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Research Paper

Hydrogen Production From Electrolysis, and Its Utilisation in Combustion Engine

Engineering

KEYWORDS : Electrolysis, Oxidation reaction, HICE, Preignition, Thermo chemical Condition.

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ABSTRACT

The study aims at the hydrogen generation / production system i.e. water electrolysis. The performance of the process under different catalyst, Concentration and conditions. This paper also deals with hydrogen internal combustion engine (HICE) for the sophistication of powering equipments and other auxiliary paraphernalia. As hydrogen imbibes gravimetrically more energy than gasoline about 2.5 times of gasoline so it is proved to be more efficient and environmental friendly fuel then gasoline or any other fossil fuels. The detail study of combustion reactions of HICE i.e. oxidation of hydrogen in combustion chamber and power generation using HICE. Also the technical challenges regarding HICE like preignition, Back fire etc...Etc... also taken in this paper.

1. INTRODUCTION

Due to increased energy requirements it is observed that fossil fuels i.e. conventional gasoline, diesel etc. are lowered in their level which causes a tremendous hike in their prices. A rise in fuel price is also a main reason for inflation. Conventional fuels are also responsible for green house gases and global warming. However several attempts have been made by scientist and engineers across the world to reduce energy cost and harmful emission. Engines are considered to be one of the biggest factors for the polluting gasses as its emissions mainly contain the green house gases. Energy generation using hydrogen is one of such attempt made by scientists. The earliest attempt to made HICE was in 1820 by Revered W. Cecil. However working with HICE is dangerous due to explosiveness of hydrogen gas. For hydrogen there are two easy and ongoing processes are available: water electrolysis and Biomass conversion. Both this process has different orientation of hydrogen generation hence both needs special and preferred environment as well as different technical skills for efficient performance.

2. Water Electrolysis:

Electrolysis is one of the oldest and most clean processes for hydrogen generation. In this process water is decomposed in to its two basic elements i.e. hydrogen and oxygen. First observation of his process was found in 1789.

At the initial stage acidic electrolysis was more popular but due to corrosive effect of acidic solution on electrodes alkaline electrolysis comes into existence. Potassium hydroxide is more popularly used as electrolyte for alkaline electrolysis. Oxygen and hydrogen gas can be obtained at noble metal electrode. Noble electrode is popularly used because of its inert nature that it does not take part in reaction and remains unconsumed throughout reaction. However erosion of noble metal due to rubbing action of acids/base present in electrolytic solution is there. But this erosion of metal electrodes is in very slow rate which will make a negligible change in maintenance cost.

Reactions involved:

$H_2O(l) \leftrightarrow H+(aq)+OH(aq)$..... (1)

Oxygen and hydrogen gas can be generated at noble metal electrodes by the electrolysis of water:

Positive Electrode (anode):

$4OH- \leftrightarrow 2H_2O+O_2+4e-$ ..... (2a)

Negative Electrode (cathode):

$2H+(aq)+2e- \leftrightarrow H_2(g)$..... (2b)

In water electrolysis there are no side reactions that could yield undesired byproducts, therefore the net balance is:

$2H_2O \rightarrow (4e-) \rightarrow O_2+2H_2$..... (3)

$2H_2O \rightarrow 2H_2 + O_2$ [Final Electrolysis step]

$2H_2 + O_2 \rightarrow 2H_2O$ [Combustion step]

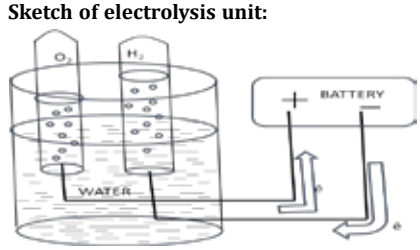
The Electrolysis of one mole of water can produce 1 mole of hydrogen and half mole of oxygen in their diatomic form. This process is to be presumed to be at 298K and one atmospheric pressure and relevant values are taken from table of thermodynamic properties.

Quantity	H_2O	H_2	0.5 O_2	Change
Enthalpy	-285.83 kJ	0	0	ΔH = 285.83 kJ
Entropy	69.91 J/K	130.68 J/K	0.5 x 205.14 J/K	$T\Delta S$ = 48.7 kJ

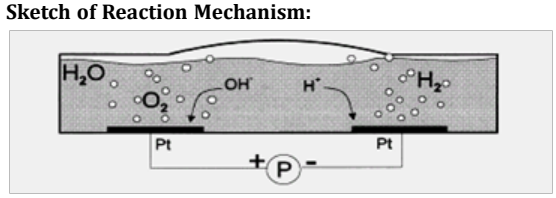
For 1kg of hydrogen generation we need 8.9368kg of water that is also equal to 8.9368 liters of water (Temp=4oC).

