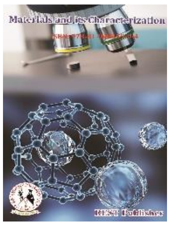
Materials and its Characterization
Vol: 2(3), 2023
REST Publisher; ISBN: 978-81-948459-0-4
Website: https://restpublisher.com/book-series/mc/



Hydrogen as an Alternate Fuel for IC engines

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Abstract: *A major portion of the world's energy needs is obtained through fossil fuels. Coal provides a dominant portion of the electrical energy production in the world and specially in India. However, the future of fossil fuels and particularly coal is clouded by the environmental threat posed by greenhouse gas effect caused by release of greenhouse gases such as CO¬2, SO2, and NOx. Several alternate technologies are under development for containing greenhouse gas emissions, and one such promising technology is the Hydrogen energy. Hydrogen holds the potential to provide a clean, reliable and economical source of energy for meeting the growing energy needs for India in future. The present paper is an attempt to review the technological options being pursued for production and storage of hydrogen energy. Also, this paper presents the road for key areas of research and development of hydrogen energy in a phased manner.*

1. INTRODUCTION

Hydrogen holds the potential to provide a clean, reliable affordable supply of energy for meeting the growing needs for India's economy while protecting the environment and ensuring energy security. Hydrogen can be used in wide range of applications including power generation, transport and heating applications. However, transition to the Hydrogen economy from the present fossil fuel-based economy will require many challenges specifically in the area of production, storage, delivery, applications and expanding infrastructure technology, economics and large-scale public awareness.
Hydrogen is about 15 times lighter than air and therefore requires large volumes to be stored like CNG and LPG. Several properties of hydrogen require safe handling, which is different from other fuels; therefore, it will be necessary to have new safety standards & codes, and regulations.
Hydrogen production is the key area of concern. Similarly in the area of hydrogen storage including gaseous, liquid and solid-state storage, various issues concerning energy efficiency of storage, its useful life on recycling, compactness etc. have been addressed in this paper.

2. HYDROGEN AS A FUEL

Hydrogen is a clean fuel and an efficient energy carrier. Hydrogen is found in water, organic compounds and hydrocarbons such as petrol, natural gas, methanol and propane. Hydrogen is a colorless, odorless, tasteless, flammable gaseous substance. Hydrogen is high in energy content as it contains120.07 Kilo Joules/gram, which is the highest for any known fuel. However, its energy content compared to volume is rather low. This poses challenges with regard to its storage for civilian applications, when compared to a storage of liquid fossil fuels. When burnt hydrogen produces water as a byproduct and is therefore, environment Friendly as the greenhouse gases emission is curbed.

Hydrogen Production:
Several known technologies with the best potential for producing hydrogen to meet future energy demand fall into four broad categories as given below:

i). Thermo chemical processes like steam reforming where hydrogen is produced from hydrocarbons such as natural gas, naphtha, methanol etc. and also renewable energy sources, such as the gasification or pyrolysis of biomass, organic material which can be used to generate a fuel / gas that can be reformed into hydrogen.

ii). Electrolysis of water to produce hydrogen by passing an electrical current through it by conventional grid power or through renewable energy sources like solar, wind etc.

iii). The photo electrochemical (PEC) process produces hydrogen in one step, splitting water by illuminating a water-immersed semiconductor, with sunlight.

iv). Biological systems gradually use the natural photosynthetic activity of bacteria, green algae and fermentative characteristics of bacteria for production of hydrogen.

3. HYDROGEN STORAGE

Hydrogen storage is one of the key areas where significant developments are required to accelerate the use of hydrogen in transportation and stationary power generation applications. For transport applications and the major technical challenge for hydrogen storage is how to store sufficient amount of hydrogen for a convenient driving range before refueling, keeping in view the constraints of weight, volume, efficiency, safety, and cost requirements for on-board storage. In addition, storage will also be required at hydrogen production and hydrogen refueling stations.

Compressed Hydrogen:
Storing hydrogen under pressure has been done successfully for a very long time. These cylinders/tanks are being made from (i) steel (ii) Aluminum core encased with fiberglass and (iii) Plastic core encased with fiberglass. In stationary systems where weights and size are not important applications, traditional pressure tanks are an issue with regard to both weight and volume. The commercially
Used tanks store hydrogen at about 120-170 bar pressure as shown in fig 1.

