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Hydrogen: The Fuel Of Future

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ABSTRACT: Hydrogen is a potential carrier that can turn our mineral - based economy into a hydrogen economy, which can provide fuel - efficient transportation. Main methods of research were reviewing literatures and individual researches. There are some problems with storage and transportation of hydrogen due to its low density. Is really hydrogen the best way to replace and solve our fuel problems, where for production we do not use renewable energy sources or clean sources? What exactly are the less efficient ways to produce and use hydrogen for transportation? Can hydrogen be the fuel of the future?

I. INTRODUCTION

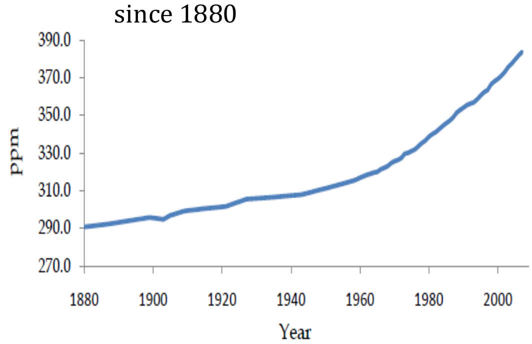
As a result of increased dependence on renewable energy sources, there has been lessons and interest in using a clean and friendly diet power. Although there is currently no current shortage of regular oil, e.g. coal, oil, and natural gas reserves provide harmful gases that help pollute our planet is not only moving forward but also helping to increase the earth's ozone layer a layer that protects our planet from UV rays. Therefore, research is being conducted to provide a stable place for future generations. One way to get clean energy is to use hydrogen. Hydrogen something that is full on Earth and stands out from other renewable species of power. This is because in such a small thing, it burns very well and helps to water production. The desired results can be obtained from any type of hydrogen, liquid and gas. One kilogram of hydrogen can produce energy the equivalent of a gallon of gasoline. This paper will discuss how hydrogen is a good source of energy without it all waste associated with normal oil. First the paper will discuss all of the methods to produce hydrogen that will be used in several processes and how it can be stored. In addition, a brief discussion of how hydrogen is stored, also known as hydrogen fuel cells, is used to supply electricity to electric vehicles. Finally, some points of benefit and the disadvantages of using hydrogen for energy will be noted.

II. LITERATURE

Hydrogen is the future fuel. As an active researcher of alternative fuels and a student of chemistry, we understand the importance of switching to a hydrogen economy. Hydrogen is an energy carrier that can be used in internal combustion engines or fuel cells that produce almost no greenhouse gas emissions. The only significant leak is water vapour. The production and storage of Hydrogen is currently undergoing extensive research. The solar-hydrogen system can provide ways of a completely inefficient hydrogen production system. Although methane conversion is currently a major route to hydrogen production, the emissions involved can also be much better controlled than our current fuel delivery system.

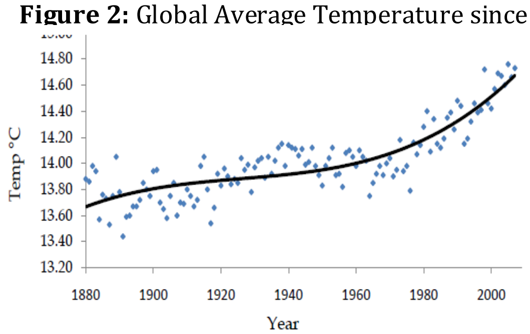
Climate change is a major problem that is clearly visible to most people. Rising CO2 levels have had a direct impact on global warming. As shown in Figures 1 and 2, CO2 levels have risen sharply over the past 200 years, as well as in global temperatures.

Figure 1: CO_2 Concentration since 1880



Source: Compiled by Earth Policy Institute, with long term historical data from Worldwatch Institute, Signposts 2001, CD-Rom (Washington, DC: 2001); 1960 to 2007 from NOAA/ESRL, "Atmospheric Carbon Dioxide - Mauna Loa,"

Figure 2: Global Average Temperature since 1880



Source: Compiled by Earth Policy Institute, with long term historical data from Worldwatch Institute, Signposts 2001, CD-Rom (Washington, DC: 2001); 1960 to 2007 from NOAA/ESRL, "Atmospheric Carbon Dioxide - Mauna Loa," at: www.esrl.noaa.gov/gmd/ccgg/trends/co2_data_mlo.html

Although I will explore the many factors involved in the hydrogen economy, I will not compare hydrogen with other fuels. Government policy will be briefly identified, but can be elaborated. The focus of the study is on the benefits of hydrogen and the current progress related to the disadvantages of hydrogen as fuel for transportation. Much work is underway to move from the fuel economy to the hydrogen economy. What are the pros and cons of this hydrogen economy? Who sponsors this study and what are their real goals? Is there a chance that hydrogen will be the fuel of the future and serve the purpose of air pollution?

