Design of Dry HHO cell to Produce Hydrogen using Electrolysis

G. S. Almassri¹, Khalid M H Jaballa², Benur Maatug³, Saeed Alqaed⁴

¹,²,³ Department of Mechanical engineering, Faculty of Engineering Gharaboulli, Elmergib University.
⁴ Department of Mechanical Engineering, College of Engineering, Najran University, Najran 61441, Saudi Arabia.

¹gsalmasri@elmergib.edu.ly, ²Kmjaballa@elmergib.edu.ly, ³bmmaatug@elmergib.edu.ly,
⁴Saeed.alqaed@gmail.com

Abstract

HHO dry cell means the cell that can separate the Oxygen and hydrogen from water molecules by DC electricity. In this paper, a simple dry HHO generation system has been designed and constructed. This system was used to investigate the effects of the electrical power and the reaction time on the production of hydroxy gas (HHO). In this experiment, the ammonia hydroxide is used as electrolyte with parallel plate of 316L-grade stainless steel as electrode. A 12-volt battery was used as an electrical power source in the experiment. For the certain electrolyte strength, the results obtained showed that, increasing in the power and the time of reaction leads to increase the yield of HHO gas, however the energy consumption to produce one liter of hydrogen is not dependent on the value of the current. Also, the results showed that, the energy consumption for the production of one kilogram of hydrogen is about 70.5600MJ. The results compared with that calculated using “Biggs HHO calculator” and was found in good agreement. In this experimental work, the ammonia hydroxide has been selected as the electrolyte of the system, because of its higher productivity of HHO compared with other common electrolytes such as sodium hydroxide (NaOH), and sodium carbonate (Na2CO3) which are used in this kind of systems. On the other hand, it was observed that the ammonia hydroxide caused excessive corrosion which is considered as disadvantage of the ammonia hydroxide.

Keywords: Dry HHO cell, Electrolysis of water, Wet HHO cell.
INTRODUCTION

Hydrogen and HHO generator are seen by many as one of the key solutions for the 21\textsuperscript{st} century, by allowing a clean efficient production of power to reduce air pollution from several primary energy sources such as fossil fuel. Even though energy systems based on hydrogen can build bridges to the future, but the challenge of planning a cost-effective, and efficient transition is hugely difficult. Furthermore, very large capital and human investments will need many years before coming to make a great achievement. However, starting to explore this path result in a more sustainable future. In a fact, hydrogen is not a primary energy source. It is an energy carrier. Initially, it is produced by using technologies existing energy systems such as the gamification technology based on different conventional primary energy carriers and sources like coal and natural gas, or by building a renewable energy system that is more sustainable and reliable will benefit from solar and wind energy by using electrolysis technologies.[1-2]. Many experiments were carried out to optimize the performance of a dry HHO cell through changing the variety of setups such as alternating the distance between the plates, by using different electrolyte concentrations, and different current values [3]. The electrolytes with different concentrations, and how much of the current value across the electrolyte to produce hydrogen in a cell are focused by Rusdianasari & Dewi [4]. Abhishek et al [5] have studied the basic properties of gas generated through electrolysis of water and then used this gas in the bike as a fuel supplement with gasoline by mixing it with air. The HHO reactor was made from high grade stainless steel and NaOH was used as an electrolyte. If there is a possibility to produce, hydrogen through water electrolysis by using a Dry HHO Cell and studying its potential by a design, a building, an experiment, and also trying development in the cell to produce much more hydrogen for longer periods.

METHODOLOGY

Hydrogen is the most abundant element in the universe however on earth it is found in compounds. There are many methods of obtaining hydrogen by decomposing other compounds.

In water electrolysis, the electric current splits distilled water into hydrogen and oxygen which is a simple electrochemical process that can be carried out. In this case, the ammonium hydroxide solution (NH4OH) was added for increasing the effectiveness of the chemical reaction in the HHO generator for more separation to obtain pure hydrogen gas. To produce a large amount of hydrogen gas, there are many types of water electrolysis can produce hydrogen gas such as wet cell and dry cell HHO generators. However, the water electrolysis process is costly, because the electrolysis equipment is required high-cost materials. Moreover, the results from a chemical reaction in HHO cell generator have a lot of problems cause corrosion and damage on layers special in a wet
HHO cell model because the electronic connections are under water, and their surface will slowly be oxidized by the electrolyte.

