Feasibility Study of Use of Water as A Fuel

C. S. Shroff[1] N. R. Patel[2] H. R. Mehta[3]
[1]Engineer [2]Associate Professor [3]Director
[1,2]Department of Civil Engineering
[1,2]BVM Engineering College, Gujarat, India [3]Happy Engineering, Gujarat, India

Abstract— Hydrogen is the future scope of Energy as the prices of fossil fuels is increases day by day. The main source of hydrogen is water. Hydrogen production can be done by alkaline water electrolyser using direct electricity. An acrylic box of 160 mm × 120 mm × 120 mm is used as reactor body. A set of different numbers of SS electrodes on anode as well as on cathode of size of 85 mm × 100 mm × 2 mm are connected to a SS plate by welding it with the other plates and joined with power supply. Two to five numbers of electrodes on anode and cathode has been used. Two Plastic casings of size of 65 mm × 100 mm × 100 mm are used to capture the processed gases generated from anode and cathode. The solution of KOH which works as an electrolyte is fed to the reactor in different percentage by weight of KOH (10%, 15%, 20%, 25%, 27.5%, 30% and 35%). There are mainly two types of electrolysers were used: A) Two separate chambers with two separator wall and 10 mm gap between them and, B) Two separate chambers with one common separator wall of size of only 8 mm. The generated hydrogen is then fed to the different applications as a fuel by maintaining proper pressure and flow. The generated oxygen is left to the surrounding. From this process 98.8% pure hydrogen is generated.

Key words: Water, Fuel

I. Introduction

Nowadays, the price of fossil fuels was increased in the recent past years, which cause the seeking of alternative energy. There are limited reserves available of fossil fuels. Two main activities have been raised because of technological advancement and the complexity between the energetic problems, technological, economic, environment, political and social aspects. The first activity is the smart use of the energy. Promote savings, avoid wasting and development of more efficient equipments are done in this activity. The second activity consists of the development of the renewable energies. The production of green energy has been increased impressively, especially in the wind and solar fields[9].

Hydrogen is a carbon free fuel; hence, it is an environmental friendly fuel. Hydrogen is present naturally in combined state; in both organic as well as inorganic compounds on Earth. It is present in as hydrocarbons, water and other substances. Hydrogen is scarcely present in the free molecular form; therefore, the elemental hydrogen is artificially produced. Hence its safe and environmentally friendly production is most important. Water electrolysis is one of the most efficient techniques to produce the hydrogen. An electrolyser uses electricity and breaks water into hydrogen and oxygen. Hydrogen can be considered as a direct energy source for fuel in automobiles and other applications where fossil fuel is used; and oxygen can be considered as a safe by-product[2].

II. Electrolyze

An ‘electrolyser’ is a cell which breaks water down into hydrogen and oxygen gasses by passing an electric current through the water. The gas generated through the process is called ‘hydroxy’ gas. Hydroxy gas is a mixture of hydrogen and oxygen. Hydroxy gas is highly explosive. It is much more explosive than hydrogen, and it is very much more dangerous than petrol vapour, which burning at least 1,000 times faster. A slightest spark will set it off immediately and exploding as little as a single cup full of hydroxy gas produces an explosion so loud that it can cause permanent hearing damage[10].

The safety devices and techniques which must be used with electrolyser is the most important. The main objectives during electrolyser operation are to keep an absolute minimum amount of hydroxy gas actually present in the system, and to prevent any spark reaching the gas.

The result of efficiency of the engine can be improved from the output from a simple electrolyser can be mixed in with the air used into the engine. This will reduce much pollution emissions. The eco-friendly hydrogen gas leads to removal of carbon deposits inside the engine, which promotes longer engine life. An advanced electrolyser is difficult to build and is likely to be heavy. There are many different types of electrolysis cells have been constructed. The different electrolysis cells can be divided into groups based on the electrolyte. Following table presents an overview of the different types of cells. All the cells presented in table are using water as reactant to produce hydrogen.

Type	Alkaline	Acidic	Polymer electrolyte	Solid Oxide
Charge Carrier	OH^-	H^+	H^+	O^{2-}
Reactant	Water	Water	Water	Water, CO_2
Electrolyte	Sodium or Potassium hydroxide	Sulphuric or Phosphoric Acid	Polymer	Ceramic
Electrodes	Nickel or SS	Graphite with Pt, Polymer	Graphite with Pt, Polymer	Nickel, ceramics
Temperature	80^0C	150^0C	80^0C	850^0C

Table 1: types of electrolysers and operating conditions

III. Methodology

Alkaline electrolyser (AEC) is a very mature technology that can be used as the current standard for large-scale electrolysis. The material that can be used as anode and cathode materials in these systems are made of nickel-plated steel or steel. The electrolyte in these systems is a highly caustic solution of potassium hydroxide (KOH). The ionic charge carrier is the hydroxyl ion, OH^-. A porous membrane to hydroxyl ions is used, which will not allow to pass hydrogen and oxygen which will also provide gas separation.

