UNIT – III
GASEOUS FUELS

HYDROGEN

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How the hydrogen is produced?

Hydrogen is produced from the steam reformation of natural gas, though it can be produced from almost any source containing hydrogen in its composition. Hydrogen can also be produced from the electrolysis of water.

Explain the methods of storing and handling of hydrogen?

Methods of storage and handling of hydrogen

There are generally three ways to store hydrogen in an automobile: as a gas dissolved in a metal (metal hydride), as a cryogenic liquid or as a compressed gas. Hydride storage is the simplest and the safest, but it increases vehicle weight and results in a severe fuel economy penalty.

Liquid hydrogen is light, but due to its low energy density occupies three times as much volume as gasoline. Storage as a compressed gas is inexpensive and provides for ease of operation but its weight and bulk is the main problem.

High pressure tank:

A high–pressure cylinder presently available for 7 m^3 of gas at standard pressure and temperature but stored at 150 atm weighs about 55g. The calorific value of hydrogen that can be accommodated in it equals that of 2.3 L of gasoline. This means the total weight of this fuel and tank on a calorific basis is 25 times as large that of gasoline. However, this method would be promising if new materials are developed that can withstand 1000atm pressure with the same weight.

Metal hybrids (mh):

Various new alloys have been developed for adsorption of hydrogen gas. TiFe has a hydrogen storage density of 1.95% (practically 1.5%). It is usually packed in a large number of rigid pipes several tens of millimeters in inside diameter because of the high pressure required for hydrogen charging and the need for heat exchange.

Discuss combustion properties of hydrogen?

The feature of hydrogen combustion that should be noticed first is that its calorific value is about 2.7 times as higher than gasoline when compared on a mass basis, but the latter is about 19% larger is combustion energy density on a volume basis of stoichiometric mixtures because of volume proportion of hydrogen in the mixture is greater than gasoline vapor.

Hydrogen has a wider flammability range and a higher burning velocity. When compared under the same running conditions, the time required to reach the maximum energy release rate after ignition is about 50% less in a hydrogen-air engine than in a gasoline-air engine. Hydrogen engines can be successfully operated with lean combustion mixtures of more than twice the theoretical air. However back fire can occur near stoichiometric air-fuel ratios.

Hydrogen has a very high flame speed (3.24 - 4.40 m/s), wide flammability limits (4.0 - 75 vol%), low ignition energy (0.017 mJ), high auto ignition temperature (520C), and flame temperature of 2050 C. Hydrogen has a very high specific energy (120.0 MJ/kg), making it very desirable as a transportation fuel.

What are the three methods of using hydrogen in S.I. engines? Discuss.

Three general fuel delivery systems have been used in hydrogen engines. These are: carburetion, inlet manifold injection, and direct cylinder injection. The first two techniques involve forming the fuel-air mixture during the intake stroke, either through the carburetor, or through the intake manifold. By directly injecting fuel into the cylinder, fuel delivery can be controlled to take place after the closure of the intake valve.

a. Carburetion: The simplest method of delivering fuel to a hydrogen engine is via a carburetor. Although carburetion is no longer a viable technology for modern vehicles, there were several advantages to using a carburetor for early hydrogen engine developments. This system is similar to that used for carbureted gasoline engines, which made it easy to convert a standard gasoline engine to a duel fueled gasoline/hydrogen or simply a hydrogen engine. This application does not require a sophisticated high pressure injector either. The disadvantage to this technique is that engines which use carburetors are more susceptible to irregular combustion due to pre ignition and back fire problems. Additionally, the power output of an ideal hydrogen engine with a carburetor is about 15% lower than that of a comparable gasoline engine.

b. Inlet manifold injection: Troubled by the dual problems of lower power output and continual pre ignition problems, a number of researches began exploring alternatives to carburetion. One solution to this problem is a technique called inlet manifold injection. This technique involves injecting fuel directly into the intake manifold rather than drawing fuel through the carburetor. Typically, the timing of the fuel injection is controlled so that the hydrogen is not injected into the manifold until after the beginning of the intake stroke, at a point where conditions are much less severe and the probability for premature ignition is reduced. The air, which is injected separately at the beginning of the intake stroke, dilutes the hot residual gases and cools off ant hot spots.

c. Direct injection: As hydrogen engines continued to progress, direct injection into the combustion cylinder stroke became more commonly used. Utilizing this technique, premature ignition during the intake stroke and backfire can be completely avoided if the fuel is injected after the intake valve is closed. The power output can also potentially be increased with this method to be 20% more than that of a gasoline engine and 42% more than that of a pre mixed gaseous hydrogen mixture.