Diagram:

Sketch of electrolysis unit:



Sketch of Reaction Mechanism:



Hydrogen Combustion Engines:

The HICE are engines which uses hydrogen as a fuel. The earliest attempt to develop HICE was reported by Reverend W. Cecil in 1820. Working with hydrogen engine can be dangerous if proper precautions are not taken into consideration. Since hydrogen is one of the most explosive gas which needs very low minim ignition energy as .02MJ which is very low when compared to that of gasoline i.e. .25MJ.

Combustive Property of Hydrogen:

Combustive properties are the main basic reasons which lead hydrogen to be used as fuel in HICE. These properties are given below:

- Wide range of flammability.
- Low ignition energy.
- Small quenching distance.

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- High auto ignition temperature.
- High flame speed at stoichiometric ratios.
- High diffusivity.

Very low density.

All this above properties plays an important role in design of HICE. Theoretical Air fuel ratio for hydrogen is 34.33:1 (Gravimetrically) and 2.4:1 (volumetrically). But as intake of air for combustion will also draw nitrogen with it which will cause the formation of NOx after combustion. In hydrogen engine supplied with air 14.2kg of NOx is formed per KWH of power. To overcome this issue an injection of pure oxygen in combustion chamber is proposed in this paper. However as a safety approach hydrogen and oxygen must be separately injected in HICE so that no direct contact of hydrogen and oxygen is there before the combustion chamber. This arrangement also checks on the main problems caused in HICE i.e. preignition. Preignition is the process in which fuel get ignited before it is injected or come in combustion chamber.

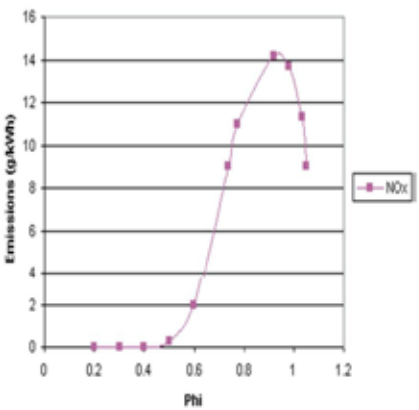

Figure:Emissions For A Hydrogen Engine.

Selected Engine conditions taken from experiment by verhelst et. Al

Engine experimental conditions	Data
Engine type	VOLVO (CVVT), Fuel injected.
Fuel Used	Hydrogen
Number of cylinders	4
Air fuel ratio	1(fixed)
Compression Ration	10.3:1
Displacement volume	1783cc
Engine Brake torque	40Nm(fixed)
Engine speed	1500~4500 rpm

The following equation shows the HICE combustion process using pure oxygen:

$2H_2 + O_2 \rightarrow 2H_2O$ +572.872 KJ. Theil and hartmann (2008) of BMW reported detailed emission of HICE. As theoretical amount of water required for production of 1kg of hydrogen is 8.9368kg so similarly 8.9364kg of steam is emitted for complete combustion of 1kg of hydrogen for an actual driving distance of 100km.

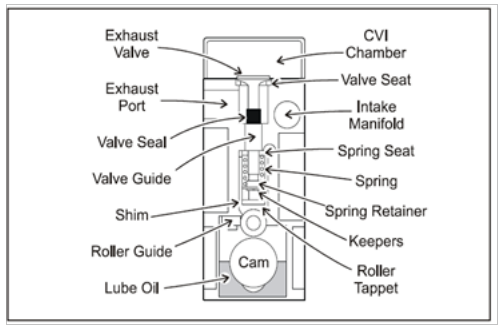

Figure: Constant Volume Injector.

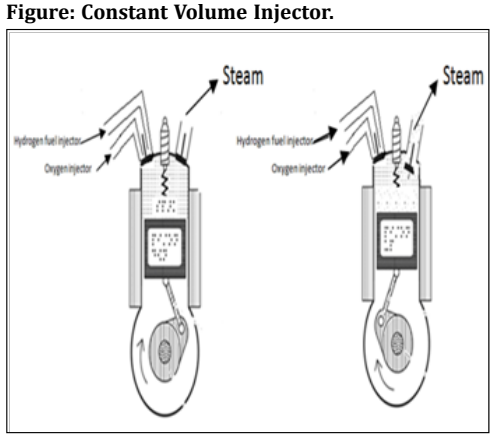

Figure: Hydrogen Combustion engine with separate hydrogen and oxygen injection system.

Above are given a commonly used design of Constant Volume Injector and proposed design of Hydrogen Combustion engine with separate hydrogen and oxygen injection system.

Conclusion:

It is concluded that hydrogen generation through electrolysis process is cleanest process for hydrogen generation. However hydrogen generation using biomass conversion is more efficient and economical process. Energy requirement for the electrolysis process can be obtained from solar cell, battery or any other power source. However biomass conversion process needs more initial cost for its auxiliary processes and it generates organic gases as a byproduct for hydrogen.

In HICE pure oxygen injection is more advantageous as it checks on preignition problem which further also reduces the chances for explosion of fuel pipes and hydrogen storage tank which results into severe damage of an engine as well as vehicle. Injection of pure oxygen for the combustion process also cease the formation of harm full NOx generation which is desirable condition for healthy environment.

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