1. Properties Of Combustion Of Hydrogen

A brief summary of previous papers is also being reviewed discussed based on the hydrogen fire base, burning, heat capacity and octane number. All the characteristics of the hydrogen will be discussed later.

Some properties of the hydrogen gas are given in table 1 comparing those with natural gas and methane .

Table 1. Hydrogen properties compared with methane and iso-octane properties. Data given at 300K and 1atm.

Property	Hydrogen	Methane	Iso-octane
Molecular weight (g/mol)	2.016	16.043	114.236
Density(kg/m^3)	0.08	0.65	692
Mass Diffusivity in air (cm^2/s)	0.61	0.16	~0.07
Minimum ignition energy (mJ)	0.02	0.28	0.28
Minimum quenching distance (mm)	0.64	2.03	3.5
Flammability limits in air (vol%)	4.75	5-15	1.1–6
Flammability limits(λ)	10–0.14	2–0.6	1.51–0.26
Flammability limits(ψ)	0.1–7.1	0.5–1.67	0.66–3.85
Lower heating value (MJ/kg)	120	50	44.3
Auto-ignition temperature in air(K)	858	723	550
Flame velocity(ms_1)	1.85	0.38	0.37–0.43
Higher heating value (MJ/kg)	142	55.5	47.8
Stoichiometric air-to-fuel ratio (kg/kg)	34.2	17.1	15
Stoichiometric air-to-fuel ratio (kmol/kmol)	2.387	9.547	59.666

1.1 Flammability limit: Flammability limit tells us about the gases which are combustible in the mixture; between these limits the mixture will be combustible. As, we can see from the Table 1 Hydrogen has a wide range of 4%-75% in air. When hydrogen is 4% in air it is seen that it is still combustible but burns incompletely. This value is related to the particular experiment that's why it can differ with the conditions. Mixture of hydrogen can be heavily lean or rich mixtures that can combust with air due to its wide ranges. Due to these reasons hydrogen engine can operate only in condition and burn hydrogen completely.
Final combustion temperature will also be lower as it has lower laminar burning velocity. As the laminar burning velocity of hydrogen operating on lean mixture is less than in the case when it operates on stoichiometric mixtures it will definitely reduce the pollutants like NO_x.

1.2 Minimum ignition energy: Minimum ignition energy is the minimum amount of energy required to ignite a combustible vapour or a gas. At room temperature the minimum ignition energy is very much lower than the other two gases methane and iso-octane as we can see in Table 1. For hydrogen concentrations of 22–26% only 0.017 MJ is obtained. Normally, capacitive spark discharge is used to measure minimum ignition energy, and thus is dependent on the spark gap [1]. The values given in the Table 1 are for the 0.5mm gap but the value of minimum ignition energy can rise up to 0.05 MJ and it can be more or less constant for 2mm gap when the concentration of hydrogen is 10%-50%. The benefits of having low minimum ignition energy are that hydrogen engine can easily ignite the lean mixture and prompt combustion can also happen. But the problem with low minimum ignition energy is that any hot spot can cause ignition in hydrogen without engine being start that can cause fire in vehicles.

1.3 Small quenching distance: Quenching distance is the distance between two plates that will just extinguish (quench) the flame front of a particular fuel oxidant mixture. When we compare quenching distance of hydrogen with other fuels like gasoline it is very less. As in Table 1 the distance given for hydrogen is 0.64mm whereas for methane it is 2.03mm and for iso-octane it is 3.4mm. This parameter can tell you that how much closer the hydrogen flames can get to the cylinder walls before they extinguish. If the distance is smaller it will extinguish the flame and it can backfire. Experimentally, from the relation between minimum ignitions energy and the spark gap size quenching distance can be derived or can be measured directly [1].