HHO cell is often referred to as a gas generator, the HHO generator is an interesting technology. It uses electrolysis to split water (H2O) into its base molecules, 2 hydrogens, and oxygen molecule. Using a dry HHO cell to produce the hydrogen by this name could be misleading as this electrolyzing cell uses the water same as any other electrolyzing unit [6]. There are many advantages and some attributes of this cell that makes it easier to design and handle compared to a wet HHO cell. Actually, with dry HHO cells, the plates are separated with rubber seals used to stop the water from leaking from the cell, the electrical connections, and the edges of the plates are not immersed in the electrolyte compared to the wet HHO cells where the whole unit is underwater that making usage more electrolytes compared with dry cells. Therefore, the volume and the weight of the cell are smaller in dry cells compared to wet cells [7]. finally, for making sure the gas goes out of the cell and the fluid flows between the layers of the plates, there are many holes in each plate on the top for the gas, and the bottom for the electrolyte as shown in Figure (1). By using water electrolysis, an electric current is applied to cause a chemical reaction in the dry HHO cell, in this case, it called "the electrolytic cell (the conversion of electrical energy into chemical energy) " [3]. Hence, hydrogen produced through this process which is the most common method of producing hydrogen and Oxygen regarding to the cost compared with other methods; it does not produce environmental pollutants [9]. Inside the dry HHO cell, the layers of plates are used as the medium to electrolyze water after supplying the cell with DC by a battery, or another electric supply such as a solar panel [2].

![Figure (1) electrolyte and gas supply connections](image)

While the electrochemical reaction started, water molecules take place decomposition and water becomes H₂ and O₂. Therefore, these electrodes are functioning as a cathode (+) and anode (−) through electrolysis prose, the negative ion will be attracted to the cathode, and the positive ion in the electrolyte solution will be attracted to the anode [7].

Net Reaction: $2 \text{H}_2\text{O} (l) + \text{electricity} \rightarrow 2 \text{H}_2 (g) + \text{O}_2 (g)$ \hspace{1cm} (1)

Cathode (reduction): $2 \text{H}_2\text{O} (l) + 2\text{e}^- \rightarrow \text{H}_2 (g) + 2\text{OH}^- (aq)$ \hspace{1cm} (2)
Anode (oxidation): 2 H_2O (l) → O_2 (g) + 4 H^+ (aq) + 4e^- \hspace{1cm} (3)

**Design and Components**

Dry HHO cell has been designed and manufactured in a laboratory and workshop, where all materials and parts were used in manufacturing obtained from the local market.

Dry HHO cell consists of several layers of metal that have a high conductivity of electrical current, in this case, the stainless steel 316L was used, Table (1) is showing the properties of the stainless steel 316L [9].

**Table (1) AISI316L stainless steel property**

<table>
<thead>
<tr>
<th>AISI 316L Stainless steel Property</th>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elastic Modulus</td>
<td>2×10^{11}</td>
<td>N/m²</td>
</tr>
<tr>
<td>Poisson’s ratio</td>
<td>0.256</td>
<td>N/A</td>
</tr>
<tr>
<td>Shear Modulus</td>
<td>8.2×10^{10}</td>
<td>N/m²</td>
</tr>
<tr>
<td>Denstiy</td>
<td>8027</td>
<td>Kg/m³</td>
</tr>
<tr>
<td>Tensile Strength</td>
<td>4.85×10^{8}</td>
<td>N/m²</td>
</tr>
<tr>
<td>Yield Strength</td>
<td>1.7×10^{8}</td>
<td>N/m²</td>
</tr>
<tr>
<td>Thermal Expansion Coefficient</td>
<td>1.65×10^{-5}</td>
<td>K</td>
</tr>
<tr>
<td>Thermal Conductivity</td>
<td>14.6</td>
<td>W/(m.K)</td>
</tr>
<tr>
<td>Specific Heat</td>
<td>450</td>
<td>J/(kg.K)</td>
</tr>
<tr>
<td>Material Damping ratio</td>
<td>N/A</td>
<td></td>
</tr>
</tbody>
</table>

The shape and size of the dry HHO cell are based on the amount of hydrogen gas required. The cell contains strips of the rubber between each layer of plates which are used as an insulator (spacer) to prevent metal electrodes contact with each other as shown in Figure (2).
The layers of plates with rubber strips were arranged and fixed until had become a small chamber to hold distilled water mixed with the solution of ammonia hydroxide. Each side of the dry HHO cell is closed by two sheets of plates made by pressurized glass resistant to the pressure and heat. The cell is fixed using bolts. Electrical wires are put on to transmit electrical current. A water tank, and tubes to carry water were put on as shown in Figure (3).

