A Review on Hydrogen Energy

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Abstract: In the age of over increasing demand of energy, hydrogen may play a major role as an alternative fuel. Hydrogen can be used as transportation fuel, whereas neither nuclear nor solar energy can be used directly. Hydrogen has very special property as a transportations fuel, including rapid burning speed, a high effective octane number and no toxicity or ozone forming potential. A stoichiometric hydrogen-are mixture has very minimum ignition energy of 0.02MJ. Combustion product of hydrogen is clean, which consist of water & a little amount of nitrides of oxygen (NOx). The main drawback of using hydrogen as a transportations fuel are huge on - board storage tank. Hydrogen stores approx. 2.6 times more energy per unit mass than gasoline. The disadvantage is that it need an estimated 4 times more volume than gasoline to store that energy. The production and storage of hydrogen are not yet standardized. This paper review the different production technique and storage system of hydrogen to be used as a I C Engine fuel. The desirable and undesirable properties of hydrogen as a I C engine fuel have also been discussed.

Keywords: Alternative fuel hydrogen, Production, Storage.

I. Introduction

Consumption of fossil fuel is associated with adverse environmental effects. The reserve of oil & natural gases are limited and are likely to be depleted in the next 50-100 years. Another factor affecting the energy use pattern is the phenomenon of global warming. Efforts have to be made to stabilize the carbon dioxide concentration in the atmosphere [1]. Therefore, search for possible alternative sources of energy to replace fossil fuels is desirable. A shift to a hydrogen-fueled economy is a possible solution [2, 3]. The main advantage of hydrogen is that it has zero emission during its use. However, production, transmission & storage of hydrogen are accompanied with emissions.

Hydrogen in the recent past have been thought of as a fuel in I C engines because of its certain properties like lowest molecular weight, high infusibility etc. The combustion product of hydrogen will be a ordinary water. In this report, we are to present prospects and facts, shortcomings about use of hydrogen as a fuel for I C engines.

II. Properties of Hydrogen [18]

Table I

	Hydrogen	Gasoline (H/C=1.87)
Molecular weight (g/mol)	2.016	~110
Mass density (kg/Nm3) at P=1atm T=00c	0.09	720-780 ((liquid)
Mass density of liquid H2 at 20 K (kg/NAm3)	70.9	-
Boiling point (K)	20,2	310-478
Higher heating value (MJ/kg) (assumes water is produced)	142.0	47.3
Lower heating value (MJ/kg) (assumes steam is produced)	120.0	44.0
Flammability limits (% volume)	4.0-75.0	1.0-7.6
Detonability limits (% volume)	18.3-59.0	1.1-3.3

	Hydrogen	Gasoline (H/C=1.87)
Diffusion velocity in air (m/s) Ignition energy (ml) - At stoichiometric mixture - At lower flammability limit	2.0 0.02 10	0.17 0.24 n/a
Flame velocity in air (cm/s)	265-325	37-43
Toxicity	Nontoxic	Toxic

III. Hydrogen Sources [8]

All primary energy sources can be used in the hydrogen-producing process. Currently, the primary route for hydrogen production is the conversion of natural gas and other light hydrocarbons. Coal and petroleum coke may also serve as raw materials for hydrogen production in the future. As shown in above approximately 96% of the hydrogen produced comes from fossil fuels' conversion, such as natural gas reforming. The production of hydrogen from fossil fuels causes the co-production of carbon dioxide, which is assumed to be the main responsible for the so-called "greenhouse effect". These processes use non-renewable energy sources to produce hydrogen and are not sustainable. Therefore, renewable energy sources and technologies for hydrogen production will be necessary in the coming decades. Hydrogen can be produced from renewable energy sources such as biomass, but yields are low. If hydrogen conversion efficiency could reach 60-80%, based upon a maximum theoretical conversion of 12 mol-H2/mol - hexose, Hydrogen production from wastewater could have great potential for economical near-term hydrogen production from renewable energy sources. The percent share of raw materials in hydrogen production. Hydrogen can also be produced from water by using a variety of energy sources such as wind, solar, geothermal, hydropower, and nuclear energy. Nuclear energy has the potential to play a significant role in a sustainable hydrogen economy.