1.4 High flame speed, High diffusivity, Low density:

Hydrogen has high flame speed of 1.85ms^{-1} at stoichiometric ratios when compared to 0.38ms^{-1} of methane and 0.37ms^{-1}-0.43^{-1} of iso-octane also given in the Table 1. As the flame speed is high hydrogen engine can act as thermodynamically ideal cycle. Hydrogen also have high diffusivity which means that it can disperse more efficiently in air compared to others. This also shows that mixtures of hydrogen with air can be easily made and if it gets leaked somehow it will not be a pollutant in air and will disperse easily. Low density of hydrogen can cause some trouble for us as we need large volumes to store hydrogen in vehicles to provide sufficient range and it can reduce power output due to low energy density.

1.5 High auto ignition temperature:

Hydrogen has high auto-ignition temperature if it is compared with methane and iso-octane, which is 858K, in accordance with table 1.The essential parameter to evaluate engine compression ratio is high auto ignition temperature, since during compression process, the increase in temperature is concerned to compression ratio in view of Otto cycle as given in equation(1) below,

$$T_2 = T_1 \ (r^c)^{k-1} \qquad (1)$$

According to this equation, compression ratio depends upon T_2 which is defined as temperature during compression. The auto ignition temperature restricts T_2 to a certain temperature prevent the mixing of fuel air with auto Ignite before the spark, which is given by spark plug. If the auto ignition temperature rise to a higher value then it results in increment of T_2 and hence increase compression ratio as well. higher compression ratio is important for thermal efficiency of the system.

2. Methods Of Producing Hydrogen

2.1 Electrolysis:

Electrolysis can be simply explained as splitting or the decomposition of a water molecule into two hydrogens and one oxygen atom using an electrical current. As shown in Figure 3, two electrodes placed in a tank filled with water; a cathode containing a negative value in above the anode carrying the opposite side. Electrical power at that time passed through electrodes to begin to rot. From hydrogen is properly charged to the water molecule, it will leave the bells on the side there other methods used for water separation are: High temperature electrolysis and high pressure electrolysis. The first is the use of high the temperature that causes the separation of atoms [2]. This method is sometimes popular because the reaction is efficient and cheap to produce at high temperatures.

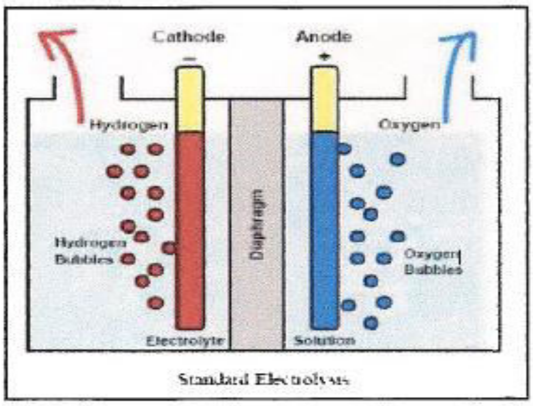


Figure 3: Hydrogen production using electrolysis. [3]

The latter is used using high pressure ranging from over a thousand psi.
Electrolysis is not considered renewable unless electrical power is generated using renewable energy as solar energy. However, hydrogen can be removed produced a small amount of fuel, over time which can be greatly reduced carbon emissions.

2.2 Gasification:

Gasification is the process by which coal or biomass is processed at high temperatures steam and oxygen-reacting pressure called gas and converted to gas components . The gas mixing effect contains hydrogen and carbon monoxide, which can be converted by steam to produce more hydrogen. Instead of burning coal, it is divided into its basic form and placed in a file of gas. Steam is then transferred to it, as mentioned, responding with coal chemicals to produce a clean way to convert coal into heat and electricity. Gas production it may seem to be the best way to produce hydrogen for use in cars. It can also be used to operate turbines and generate electricity. The combination in which it can use coal waste, in case of sulphur can be converted into hydrogen sulphide, gasification can be used in the chemical industry for better use of it. In addition, waste disposal it is much lower than the use of natural gas, which is considered to be a cleaner alternative petrol and coal.

