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HHO Gas Generation in Hydrogen Generator using Electrolysis

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Abstract. Recently some researches concerning how to produce HHO gas using electrolysis have been conducted by using several methods and parameters. The problems were the conditioning of hydrogen generator to produce HHO gas that can affect the efficiency of electric current applied on the equipment. The surface of the anode and cathode used in a hydrogen generator have to be considered. Based on Faraday Law, the number of particles produced by the electrode is proportional to the amount of electric current applied to the electrolysis cell. After some calculation, the surface of the stainless steel electrode used in the hydrogen generator was 66 cm^2. This research conditioning is focused on the variation of electrolyte concentrations used and how much electric current applied to hydrogen generator. Variations of electrolyte concentrations and applied electric current were conducted to see the relation between those parameters and HHO gas produces, and finally, the best set up was achieved to get the highest volume of HHO gas by electrolysis. The best set up was electrolyte concentration of sodium hydroxyl was 0.05 M and applied current was 15 A to produce 0.1028 LPM HHO gas with the electric current efficiency of the hydrogen generator 89.13%.

1. Introduction

Energy has become a basic need for human and researchers keep on aiming for an efficient method of energy conversion. Conventionally, wood, coal, and petroleum are used to generate power. However, these materials are diminishing after being exploited for ages. Therefore, scientists have to keep on researchingin finding the new energy resource to overcome this problem. This new energy is called renewable energy.

In a quest for finding the solution for this energy problem, we have to explore nature more. Natural gas has been considered as the alternative, and so has the coals. However, natural gas and coals are also considered as fossil fuel, or unrenewable energy, therefore these choices are not sufficient to fulfill the energy needs in the future. Many efforts have been made to substitute hydrocarbon energy into the new alternative of renewable energy. Among the alternative energy are solar energy, the energy potential of water, and biomass energy. Hydrogen energy is one of the most researched among those alternatives since hydrogen is the most found element on earth although it comes in a compound. Hydrogen can be readily applied to substitute hydrocarbon fuel without changing the current machine structure, causing high heat, and the emitted emission is close to zero [1-4].

To convert water into hydrogen fuel, we need an electrolyzer. The electrolyzer is a machine or equipment to separate water to be hydrogen and oxygen and create brown gas. This machine is also called a hydrogen generator. Electrolysis is the process to separate molecule into its original

elements by letting the electric flow on it, while water electrolysis is the process of separating water molecule back to its original elements by letting the electric flow on it. This electrolysis creates HHO gas [5]. HHO gas known as brown gas is obtained from the electrolysis process of water. If the electrolyte used is a base solution such as KOH, an alkaline reaction will occur. In an alkaline reaction, the reduction reaction occurs at the cathode where the water molecule binds electrons (e-) so that it breaks into hydrogen gas (H2) and OH- anions. The OH-anion is then attracted to the anode side and split into oxygen gas and H2O molecules. Hydrogen gas has several characteristics, which are colorless, flammable, very light, and very easy to react with other chemicals. However, HHO gas in normal conditions will not burn on its own without fire. The efficiency of electrolysis equipment can be improved by considering the effective surface of electrodes. Therefore when electricity is applied to the electrode, the available current can be minimized [6-8].
Electrodes used in this research is a stainless steel 316 and NaOH solution used as the electrolyte. In conditioning electrolysis equipment, the surface of the electrodes has to be considered to by minimizing the over-current that can increase overheat when using the electrolysis equipment. Measurements using flowmeter will be conducted to record the volume of gas output created by generator and composition analyses by using gas chromatography are also conducted. The measurement results are used to calculate HHO gas resulted by the generator and the efficiency of electric current used in the equipment [9-11]

2. Methodology

2.1. Electrode Cells Configuration Design

In previous researches, researchers used the HHO calculator program as shown in Figure 1, published by David Biggs on the website: www.hhh4free.com to collect information about how to decide cell configuration and how much gas can be produced [12].

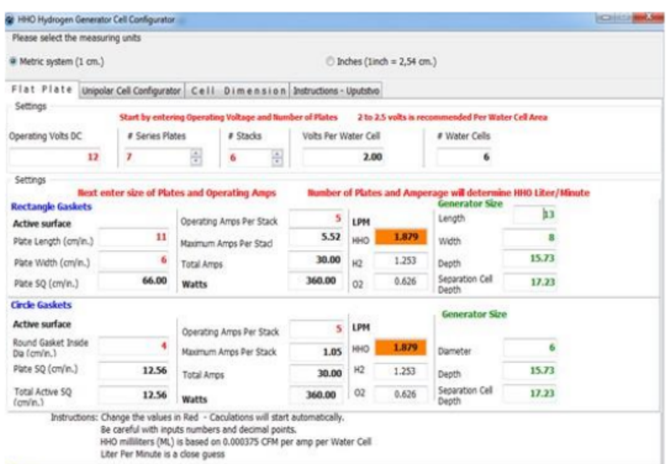

Figure 1. HHO Calculator

2.2. Functional Design Approach

In this approach, the hydrogen generator is designed based on the functionality of each chamber. Hydrogen generator consists of Feed Chamber functioning as the reservoir for electrolyte feed water that can hold water up to 5 liters. Below the feed chamber, a safety valve is placed for safety, to anticipate the possible problem with feed water or if an overload occurs. The place where electrolysis takes place is a reactor.