What are the advantages of hydrogen as S.I. engine fuel?

1. Its calorific value is about 19% larger in combustion energy density on a mass basis.
2. The combustion characteristics of Hydrogen are best suited to I.C. engines. Its wide flammability (4 to 74% by volume) allows its utilization over extremely wide range of air fuel ratio without misfire.
3. Its gaseous form eliminates the problem of atomization, vaporization, evaporation, mixing and recondition.
4. Its low ignition energy allows utilization of spark, hot wire and diesel ignition with equally good performance.
5. Hydrogen is easily ignites and has a very high flame velocity. As a result combustion as to approach the instant combustion idealization of the Otto cycle.
6. Its low emissivity allows less heat losses to cylinder walls, thereby increasing thermal efficiency of the engine.
7. Its self ignition temperature (857 ° K) allows higher compression ratios to be used with out detonation.
8. It is extremely clear fuel, less toxic and no carbonization in the engine.

What are the demerits of using hydrogen as fuel in S.I. engines?

1) Any hot spot can cause a violent flash back into the inlet manifold. The wide ignition limits and low ignition energy of hydrogen are responsible for this.
2) There is a high rate of pressure rise.
3) Substantial portion of the energy of the hydrogen is consumed in compression or liquefaction.
4) Storage and handling of hydrogen is difficult.
5) Higher flame speed leads to pre ignition.
6) Hydrogen has an extremely low density. This necessitates a large volume to store enough hydrogen. And also the low energy density of hydrogen air charge makes power output lower.
7) Hydrogen is currently more expensive than most conventional or alternative fuels.
8) A problem with an I.C. engine running on hydrogen is that NOx are produced, and because they are very toxic pollutants, this causes significant emissions.

What safety precautions have to be taken while using hydrogen as fuel in I.C. engines?

From the perspective of safety, storing and transporting hydrogen safely is very similar to handling natural gas or propane. A safe hydrogen infrastructure will include a system of detectors to pinpoint leaks, alarms in order notify of leakage, and a system of cut-off points, all of which will be regularly tested.

Due to the highly explosive nature of hydrogen flame traps and flame arresters of the wet or dry variety, have to be provided between the hydrogen tank and engine. Crank case has to be positively vented to the atmosphere. Open flame and loose electrical connections have to be avoided where air surge tanks are used for air flow measurement, Bursting diaphragm have to be provided to vent accidental explosion.

Liquid hydrogen (lh$_2$):

Liquid hydrogen of the same calorific value can be stored in much the same manner as gasoline if a light weight, low pressure aluminum tank is used. As described later, this system makes it possible to perform fuel injection into engine cylinders and to cool the wall of the combustion chamber, which provides great advantages in improving engine output and thermal efficiency, lowering NO_x level, and minimizing backfire.

On the other hand, the LH_2 system has the following disadvantages.

(1) Special construction is required for the fuel tank to maintain the low temperature of -253° C.

(2) The specific gravity of LH_2 is o.o71, one-tenth that of gasoline, and hence a volume 3.8 times as large is required for the same calorific value. The tank must be a double wall, insulated structure weighting 4-5 times as much compared with that for gasoline, a weight similar to that in the MH system.

Explain the steps that are involved in the conversion of a C.I. engine to S.I engine for using hydrogen.

The self ignition temperature of hydrogen is 858 K. this means it is very difficult to ignite hydrogen by the compression ignition process. Due to this property, hydrogen is an extremely unsuitable fuel for conventional diesel engines. An attempt by several research workers has confirmed this expectation. At the same time, it would be highly desirable to develop a way to use hydrogen in diesel engines since them for a sizable portion of the engines used in transportation power generation, agricultural machinery, etc. attempts have been made to inject hydrogen under pressure into compressed air as in the normal diesel engine. The aid of glow plugs or very high compression ratios has been found to be necessary to initiate compression ignition.

