 to full)	500	1000	1500

*For reference, liquid H_2 density is 70gm/l

Hydrogen Storage Options

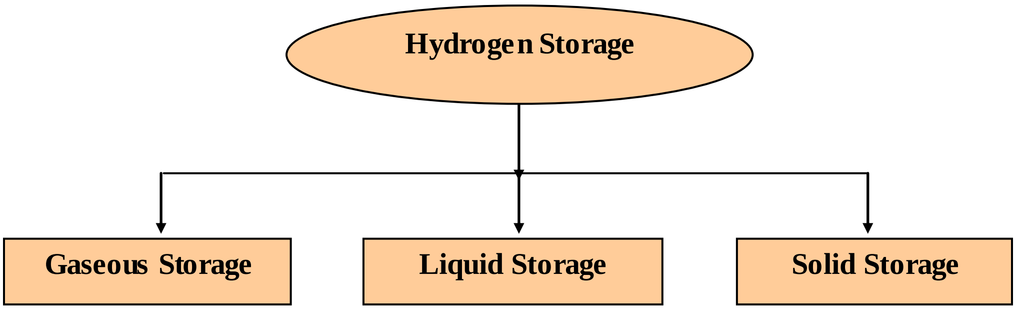

Figure 2 – Storage Options

Gaseous	Liquid	Solid
• High Pressure tanks in the range of 5000 psi → 10000 psi.	• Cryogenic tanks.	• Wt% achieved is less.
• Large Weight-Volume ratio.	• Boiling point -253°C.	• Relatively safe method.
• Bulky and Low Efficiency.	• Liquefaction needs 40% of Energy Contents.	• Storage efficiency very low.

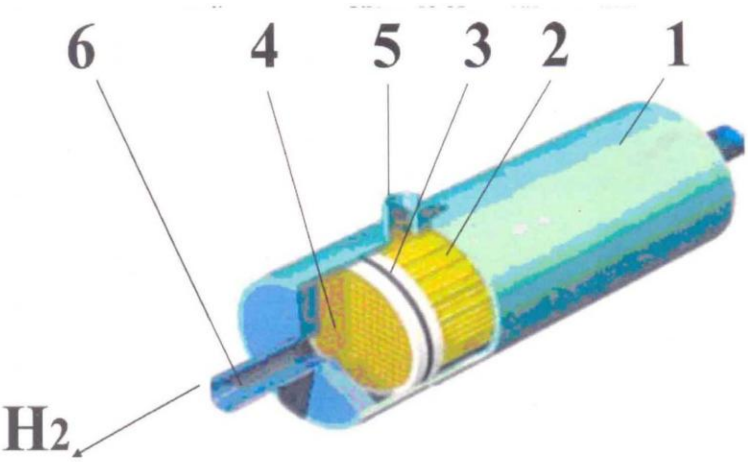

Figure 3 – Schematics of Hydrogen Storage Vessel [5]

1. Body
2. Hydrogen Accumulator
3. Heater
4. Hydrogen Collector
5. Safety Valve
6. Tube for Hydrogen supply and release.

Gaseous Storage:-

Unlike electricity, hydrogen can be stored for long periods of time without significant losses. Hydrogen can be stored as cryogenic liquid or compressed gas and can be

transported by high pressure trucks or gaseous pipelines. Most prototype vehicles store hydrogen in composite tanks at high pressures of around 5000 psi to 10000 psi. Due to low weight volume ratio, the tanks for gaseous storage become bulky.
The best vehicles for applications of gaseous fuel are those with less space constraints and less rapid acceleration. Larger vehicles with space for accommodating hydrogen tanks find it convenient for implementation.

Liquid Storage:-

Cryogenic or liquid storage needs extreme low temperatures (-2530C) and liquefaction needs around 40% of energy contents. It is the best method for high gravimetric densities.