IV. Hydrogen Production Methods

Table II: Hydrogen is Produced by Following Methods [1]

Method	Process	Implementation
Steam reforming of methane gas	In presence of nickel catalyst & at 700-1100 C $CH_4(g) + H_2O(g) \rightarrow CO(g) + 3H_2(g)$ Next reaction at lower temp $CO(g) + H_2O(g) \rightarrow CO_2(g) + H_2(g)$	Current major source of hydrogen
Hydrogen from coal (Gasification)	At high temp & pressure $Coal + H_2O(g) + O_2(g) \rightarrow Syngas$ $Syngas = H_2 + CO + CO_2 + CH_4$	Current method of mass hydrogen production
Electrolysis of Water	Electric current passed through water: $2H_2O(l) \rightarrow 2H_2(g) + O_2(g)$	Not in widespread use due to cost of electricity
Solar-Hydrogen system	Electric current passed through water: $2H_2O(l) \rightarrow 2H_2(g) + O_2(g)$	Not in widespread use due to cost of renewable energy sources

Table III: Advantages & Disadvantages of Hydrogen Production Methods [1]

Sr No	Method	Advantages	Disadvantages
1	Steam reforming of methane	65-75% efficiency Economical (Least expensive method) Established infrastructure	Nonrenewable resources Produce CO_2 emissions
2	Gasification	Large supplies of coal in US Inexpensive resources	Produce CO_2 emissions Carbon sequestration would raise costs 45% efficiency
3	Electrolysis of water	Depend on electricity source	Input into production may require more energy than released
4	Solar-Hydrogen System	No emission 65% efficiency	Expensive

V. Hydrogen Storage

Hydrogen storage & transport is a critical issue. The is the low density of hydrogen gas. Hydrogen can be stored by compressed tube trailer, liquid storage tank or truck and compressed gas pipelines [2].

Table IV

Storage Form	Advantages	Disadvantages
Compressed gas	Reliable, Indefinite storage time, Easy to use	High capital & operating cost, Heat can cause container rupture
Liquid	High density at low pressure	High cost Low temp needed Escape can cause fire or asphyxiation
Metal Hydride	High volume efficiencies Easy recovery Very safe	Expensive materials Heavy storage tanks

VI. Economics of Hydrogen Delivery

Hydrogen delivery is important for a viable hydrogen economy, which requires an infrastructure to deliver hydrogen from where it is produced to the dispenser at a refueling station or stationary power facility. Two types of hydrogen delivery are considered [18]: Hydrogen transmission (from a central hydrogen production plant to a single point), and Hydrogen distribution (from a central hydrogen plant to a distributed network of refueling stations within a city or region). There are three potential delivery pathways: (1) Compressed tube trailers, (2) Cryogenic liquid trucks, and (3) Compressed gas pipelines. A combination of these three options could be used during various stages of hydrogen fuel market development. Tube trailers could be used during the initial introductory period because the demand probably will be relatively small and it would avoid the boil-off incurred with liquid hydrogen storage. Cryogenic tanker trucks could haul larger quantities than tube trailers to meet the demands of growing markets. Pipelines could be strategically placed to transport hydrogen to high demand areas as more production capacities are placed on-line. For hydrogen delivery, the most important factors affecting the delivery cost (US$/kg) are: Scale (or hydrogen flow rate into the city), number of stations, delivery distance. Scale is important for liquid hydrogen delivery systems because liquefiers have strong scale economies. For pipeline systems, the pipeline capital cost contribution is strongly scale dependent. For compressed gas truck delivery there are mild scale economies in compression. Number of stations determines the spatial extent of the infrastructure, and is particularly important for pipeline delivery costs (For fewer stations, a less extensive pipeline network is required). Delivery distance is related to the physical size of the city (expressed as a characteristic length such as the city radius, and is particularly important for compressed gas trucks and for pipeline delivery, and less so for liquid hydrogen delivery).

a. *Hydrogen Delivery by Pipeline:* The cheapest option of transporting hydrogen s by high capacity pipeline, which can cost less the 0.1 US$/kg over 100. The cost of pipeline delivery with distance at different pipeline capacities. Pipeline costs are composed of labor (45% by weight), followed by materials (26% by weight), right-of-way costs (22% by weight) and other miscellaneous costs such as planning and management range of about 30-80 bar.
b. *Compressed Gas Truck Delivery:* The delivery of compressed hydrogen gas is tube trailer trucks requires the compression of gaseous hydrogen to 180 atm (18.2 MPa) at the conversion facility with storage and trucks with compressed gas tube trailers to transport the hydrogen to the refueling stations [17]. A typical trailer might carry 300 kg of hydrogen, which represents about 1% of the total mass of the truck.
c. *Cryogenic Liquid Hydrogen Delivery:* Delivering hydrogen as a cryogenic liquid requires the liquefaction of the hydrogen at the conversion facility with storage and delivery via tanker trucks. Tank trucks can carry between 400 and 4000 kg liquid hydrogen, a factor of ten more than tube trailers. Boil-off can be a problem, which typically runs at 0.3-0.6% per day. The primary barriers to using liquid hydrogen for delivery are the high cost and high energy use of liquefaction.