Inside the reactor, electrodes are used as the medium to electrolyze water. Therefore decomposition reaction for water molecules takes place, and water becomes H_2 and O_2. These electrodes are functioning as a cathode (+) and anode (−). In electrolysis proses, the positive ion in electrolyte solution will be attracted to the anode, and the negative ion will be attracted to the cathode. In order to make HHO gas flow becomes optimal, in the equipment a check valve is added as a closure to let the HHO gas flow or to stop the flowing. The valve is closed for 1 minute at the first running equipment, and later the valve is opened to discharge the gas. A power supply supplies the flowing electricity through the anode and cathode and to ensure electrics current synchronizer from the source a PWM (Potential Width Module) is used.

The formed gas from the electrolysis process is out to Bubbler Tube. Bubbler Tube is the medium functioning to purify the formed gas, to eliminate all the impurities. Purification medium used in Bubble Tube is water. Bubbler Tube is equipped with one-way direction valve to prevent reverse gas flow. After the gas flows through Bubbler Tube, the gas flows through safety arrestor functioning as anti-flashback to avoid explosion during the burnt of HHO gas. Beside that equipment, the hydrogen generator is also equipped with Flowrate Transmitter to measure the speed flow of the resulted HHO gas and discharged in volume per time unit. At the end of the pipe, a nozzle is attached in order to make sure the resulted gas can be burnt directly and used as alternative energy.

2.3. Structural Design Approach

Design steps are divided into Electrolysis Reactor and Bubbler Tube Design. Electrolysis reactor is made of an acrylic tube with 40 cm height and 20 cm diameter, and it consists of auxiliary chambers, which are feed chamber, 5-liter capacity positioning on top of hydrogen reactor with a casing close designed based on the reactor tube design.

The number of cathodes and anodes that are made of stainless steel are 42, with 6 cm width and 11 cm in length and will be placed inside the electrolysis reactor and connected. Electrode cells configuration is decided using HHO calculator. Electrode consists of stainless steel plates of 6 stacks and seven plats of cathodes and anodes in parallel connection. Stainless steel used in this research is type 316 L.

At the gas output, a running made using a hose that connected directly to Bubbler Tube equipped with flowrate transmitter and check valve. Bubbler tube is made of an acrylic tube design with 40 cm height and 20 cm diameter. On the upper part of the tube, a closure is attached and connected with a hose and equipped with a bypass valve to control the flow gas product to flowrate transmitter or flow to Arrestor-Nozzle. The hose is also equipped with safety arrestor functioning as the safety for a flashback. To make a safer integrated hydrogen generator, a Fiber Board Buffer is designed with 80 cm width and 60 cm in height, uses as a buffer frame. Hydrogen generator used in this experiment is shown in Fig. 2.

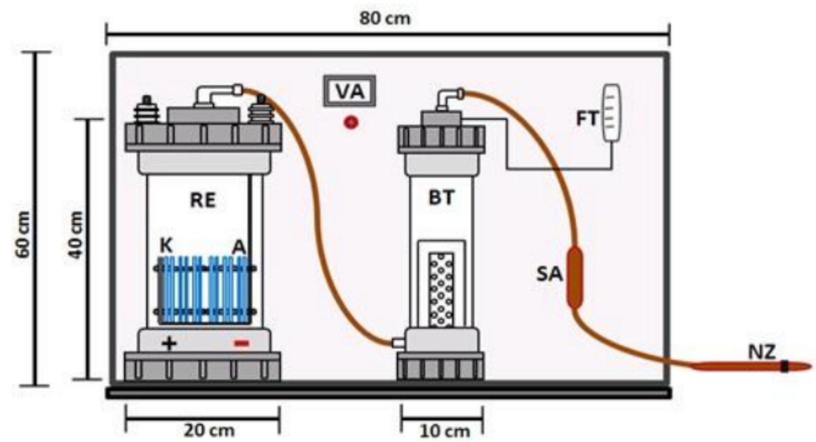

Figure 2. Hydrogen Generator Design

3. Results and Discussions

3.1. Effect of Electrolyte Solution NaOH Concentration to the volume of Hydrogen Gas

The choice of NaOH as the electrolyte is based on the consideration that Na^+ cation has the potential of electrode ion standard lower than hydrogen ion. In the electrolyte process, there is a competition between anion in electrolyte and hydroxide to release electron (oxidation). Anion with potential electrode standard smaller compare to hydroxide ion will be oxidized therefore oxygen gas is not produced, while cation with electrode potential standard higher compares to hydrogen ion will go through reduction process, therefore, hydrogen gas will not be produced. Another reason is the NaOH electrolyte is cheaper and more efficiently to be saluted.