Key advantages of this technology are its maturity and its durability. Key disadvantages are its use of a highly caustic electrolyte and its inability to produce high pressure hydrogen. This inability to produce high pressure hydrogen for storage will lead to the need of a compressor, which leads to addition of cost and complexity to the system.

The cell reactions are:

$$4H_2O_{(l)} + 4e^- \rightarrow 2H_{2(g)} + 4OH^-_{(aq)} \quad (1.1)$$

$$4OH_{(aq)} \rightarrow O_{2(g)} + 2H_2O_{(l)} + 4e^- \quad (1.2)$$

$$2H_2O_{(l)} \rightarrow 2H_{2(g)} + O_{2(g)} \quad (1.3)$$

The main difference between original design and my design is that original design has a diaphragm or nothing, while, my design have two plastic casings that separate the generated gases with each other which did not generate hydroxy gas and pure hydrogen gas and oxygen gas is produced separately. So there is no need of any other separating mechanism.

The electrolyte is an alkaline solution in water, typically 30% potassium hydroxide. It is contained in a porous felt separator traditionally made of asbestos. The electrodes are made of nickel or nickel plated metal on which a catalyst is applied.

The performance of the alkaline electrolyser and the electricity to hydrogen efficiency can be increase by increasing the operation temperature to above 200 °C significantly. But, this will lead to lower stability of materials for operating at elevated temperature. To develop a suitable water electrolyser cell for large scale plant, it is necessary to develop suitable materials for the cell[11].

There are two types of electrolyser designed.

IV. Two Separate Chambers with Two Separator Wall and 10 mm Gap Between Them:

The two chambers which have size of 65 mm × 100 mm × 100 mm are joined in such way that the chambers have gap of 10 mm from every side. So the overall gap between two last electrodes is 36 mm.

V. Two Separate Chambers with One Common Separator Wall of Size of Only 8 mm:

The two chambers which have size of 65 mm × 100 mm × 100 mm are joined in such way that the chambers have only one common wall thick of 8 mm. So the overall gap between two last electrodes is 18 mm.

Fig. 1: Design of Electrolyser of *A* module

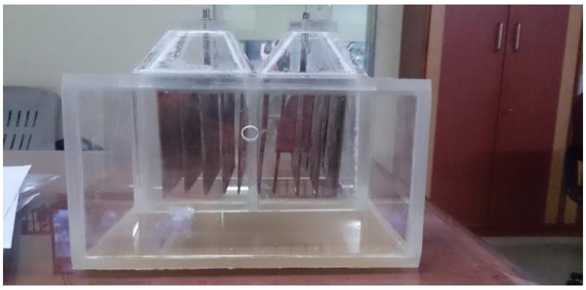

Fig. 2: Design of Electrolyser of *B* module

Transformer of 12 V, 20 A is used to supply DC power supply to the electrolyser. The water with KOH is fed and the electric current is paased through electrodes. The gases are generated from the upper side of the electrolyser. The gases are passed through flame arrester and non–return valve so that if the flame or spark is there in pipeline than it could be saved. Oxygen gas is released to the environment.

Fig. 3: Electrolyser Set-up

VI. Results

The power supply is supplied from dirrect grid which is passed through transformer which gives power of 240 W (12 V, 20A) of DC current. The water with KOH is fed and the electric current is paased through electrodes. The gases are generated from the upper side of the electrolyser. The gases are passed through flame arrester and non–return valve so that if the flame or spark is there in pipeline than it could be saved. Oxygen gas is released to the environment. In this research work, the percentages of KOH solution by weight is used to notice the optimum production of the hydrogen.