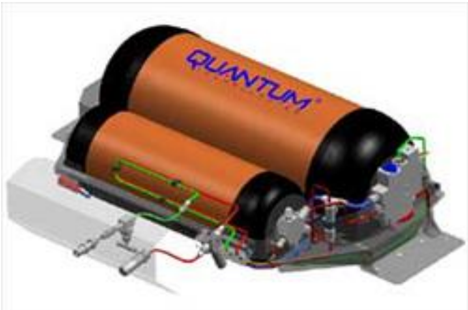


FIGURE 1. Compressed storage tank of hydrogen.

Liquid Hydrogen Storage:
Liquid hydrogen can be stored just below its normal boiling point of 20K at or close to ambient pressure in a double walled, super insulating Dewar's. Liquid hydrogen tanks do not need to be as strong as high-pressure gas cylinders although they need to be adequately robust for automotive use. However, hydrogen cannot be stored in liquid form indefinitely. All tanks, no matter how good the insulation, allow some heat transfer from ambient surroundings. The heat leakage rate depends on the design and size of the tank and in this case bigger is better. This heat causes some of the hydrogen to vaporize and tank pressure to increase. Stationary liquid hydrogen tanks are often spherical since this shape offers the smallest surface area for a given volume, and therefore presents the smallest heat transfer area. The storage tanks have a maximum capacity of about 5 bar.

Solid State Storage:
Some metals readily absorb gaseous hydrogen under conditions of high pressure and moderate temperature to form metal hydrides. In the metal hydride storage systems hydrogen becomes part of the chemical structure of the metal itself as shown in Fig 2. Therefore, solid state storage does not require high pressures or cryogenic temperatures for operation. In essence, the metals soak up and release hydrogen like sponge. Since hydrogen is released from the hydride for use at low pressure, hydrides are the most intrinsically safe of all methods of storing hydrogen.
Metal hydrides are required to be stored in tanks before actual use in a convenient manner. A metal hydride storage tank contains, in addition to a heat exchanger system, granular metal that absorbs the hydrogen like a sponge absorbs water. The heat system draws heat away when hydrogen is filled into the tank and applies heat when the hydrogen is taken out of the tank. The hydrogen is released from the metal hydride when heat is applied.

Issues in hydrogen storage:
The existing storage methos with some improvements may be adequate stationary power generation plants. However, the on-board storage requirement for vehicular applications is far more stringent. The present cost of on-board hydrogen storage systems is very high, as compared to the petroleum fuels. Low-cost materials and components for hydrogen storage systems are needed, as well as low-cost, high volume manufacturing methods.

The weight and volume of hydrogen storage systems are also high, resulting in inadequate vehicle range compared to conventional petroleum fueled vehicles.

4. HYDROGEN APPLICATIONS

Hydrogen can be used directly in internal combustion engines and turbines in place of fossil fuels or as a blended mixture with fossil fuels. It can also be used in the fuel cells to generate electricity. Hydrogen to electricity conversion efficiency in fuel cell systems, which are based on electro chemical conversion, is higher than thermal based conversion in internal combustion engines and turbines. Further, hydrogen's advantage in transport applications is especially significant because IC engines when running on low loads are less efficient, whereas fuel cells continue to remain very efficient even at low loads.

Hydrogen use in Internal Combustion Engines/Turbines:

1. Hydrogen has a wide flammability range in comparison with all other fuels. Therefore, hydrogen can be combusted in an internal combustion engine over a wide range of hydrogen-air mixtures, especially a lean mixture. Because of hydrogen's wide range of hydrogen flammability, hydrogen Can run on air-fuel ratios ranging from 34:1 (stochiometric) to 180:1. Hydrogen has very low ignition energy. The amount of hydrogen is significantly less than that required for petrol. This enables hydrogen engines to ignite lean mixtures and ensure easy ignition. Additionally, the final combustion temperature is generally lower, reducing the number of pollutants, such as nitrogen oxides, emitted in exhaust.
2. The auto ignition temperature of hydrogen allows larger compression ratios to be used in a hydrogen engine than in a petrol engine. However, hydrogen is difficult to ignite in a compression ignition or diesel configuration, because the temperatures needed for those types of ignitions are relatively high.
3. Hydrogen has high flame speed at stoichiometric ratios, which is significantly higher than that of petrol. This means that hydrogen engines can more closely approach the thermodynamically ideal engine cycle. At leaner mixtures, however, the flame speed decreases significantly. The stoichiometric ratio for the complete combustion of hydrogen in air is about 34:1 by mass which is much higher than 14.7:1 for petrol.