2.3 Natural gas reforming:

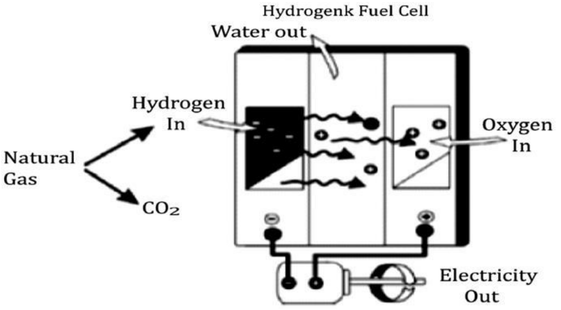
Synthetic gas (methane CH_4), a mixture of hydrogen, carbon monoxide, and a small amount the amount of carbon dioxide, produced by the reaction of natural gas with high temperatures smoke and pressure between 3 - 25 bars using a processor called corrector . This process is endothermic and requires more catalyst than carbon dioxide reactions to effectively produce hydrogen.
This method is the cheapest, most efficient, and most common method of extraction hydrogen from hydrocarbons

especially methane. The figure below shows the proposed reaction to hydrogen is obtained using a conversion method.

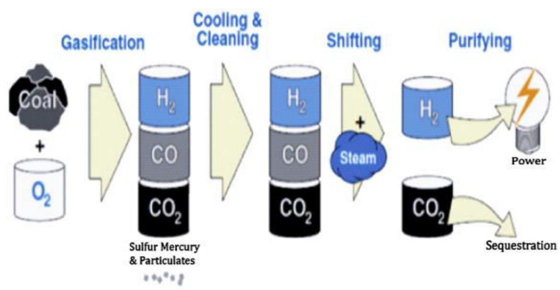
$$CH_4 + H_20 + heat \rightleftharpoons CO + 3H_2$$

Another way to extract hydrogen is to use a partial filling method . Hydrocarbons react with a small amount of oxygen in this process. This way considered faster than the method of conversion, however, also produces less the hydrogen value of the same amount of fuel used. So, it goes on it is better to use a conversion method to produce hydrogen on a larger scale. The equation below shows the reaction to receive hydrogen using partial fullness method.

$$2CH_4 + H_20 \rightleftharpoons CO + 2H_2 + heat$$



Hydrogen from natural gas for fuel cell application [4]



Coal gasification process [4]

2.4 Fermentation: Biomass is converted into sugar-rich feedstock that can be fermented to produce hydrogen. In other words, bacteria is sued for the production of hydrogen. Since some kind of bacteria can survive without light we can use them for production of hydrogen all day and all night. An example of this is by using Rhodobacter sphaeroides SH2C to convert molecular fatty acids into hydrogen [5].

2.5 Photolytic processes: Photolytic processes use energy from light to convert water into its components as hydrogen and oxygen. These days it offers long term potential for the production of hydrogen and very less harm to the environment. There are two processes which can be used for the production of hydrogen as photolytic processes namely, photo biological water splitting and photo electrochemical water splitting.

2.5.1 Photo biological water splitting: In this process, sunlight and special microbes are sources of hydrogen production, such as green and cyanobacteria. Hydrogen is produced as a product of these insects as part of the product of their natural process, just as plants produce oxygen during photosynthesis. Water separation image water separation is a long-term technology. Currently, in order to produce efficient and commercially available hydrogen, bacteria break down water very slowly, which should be used. There are many methods that scientists are studying to mutate microorganisms and to detect the presence of other organisms, which can produce high levels of hydrogen. The separation of the natural water image gives long-term sustainable hydrogen production with low environmental impacts, even in the early stages of research .

2.5.2 Photo electrochemical water splitting: Sunlight and special semiconductors are called photo electrochemical materials used to produce hydrogen, in this process.
In the photo electrochemical (PEC) system, light is used directly to separate water molecules into hydrogen and oxygen by a semiconductor. Various semiconductor materials operate at certain wavelengths of light and energy.
Researches are still going on to find the semiconductors with the perfect energies to split water into its components. Photo electrochemical water splitting offers long-term potential for sustainable hydrogen production with low environ- mental impacts, even though it is in very early stages of research [6].

3. Thermal Efficiency

The theoretical thermodynamic efficiency of an Otto cycle engine is based on the compression ratio of the engine as shown in Eq. (2).

$$\eta_{th} = 1 - \left(\frac{1}{r^c}\right)^{\gamma - 1} \qquad (2)$$

The compression ratio (r^c) is high or the specific heat ratio γ indicates the thermodynamic efficiency of the engine. Hydrogen (γ=1.4) has higher specific heat ratio than the gasoline (γ= 1.1) as gasoline has more complex structure than hydrogen. Result of which is that hydrogen engine has higher thermal efficiency when compared to gasoline engine. High thermal efficiency of hydrogen in an internal combustion engine is due to high RON and low flammability limit of hydrogen . In DI-H2ICE, We can achieve the thermal efficiency higher than 38.9% and the brake mean effective pressure 0.95MPa by injecting hydrogen at later stages of the compression stroke .