The two methods used in feeding hydrogen into a diesel engine are the induction of hydrogen through the suction process and direct injection of hydrogen into the combustion chamber.

This method consists of inducting hydrogen along with the air into a diesel engine and employing a pilot spray of diesel oil to ignite the mixture. This dual-fuel method has the virtue of simplicity and flexibility since existing diesel engines can be easily converted to work on this method.

Brake thermal efficiency of the dual fuel engine is approximately the same as that of the diesel engine through out the range of operation. With lower diesel flow rates, there is a significant rise in thermal efficiency when hydrogen induction starts.

Engine output rises smoothly when hydrogen is inducted. There is, however, a noticeable point, that of knocking setting in at low diesel flow rates when hydrogen is increased beyond a certain limit. At the highest diesel flow rates tried, the thermal efficiency remains practically unaltered when hydrogen is inducted. Hence, overall, the hydrogen dual fuel engine behaves similar to the normal diesel engines.

Discuss the emission characteristics and performance characteristics while using hydrogen in S.I engines.

Emissions:

The most important advantage of hydrogen vehicles is that they emit fewer pollutants than comparable gasoline vehicles. For a hydrogen engine, the principle exhaust products are water and some nitrogen oxides (NO_x). Emissions of unburned hydrogen carbons, carbon monoxide (CO), carbon dioxide ($CO_{2)}$, oxides of sulfur (So_x), and smoke from hydrogen vehicles are either not observed or are much lower than those from gasoline vehicles.

If a hydrogen engine burns excess oil, hydrogen and CO emissions can become significant, but they are still less than the emissions can become significant, but they are still less than the emissions from a gasoline engine on a relative scale. Small amounts of hydrogen peroxide have also been observed in the exhaust of hydrogen engines that were operated very inefficiently. Such inefficiencies should not occur in a properly functioning engine, however. Hydrogen itself can also be emitted form an engine, but this is not a problem since hydrogen is nontoxic and not involved in any smog producing reactions.

NO$_x$ are the most significant emissions of concern from a hydrogen vehicle. Unfortunately, NO$_x$ emissions can have an adverse affect on air quality through the formation of ozone or acid rain. The NO$_x$ level can be brought down using several methods. Hydrogen engines can be run on very lean mixtures to reduce the combustion temperature, for example. NO$_x$ emissions can also be lowered by cooling the combustion environment using techniques such as water injection, exhaust gas recirculation.

Thermal Efficiency:

The overall thermal efficiency of a hydrogen engine is typically greater than that of a gasoline engine. The thermal efficiency can be improved by increasing either the compression ratio or the specific heat ratio. In hydrogen engines, larger compression ratios, than those used in gasoline engines can be used since the self ignition temperature of hydrogen is so high. Hydrogen engines can also operate more effectively under lean mixtures. This means that the temperature of the burnt gases can be lowered resulting in higher specific heat ratios. Thus, the combined effect of larger compression ratios and larger specific heat ratios increases the thermal efficiency for hydrogen fueled engines.

Power Output:

A comparison of the heat output of hydrogen and gasoline engines is shown in figure for various conditions. A stoichiometric mixture of gasoline and air and gaseous hydrogen and air pre mixed externally occupy 2% and 30% of the cylinder volume, respectively. Under these conditions, the energy of the hydrogen mixture is only 85% that of the gasoline mixture, resulting in about a 15% reduction in power. The problem is compounded even further when the engine is operated on lean mixtures or experiences pre ignition.

The power output of hydrogen can be improved using more advanced fuel injection techniques or liquid hydrogen as shown in figure. If liquid hydrogen is premixed rather than gaseous hydrogen, the amount of hydrogen that can be induced into the combustion cylinder can be increased by approximately one third and the power output increased by about 37%. The output can be further increased by directly injecting hydrogen into the cylinder under high pressure. Using this technique, the maximum amount of both air and hydrogen are introduced into the combustion chamber resulting in a 20% increase in power compared to a gasoline engine using a carburetor and a 42% increase in power compared to a pre mixed gaseous hydrogen mixture. It should be noted that the pressure provided by a hydride storage system would be insufficient for high pressure injection.

THANK YOU