VII. Environmental Benefits Hydrogen

Air pollution is a serious public health problem throughout the world, especially in industrialized and developing countries. In industrialized and developing countries, motor vehicle emissions are major contributors to urban air quality. The major emissions from motor vehicles include carbon monoxide (CO), nitrogen oxides (NOx), hydrocarbons (HCs), lead, and particulate matter. One can attribute to transportation more than 70% of total global CO emissions and more than 40% of total global NOx emissions. Almost 50% of total global HCs, around 80% of total global benzene emissions and least 50% of atmospheric lead emissions.

VIII. Advantages of Using Hydrogen as a Fuel in I.C. Engines

Many experts think that hydrogen has a major role to play as an energy carrier in future energy supply. Hydrogen as a future energy carrier has a number of advantages. One of hydrogen's primary advantages is that it can be produced from a variety of primary resources, one of which will most likely be readily accessible almost anywhere in the world. Another important advantage of hydrogen over other fuels is that its only major oxidation product is water vapor; its use produces no CO_2. Hydrogen can be used as a transportation fuel, whereas neither nuclear nor solar energy can be used directly. It has good properties as a fuel for internal combustion (IC) engines in automobiles. Hydrogen can be used as a fuel directly in an IC engine not much different from the engines used with gasoline. The blending of hydrogen and ethanol has been used as an alternative renewable fuel in a carbureted spark ignition engine [16]. Hydrogen has very special properties as a transportation fuel, including a rapid burning speed, a high effective octane number, and no toxicity or ozone-forming potential. It has much wider limits of flammability in air (4-75% by volume) than methane (5.3-15% by volume) and gasoline (1-7.6% by volume). A stoichiometric hydrogen-air mixture has very low minimum ignition energy of 0.02 MJ. A hydrogen engine is easy to start in cold winter because hydrogen remains in a gaseous state until it reaches a low temperature such as 20 K. Such characteristics play a role to decrease engine cycle variation for the safety of combustion. However, it is frequently observed that the values of cycle variation for hydrogen-fueled engines with direct injection are higher than those of hydrogen-fueled engines with manifold injection or those of gasoline engines, due to a decrease in the mixing period by direct injection in the process of compressing hydrogen.

Combustion product of hydrogen is clean, which consists of water and a little amount of nitrogen oxides (NOx). With proper measurements it is believed that this amount of NOx can be reduced, even attaining 1/200 as low as diesel engines [11].

IX. Disadvantages

The main drawbacks of using hydrogen as a transportation fuel are huge on-board storage tanks, which are required because of hydrogen's extremely low density. Hydrogen can be stored on-board a vehicle as a compressed gas, as a liquid in cryogenic containers, or as a gas bound with certain metals in metal hydrides [4]. However, because of the low density, compressed hydrogen will not be able to give a comparable range to that of gasoline. Hydrogen can achieve a reasonable density adsorbed in these metal hydrides, but the weight of the metals makes the system very heavy.

X. Conclusion

Hydrogen is to be used as an alternative transportation fuels so as to negate the concern for the greenhouse effect. Greenhouse gas emission reductions should be estimated on an annual basis. Where the levels from year to year vary significantly these should be specified on an annual basis. Hydrogen as a future energy carrier has a number of advantages. One of hydrogen's primary advantages is that it can be produced from a variety of primary resources, one of which will most likely be readily accessible almost anywhere in the world. Another important advantage of hydrogen over other fuels is that it's only major oxidation product is water vapor; its use produces no CO_2. Hydrogen can help reduce carbon emissions, if produced from renewable energy sources and nuclear energy. The production of hydrogen from fossil fuels causes the co-production of carbon dioxide, which is assumed to be mainly responsible for the so-called ''greenhouse effect''. These processes use non-renewable energy sources to produce hydrogen and are not sustainable. Therefore, renewable energy sources and technologies for hydrogen production will be necessary during coming decades. Hydrogen has good properties as a fuel for IC engines in automobiles. It can be used as a fuel directly in an IC engine not much different from the engines used with gasoline. The problem is that while hydrogen supplies three times the energy per pound of gasoline it has only one tenth the density when the hydrogen is in a liquid form and very much less when it is stored as a compressed gas. The blending of hydrogen and ethanol has been used as an alternative renewable fuel in a carbureted spark ignition engine.

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