**Figure (2) the strips of the rubber in HHO cell**

**Figure (3) the main elements of HHO dry cell**

**Structural Design Approach**

The HHO cell used 19 plates with a hexagonal shape, height 15 cm, width 15 cm, and the size of the edges 7.5 cm. A 20 circle strips of rubber of 3 mm thickness, and 12 cm diameter works as insulator are arranged as shown in Figure (4). There are two holes for each plate to pass gas and water into the cell.

**Figure (4) the design of HHO cell**

Two plastic sheets (20 cm × 20 cm × 1 cm) were used as cover. 8 holes were made inside the glass sheets for anchoring metal plates in the cell by using nuts. Figure (5) shows the image of the dry HHO cell used in the experimental work.
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Experiment

The experiment taked the following procedure

1) Preparation of the solution, (ammonia solution and distilled water with a ratio of 0.3-liter ammonia to 3 liters distilled water).
2) Experiments runs using a battery of 12 volts as an electrical power source for electrolysis.
3) The voltage was constant (from batary), and the current was recorded
4) The HHO was collected and measured for every one minute. Water displacement method was used for measuring the gas production from dry HHO cell. The gas generated is filled in a plastic bag submergeg in a basin filled with water.

RESULTS AND DISCUSSIONS

The main aim of this research is to evaluate the energy consumption for the production of one kilogram of hydrogen. Table (2) presents the results were obtained from the experiments. The results showed that the energy consumption to produce one liter of hydrogen is not dependent on the value of the current see Table (2).
Table (2) the results of the experiment

<table>
<thead>
<tr>
<th>time</th>
<th>Voltage (Volte)</th>
<th>Current (Amp)</th>
<th>Power (Watt)</th>
<th>H+O production (L/m)</th>
<th>(W/L) for 1 m</th>
<th>Calculated (H+O) using Bigges calculator (W/L) for 1 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>First min</td>
<td>12.8</td>
<td>16.5</td>
<td>211.2</td>
<td>3.37</td>
<td>62.67</td>
<td>3.101</td>
</tr>
<tr>
<td>Second min</td>
<td>12.8</td>
<td>17.9</td>
<td>229.12</td>
<td>3.66</td>
<td>62.60</td>
<td>3.364</td>
</tr>
<tr>
<td>Third min</td>
<td>12.8</td>
<td>20</td>
<td>256</td>
<td>3.84</td>
<td>66.66</td>
<td>3.758</td>
</tr>
<tr>
<td>Fourth min</td>
<td>12.8</td>
<td>24</td>
<td>307.2</td>
<td>4.915</td>
<td>62.50</td>
<td>4.510</td>
</tr>
<tr>
<td>Fifth min</td>
<td>12.8</td>
<td>26</td>
<td>332.8</td>
<td>5.324</td>
<td>62.55</td>
<td>4.886</td>
</tr>
<tr>
<td>Sixth min</td>
<td>12.8</td>
<td>30</td>
<td>384</td>
<td>6.144</td>
<td>62.5</td>
<td>5.262</td>
</tr>
<tr>
<td>Seventh min</td>
<td>12.8</td>
<td>32</td>
<td>409.6</td>
<td>6.96</td>
<td>58.85</td>
<td>6.013</td>
</tr>
<tr>
<td>Total 7 min</td>
<td>2129.92</td>
<td>34.213</td>
<td></td>
<td>Av= 62.61</td>
<td></td>
<td>Av= 68.9</td>
</tr>
</tbody>
</table>

From Table (2) the total amount of mixture hydrogen and Oxygen is 2129.92 W it is calculating every minute the mean for every minute.

The mean = (2129.9/7) = 304.274 W

The amount of energy every minute = 304.27 * 60 = 18256.46 J

The total production is 34.23 L

The energy for every $m^3 = [18256.46 \times 7] / [(0.03423 \times 2) / 3] = 5638023.5 J/m^3 = 5.638 MJ/m^3$

The hydrogen density at 30°C = 0.0799 kg/m$^3$

The energy for every kg = (5.638/0.0799) = 70.5635 MJ/kg

that mean, the energy consumption for the production of one kilogram of hydrogen is about 70.5600 MJ.