Solid State Storage:-

Solid state is apparently safe method of storage for on board applications. Even though most mature techniques today are cryogenic or gaseous storage, key issues is the safe fuel for a hydrogen based vehicle. The solid state materials offer increased safety as in case of tank ruptures, they won't result in large energy releases. This method will also benefit stationary and steady applications.
Gas-on-solid adsorption is inherently safe and potentially high density storage. Different solid state materials are recommended, each having advantages as well as limitations. Many intermetallic compounds such as Magnesium, Nickel and complex chemical hydrides such as $NaAlH_4$ and carbon based materials have promise of high storage density and safety factors.
From the storage point of view, classical intermetallic compounds have too low gravimetric hydrogen storage capability. Light weight metals such as Li, Be, Na, Mg, B, Al in their compounds are in various stages of research for improving Kinetics, adsorption/desorption temperatures, reversibility of hydrogenation of these compounds. The metals alloys, their characterization for weight % improvements are showing promising results. It is expected that many of these compounds may satisfy the DOE targets simultaneously.

Safety issues in Hydrogen Transportation

One of the greatest concerns of hydrogen with the public is the safety issues and storage for mobile application. Current storage pressures of compressed natural gas, CNG are 3600psi, while that of compressed hydrogen is 5000 and 10000 psi. Storage of hydrogen in cryogenic tanks requires extensive insulation, and is a source of frostbite in case of accidental release or rupture of the nozzle. A system that is airtight is not hydrogen tight due to hydrogen's lightness. This requires new materials for seals and fuel lines. These aside, the issue of hydrogen embrittlment is a major concern and under no circumstances current stock items meant for fossil fuel systems be used for hydrogen systems.
Safety issues are getting attention and much progress has been made in making hydrogen economy a reality.

Safety issues related to hazards in handling and storage [6]

Storage tank failures : Results in the release of hydrogen due to material failures. Release of liquid / gases form results in fire and explosion. Excessive pressure caused by heat leaks, failure of pressure relied systems.

Transfer Leaks : Deformed seals / gaskets, value misalignment, failure of flanges, failure of construction materials such as vacuum jacketed lines.

Collision during transportation : May result in disastrous effects as spills cause fire and explosion.

Hazard Elimination and Control [3]

High-level hazard elimination can be achieved by proper design process. Use of safety devices through routine functional checks for maintaining their level of protection. Using warning devices, warning signals may be provided to help the workers react promptly and correctly to a hazardous situation. Safe operating procedures and safety training programmes should be developed to eliminate hazards and reduce their risks to acceptable levels through design selection. Personal protective equipments can be used to prevent injuries and illnesses. Typical Hydrogen Storage device model schematic will be prepared with trial values for mathematical modeling of safety analysis.

Inference

Unlike electricity, hydrogen can be stored for long periods of time without significant losses. Today, hydrogen is stored as a cryogenic liquid or compressed gas, and transported by cryogenic liquid or high-pressure trucks; and, to a limited extent, by gaseous pipelines. In the future, it could be stored and possibly transported in chemical and metal hydrides, carbon nanostructured materials, and high surface area adsorbents. In such forms, hydrogen would be more amenable to safe and efficient distribution and storage.

References

[1] Towards true zero-emission vehicles in a single step: Air pollution and greenhouse gas reductions through hydrogen fueled ships with carbon management by J.J. Corbett and Others, 0-7803-655 1-8/00/$10.00 02000 IEEE.

[2] Optimal Operation of Hydrogen Storage for Energy Sources with Stochastic Input by Magnus Korpaas and others, IEEE, 0-7803-7967-5/03/$17.00 ©2003 IEEE.

[3] Safety issues in hydrogen transportation by Etim U. Ubong, Kettering University, 0-941783-23-5/03/$17.00©2003 IEEE.

[4] Hydrogen storage : The key challenge facing hydrogen economy T. Motyka, R. Zidan and W.A. Summers SRTC, Aiken SC 29808 USA 2008

[5] A.F. Chabak, Developing Hydrogen Accumulators with High Capacity and Instant Supplying it to Fuel Cells, HTEP Moscow, 6th to 10th February 2006.

[6] Hydrogen Safety Review Panel report by Steven. C.Weiner, Pacific North West National lab Washington DC. Dept. of Energy US 2008.