KOH % by Weight	Numbers of electrodes used on each side			
	2 plates	3 plates	4 plates	5 plates
10 %	1.61	2.83	4.72	6.25
15 %	1.61	2.97	4.78	6.37
20 %	1.63	3.26	4.93	6.54
25%	1.90	3.48	5.19	6.89
27.5 %	2.16	3.79	5.37	7.36
30 %	1.98	3.63	5.22	7.08
35 %	1.72	3.43	4.97	6.79

Table 2: Hygrogen generation in grams of system *A*

KOH % by weight	Numbers of electrodes used on each side			
	2 plates	3 plates	4 plates	5 plates
10 %	0.67	0.63	0.60	0.66
15 %	0.69	0.67	0.67	0.68
20 %	0.66	0.64	0.63	0.64
25%	0.63	0.66	0.66	0.66
27.5 %	0.68	0.63	0.67	0.67
30 %	0.70	0.68	0.70	0.70
35 %	0.72	0.69	0.67	0.66

Table 3: Power Consumption in kwh of system *A*

KOH % by weight	Numbers of electrodes used on each side			
	2 plates	3 plates	4 plates	5 plates
10 %	1.78	3.38	5.57	7.39
15 %	1.79	3.45	5.66	7.53
20 %	1.79	3.78	5.98	7.69
25%	2.21	3.98	6.23	7.84
27.5 %	2.43	4.18	6.46	8.10
30 %	2.11	3.96	6.25	7.89
35 %	1.87	3.73	6.02	7.63

Table 3: Hydrogen generation in grams of system *B*

KOH % by weight	Numbers of electrodes used on each side			
	2 plates	3 plates	4 plates	5 plates
10 %	0.62	0.73	0.72	0.64
15 %	0.67	0.69	0.67	0.66
20 %	0.60	0.63	0.66	0.63
25%	0.59	0.67	0.66	0.62
27.5 %	0.68	0.62	0.69	0.68
30 %	0.70	0.69	0.68	0.70
35 %	0.68	0.69	0.70	0.72

Table 4: Power Consumption in kwh of system *B*

These tables show that the optimum production of hydrogen can be obained by system *B* with 27.5% of KOH solution by weight. The system *B* using 0.68 kwh of power supply averagely and producing 102.5 grams of hydrogen gas from 1 litre of water. Thus, the efficiency of this system is 93.55%. Thus, the total cost to produce 1 kilogram of hydrogen is Rs. 300 nearly in system *B*.

VII. Conclusions

Thus, these processes for producing hydrogen is not feasible currently; but in near future with some modifications to the instruments could make it feasible to use as cooking fuel. These processes for producing hydrogen is not that much feasible currently as system *A* and system *B* producing hydrogen gas at Rs. 340 per kg and Rs. 300 per kg respectively. The cost to produce the LPG (Liquified Petroleum Gas) is approx. Rs. 30 per kg while, the cost to produce PNG (Piped Natural Gas) is Rs. 40 per kg. Generally, a household cylinder of 14.2 kg is works for a month that means averagely 0.5 kg of LPG is used daily, which, compared to hydrogen gas the daily usage is 0.1 kg.

In near future with some modifications to the instruments and electrolyser cells and mateials can make it feasible to use as cooking fuel. These modifications are changes in electrode material, changes in electrolyser cell, Changes in electrodes size to decrease power losses.

The use of nickel instead of SS electrodes will give more efficient use of electricity and this will lead to more production of hydrogen gas. Moreover, the temperature is slowly increase and corrosion of plates is slow.

The tables show that as the distance between the electrode plates is decreased the production of hydrogen is incresed.

The tables show that there is optimum hydrogen production while using 25% to 30% of KOH solution by weight.

Reducing or inceasing the thickness of electrodes according to the size of acrylic box will lead to reducing power losses which is helpful to increase the efficiency of the electrolyser.

Use of solar energy to run the electrolyser will lead to independent power supply system which will decrease the dependence on the Government.

Acknowledgement

The author acknowledge the support provided by the coaching staff of BVM Engineering College, Vallabh Vidyanagar. The author also acknowledge the support provided by the mentor **Mr. Hetal R. Mehta**, President, Surat Engineering Vikas Association. The author would like to thank **Ms. Rakhi Mehta**, Head Of Department, Chemical Engineering Department, SCET, Surat. The author would like to thank his parents to realize his potential to do the research.

References

[1] Dukic A and Firak M, "Hydrogen Production Using Alkaline Electrolyser and Photovoltaic (PV) Module", International Journal of Hydrogen Energy, 2011, 36, 7799-7806.
[2] Joshi A, Dincer I, Reddy B V, "Solar Hydrogen Production: A Comparative Performance Assessment", International Journal of Hydrogen Energy, 2011, 36, 11246-11257.
[3] Negrou B, Settou N, Chennouf N, Dokkar B, "Valuation and development of the solar hydrogen production", International Journal of Hydrogen Energy , 2011, 36, 4110-4116.
[4] Ursua A, Sanchis P, "Static-dynamic modelling of the electrical behaviour of a commercial advanced alkaline water electrolyser", International Journal of Hydrogen Energy, 2012, 37, 18598-18614.
[5] Ursua A, Marroyo L, Gubia E, Gandia L M, Dieguez P M, Sanchis P, "Influence of the power supply on the energy efficiency of an alkaline water electrolyser", International Journal of Hydrogen Energy, 2009, 34, 3221-3233.
[6] Douglas T G, Cruden A, Infield D, "Development of an ambient temperature alkaline electrolyser for dynamic operation with renewable energy sources", 2013, 38, 723-739.
[7] Ursua A, Martin I S, Barrios E L, Sanchis P, "Stand-alone operation of an alkaline water electrolyser fed by wind and photovoltaic systems", 2013, 38, 14952-14967.
[8] Wu X, Scott K, Xie F, Alford N, "A reversible water electrolyser with porous PTFE based OH^- conductive