Figure (6) shows the comparison between the experimental and that from “Biggs HHO calculator”.

Even the Biggs calculator based on the hydroxide solution as electrolyte, the results still shows a good agreement where in this experimental work, the ammonia hydroxide has been selected as the electrolyte of the system.
It was observed that the ammonia hydroxide caused excessive corrosion which is considered as disadvantage of the ammonia hydroxide. Using mixture of distilled water and potassium hydroxide is good to avoid excessive corrosion and chemical reaction of the metals. Also, low gas production is observed at the starting of experimental which is may be due to the much of water in the cells of the system, however the generation of the gas continuous for a long period about 50 minutes; this makes the rate of hydrogen production in the dry cell is relative higher than other types.

**CONCLUSION**

1. In this experiment ammonia hydroxide is used because of its higher productivety of HHO compared with other common electrolytes such as sodium hydroxide (NaOH), and sodium carbonate (Na2CO3). On the other hand, it was observed that the ammonia hydroxide caused excessive corrosion which is considered as disadvantage of the ammonia hydroxide.

2. The results compared with that calculated using “Biggs HHO calculator” and was found in good agreement.

3. The results showed that the energy consumption to produce one liter of hydrogen is not dependent on the value of the current

4. the results showed that, the energy consumption for the production of one kilogram of hydrogen is about 70.5600MJ.
RECOMMENDATIONS

1- To give the best possible amount of hydrogen gas mixture (HHO), distilled water should be used with potassium hydroxide or sodium hydroxide.

2- Using electronic devices called (PULSE-WIDTH MODULATION) to control the current passing through the cell.

3- Stainless steel 316 L is better than Stainless steel 304 in terms of its corrosion resistance and terms of chemical properties.

4- The resulting HHO gases can theoretically be used to power internal combustion engines and can also replace butane gas used in homes and restaurants.

5- It is preferable to use plastic glass because it is better than normal glass in terms of its resistance to pressure and fixation.

6- Using the electricity regulator to avoid the high consumption of electrical current.

REFERENCES


الخلايا الجافة لإنتاج الهيدروجين يستخدم المحاليل HHO
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1قسم الهندسة الميكانيكية، كلية الهندسة الفرقة بولمي، جامعة المرقب، ليبيا.
2قسم الهندسة الميكانيكية، كلية الهندسة، جامعة نجران، السعودية.

ملخص البحث
الخلايا الجافة HHO هي الخلايا التي يمكنها فصل الأكسجين والهيدروجين من جزيئات الماء عن طريق الكهرباء المستمرة. في هذه الورقة، تم تصميم وبناء نظام توليد HHO جاف بسيط. وقد استخدم هذا النظام لدراسة تأثير الطاقة الكهربية وقت التفاعل على إنتاج غاز الهيدروجين. في هذه التجربة، تم استخدام هيديروكسيد الأمونيا كإلكترولفيت مع لوحة متزامنة من الفولاذ المقاوم للصدأ من فئة 316 لـ16 كفطط كهربائي. واستخدمت بطارية بقوة 12 فولت كمصدر للطاقة الكهربية في التجربة. بالنسبة لقوة الماء بالكهرباء، أظهرت النتائج التي تم الحصول عليها أن زيادة في الطاقة وقت التفاعل تؤدي إلى زيادة إنتاج غاز الهيدروجين، ولكن استهلاك الطاقة لإنتاج نتر واحد من الهيدروجين لا يعتمد على كمية التيار. كما أظهرت النتائج أن استهلاك الطاقة لإنتاج كيلوغرام واحد من الهيدروجين حوالي 70.6000 ميجا جول. النتائج بالمقارنة مع تلك المحسوبة باستخدام حساب "Biggs" ووجدت في اتفاق جيد. في هذا العمل التجريبي، تم اختيار هيديروكسيد الأمونيا كإلكترولفيت للنظام بسبب ارتفاع تأجيجه من مقارنة مع الألكتروليات الشائعة الأخرى مثل هيديروكسيد الصوديوم (NaOH)، والكربونات الصوديوم (Na2CO3) التي تستخدم في هذا النوع من النظم. من ناحية أخرى، لوحظ أن هيديروكسيد الأمونيا تسبب التآكل المفرط الذي يعتبر عيب هيديروكسيد الأمونيا.

الكلمات المفتاحية: خلية HHO، خليية HHO الجافة، خليية HHO الرطبة، التحليل الكهربائي للماء.