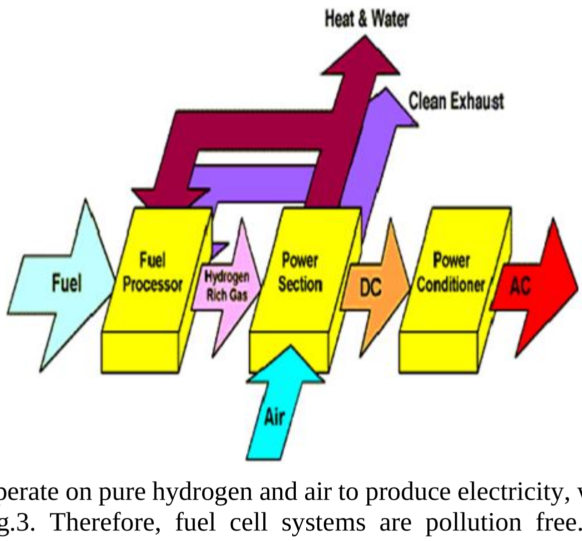
Status of Development of Hydrogen for IC Engine:

a) Small vehicles and generators, which work with internal combustion engines, have been modified to work with hydrogen. Hydrogen operated motorcycles and three wheelers have been developed and demonstrated.

b) A 10Kw, single cylinder spark ignition (petrol) engine generator set has been converted by IIT-Delhi to operate on hydrogen stored in cylinders.

Hydrogen Applications in Fuel Cells:

A fuel cell is an electrochemical device that converts energy into electricity and heat without combustion. Fuel Cell is similar to a battery as it has electrodes, an electrolyte and positive and negative terminals. But it is different from a battery as it does not release energy stored in the cell nor does it require recharging. Fuel cell continues to work as long as hydrogen is supplied. The use of fuel cells does not permit pollutants. Fuel cells are not heat engines, but significant amount of heat is also produced in a fuel cell system, which can be used to produce steam or converted into electricity using turbines.



Fuel cell systems generally operate on pure hydrogen and air to produce electricity, water and heat being the only by-products as shown in fig.3. Therefore, fuel cell systems are pollution free. Fuel cells are modular in construction and their efficiency is independent of size Fuel cells are the long-term option for hydrogen

applications both for transportation and power generation. Fuel cells especially for vehicular applications in the early stages of development and the country needs to identify the path for fuel cell development taking into account the technology development efforts going on worldwide and country's specific priorities and the achievements in this area so far.
These fuel cell power packs work with hydrogen and oxygen/air as fuel to produce electricity. The SPIC Science foundation has been working on development of Polymer Electrolyte Membrane Fuel cells (PEMFC). PEMFC systems are considered to be most suitable for use in vehicles due to their low operating temperature and better no-load characteristics.

5. RESEARCH AREAS ON HYDROGEN PRODUCTION AND STORAGE

Research on H_2 Production:
There are two main biological processes where hydrogen is released or appears as an intermediate product: Photosynthesis process using algae and photosynthetic bacteria and fermentation process based on anaerobic decomposition of organic matter. The fermentative hydrogen production is more advantageous as it can convert a variety of biomass resources; and it has the ability to recover energy from waste materials produced from agriculture and industry. At a pilot scale
about 1250-1400 litres per hour hydrogen production from distillery waste has been demonstrated. In photolytic process light energy is used to split water and produce hydrogen and potentially offer low cost and higher efficiency for collecting solar energy.

Research on Hydrogen Storage:
Further research is necessary on developing techniques for higher compression pressure beyond 300 bar, preferably up to 700 bar. This will also require research on materials required to store hydrogen. It may also be necessary to redesign the storage tanks for optimal space utilization in vehicles and also to allow sufficient range to the vehicles. The goal for research is hydrides and other solid storage materials should be to achieve 9 wt% storage by 2025.

6. CONCLUSION

Keeping in view the present status of development of hydrogen energy technologies in the country for stationary and vehicular applications and the need to systematically improve these technologies to make them commercially viable To begin with the technical developments pursued in developing hydrogen powered motor cycle, three wheeler and fuel cell hybrid van, it is necessary to take up a planned demonstration of these vehicles to monitor their performance and introduce further improvements in the performance of vehicles and all sub systems including the on-board storage system. This phase may be followed by demonstration of improved engineering models. The ultimate aim by 2025 should be to introduce such vehicles which are capable of providing technical performance matching with conventional petroleum driven vehicle.

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