membraneas energy storage cells", International Journal of Hydrogen Energy ,2014, 246, 225-231.
[9] Aranguren P, Astrain D, María M S, Rojo R, "Computational study on a thermoelectric system used to dry out the hydrogen produced in an alkaline electrolyser" ,International Journal of Hydrogen Energy ,2015, 75, 984-993.
[10] Kelly P J, "A Practical Guide to 'Free Energy' Devices", 9, 2005.
[11] Department of Chemistry, Technical University of Denmark, "Pre-investigation of water electrolysis", 2008.
[12] Garud S, Purohit I, "Making solar thermal power generation in India a reality: Overview of technologies, opportunities and challenges", The Energy and Resources Institute (TERI), India.
[13] Barbir F, "PEM electrolysis for production of hydrogen from renewable energy sources", International Journal of Hydrogen Energy, 2005, 78, 661-669.
[14] Ganguly A, Misra D, Ghosh S, "Modelling and analysis of solar photovoltaic – electrolyser – fuel cell hybrid power system integrated with a floriculture greenhouse", Energy and Building, 2010, 42, 2036-2043.
[15] Valverde R G, Miguel C, Martinez-Bejar R, Urbina A, "Optimized photovoltaic generator – water electrolyser coupling through a controlled DC – DC converter", International Journal of Hydrogen Energy, 2008, 33, 5352-5262.
[16] Bergen A, Pitt L, Rowe A, Wild P, Djilali N, "Transient electrolyser response in a renewable – regenerative energy system, International Journal of Hydrogen Energy, 2009, 34, 64-70.
[17] Atlam O, Kolhe M, "Equivalent electrical model for a proton exchange membrane (PEM) electrolyser", Energy Conversion and Management, 2011, 52, 2952-2957.
[18] Paul B, Andrews J, "Optimal coupling of PV arrays to PEM electrolysers in aolar – hydrogen systems for remote area power supply", International Journal of Hydrogen Energy, 2008, 33, 490-498.
[19] Derbal-Mokrane H, Benzaoui A, M'raoui A, Belhamel M, "Feasibility study for hydrogen production using hybrid solar power in Algeria", International Journal of Hydrogen Energy, 2011, 36, 4198-4207.
[20] Zhang H, Su S, Chen X, Lin G, Chen J, "Performance evaluation and optimum design strategies of an acid water electrolyser system for hydrogen production", International Journal of Hydrogen Energy, 2012, 37, 18615-18621.
[21] Ghribi Dj, Khelifa A, Diaf S, Belhamel M, "Study of hydrogen production system by using PV solar energy and PEM electrolyser in Algeria", International Journal of Hydrogen Energy, 2013, 38, 8480-8490.
[22] Ural Z, Gencoglu M T, "Design simulation of a solar hydrogen system for different situation", International Journal of Hydrogen Energy, 2014, 39, 8833-8840.
[23] USNRC Technical Training Center, "Nuclear Power for Electrical Generation".
[24] Fan Z, "Tidal Power Energy".
[25] Chen F F, "The Future of Energy I: Fossil Fuels", 2011.

A. Links:

[26] http://www.conserve-energy-future.com/How FossilFuelsWorks.php
[27] http://www.edfenergy.com/energyfuture/generation-wind
[28] http://www.ucsusa.org/clean_energy/our-energy-choices/renewable-energy/how-geothermal-energy-works.html#.VKJ3_l4BQ
[29] http://www.edfenergy.com/energyfuture/generation-hydro
[30] http://www.mpoweruk.com/fossil_fuels.htm
[31] http://greenterrafirma.com/solar-thermal-for-electricity.html
[32] http://kenergywind.com/uat2/wind_technology/functioning.html
[33] http://www.intechopen.com/books/new-developments-in-renewable-energy/orc-based-geothermal-power-generation-and-co2-based-egs-for-combined-green-power-generation-and-co2
[34] http://www.mpoweruk.com/hydro_power.htm
[35] http://www.atlanticaenergy.org/hydroelectric