4. Emission Production

Hydrogen is considered as the ideal alternative fuel for conventional hydrocarbon fuels because of the reason that hydrogen can be produced from any kind of energy source and it is combusted without emitting carbon dioxide or any other harmful gas . The only potential pollutants from hydrogen combustion are the emission of nitrogen oxide NO_x hence this is very important to minimise the emission of nitrogen oxide from the combustion of hydrogen. Equations (3) and (4) shows the exhaust gas emission from hydrogen which is water and nitrogen oxide NO_x ,

$$2H_2 + O_2 \rightarrow 2H_2O \quad (3)$$

$$H_2 + O_2 + N_2 \rightarrow H_2O + N_2 + NO_x \quad (4)$$

Due to the high temperatures which are generated within the combustion chamber during combustion formation of oxides of nitrogen occurs. These higher temperatures causes nitrogen and oxygen to combine that is present in air . We can use the technique of rich lean combustion or staged combustion to reduce the formation of nitrogenous oxides in continuous combustion Burners such as gas turbines and boilers . We can also use water injection in the compression engine which may help to control the combustion temperature that will reduce the unwanted emissions. In many researches the effect of water injection is demonstrated with conventional hydrocarbon fuels .

The amount of NO_x formed depends on;

- The air/fuel ratio.
- The engine compression ratio.
- The engine speed.
- The ignition timing.
- Thermal dilution is utilized or not [7].

III. Conclusion

The important results of the study are given below:

- In terms of advantages hydrogen in internal combustion engines has many of the advantages in form of combustive properties but it needs detailed consideration of engine design to avoid any abnormal combustion which can be a measure problem in engine. If we take more precautions about this we can also improve engine efficiency power output and reduced nitrogenous oxides emissions.
- There are many sources and ways to generate hydrogen as an energy carrier. Nowadays it is mainly produced from fossil fuels and as a by-product hydrogen in chemical processes. But there are different type of sources for different type of hydrogen productions and it it can also vary in the terms of system applications.
- The best method to produce hydrogen is the one in which the process is simplest and it is easier to get the main sources, the cost is low and also environmentally safe.
- The deep study of production methods vehicle performances emissions and air pollution is needed before we start commercializing the hydrogen fuel and vehicles and these vehicles start competing with other type of fuel vehicles.
- Restart using hydrogen and other renewable sources in our daily life combine then it can prove reliable carbon emission will reduce dramatically. This can also help in the repair of ozone layer clean air and the well-being of our planet. All in all a better place will be left for the future generations.

IV. REFERENCES

[1] Verhelst S, Thomas W. Hydrogen-fueled internal combustion engines. Pro- gress in Energy and Combustion Science 2009;35(6):490–527.

[2] Jim, 0 'Brien, *"High Temperature Electrolysis for Efficient Hydrogen Production from Nuclear Energy".* Electrolytic Hydrogen Production Workshop. Feb 27, 2014.
Website:http://energy.gov/sites/prod/files/2014/08/f18/fcto_2014_ electrolytic_ h2_wkshp_ obrien1.pdf

[3] "Understanding Electrolysis". Website: http://www.viewzone.com/verichipx.html , Web. 28 May 2015.

[4] Anonymous. Secondary Energy Infobook 2008.

[5] Yongzhen Yao, *et.al,* '1Iigh hydrogen yield from a two-step process of dark-and photo-fermentation of sucrose". Vol. 32, pp. 200-206, 2007. 28 May 2015.
Website:http://cat.inist.fr/?aModele=afficheN&cpsidt=l8477081

[6]U.S Department of Energy, A Prospectus for Biological H2 Production; Retrieved on10-05-2012;Availableat:http://www1.eere.energy.gov/hydrogenandfuelcells/production/pdfs/photobiological.pdf .

[7] HICE. Hydrogen Internal Combustion Engine. 2010; Available from: www.ika.rwth-aachen.de/r2h/index.php/ICE.