The increment of NaOH concentration is proportional with the increment of hydrogen gas volume due the more sodium is used, the more Na^+ and OH^- ions will be formed, this condition will increase water conductivity. The increment of conductivity will create a more electric current. Therefore, the process of water decomposition into its original form of hydrogen and oxygen will be faster. The relation of NaOH electrolyte solution concentration to the hydrogen gas volume after the electrolysis process is shown in Figure 3. Figure 3 shows that the production of hydrogen gas will increase linearly to the addition of sodium chloride solution concentration. Therefore the more NaCl electrolyte concentration solution used, the more electrons are formed and more substantial to make the electrons transfer from solution to electrode more comfortable [13].

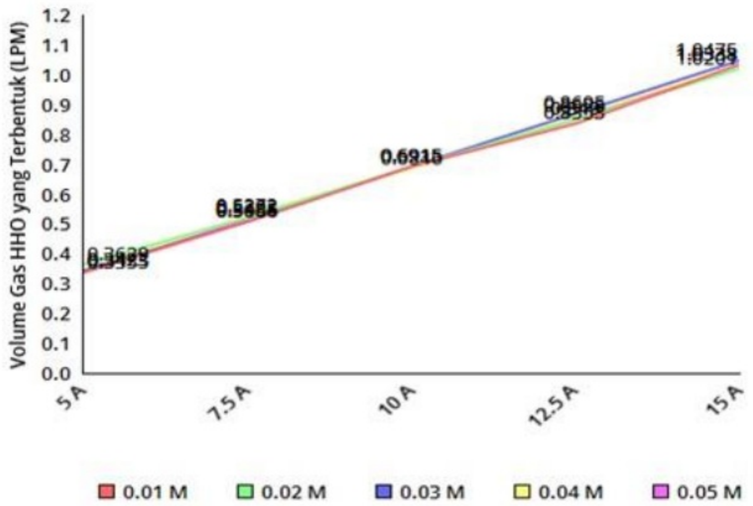

Figure 3. The Theoretically Effect of NaOH Solution Concentration to Gas Hydrogen Volume

Just as presented in Figure 3, the formation of hydrogen gas in the experiment is also affected by the concentration of the NaOH solution. The data for the effect of NaOH solution concentration on the resulted hydrogen gas volume is shown in Figure 4.

An experiment was conducted, and data was recorded in the form of HHO gas volume measured with a flowmeter (LPM) as the output of electrolysis. By using Faraday I and ideal gas equation, the mole of H_2 gas and O_2, and also the mass of gas H_2 and O_2, H_2 gas volume are calculated by using the ratio of reaction coefficient based on Gay Lussac Law. [14, 15]. Data taken from the calculation is shown in Figure 4.

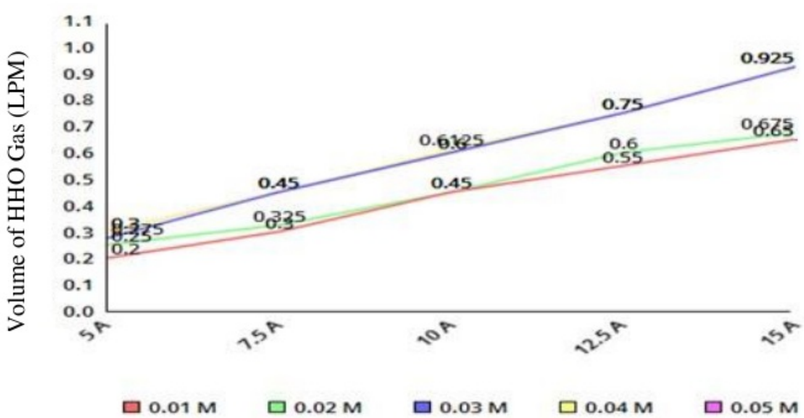

Figure 4. Experimental Result of NaOH Solution Concentration Effect to Gas Hydrogen Volume

The experiment was conducted five times based on the variance of NaOH solution concentration used, 0,01 M, 0,02 M, 0,03 M, 0,04 M, and 0,05 M. From the experiment result, it is shown that the higher NaOH solution concentration used, the more HHO gas volume resulted.
Minimum operating condition is 5 A and maximum operating condition is 15 A and based on that operating condition, the data result is in concentration 0.01 M, volume HHO gas in 5 A is 0.2000 LPM and 0.6500 LPM in 15 A. in concentration 0.02 M, volume HHO gas in 5 A is 0.25000 LPM and 0.6750 LPM in 15 A. While in NaOH concentration 0.03 - 0.05 M, volume HHO gas in 5 A is 0.3000 LPM and 0.9250 LPM in 15 A.
From data result above, the electrolysis process was efficient in NaOH concentration 0.03 M. Volume of HHO gas resulted in concentration 0.03 M is the same in concentration 0.04 and 0.05 at the same current. This condition is known as over potential concentration. Over-potential concentration exists due non-uniformity of electrolyte concentration profile and makes the diffusion velocity slower. Proportional to the increment of the electrolyte concentration solution, the increment of hydroxyl ion concentration will reduce the potential oxidation value. The increment of hydroxyl ion (OH^-) also reduces the amount of hydroxyl ion produced by hydrogen gas. This condition is due to the decrement of reduction current in the cathode.

3.2. Effect of Electric Current to The Resulted Hydrogen Gas Volume

The experiment results of the resulted HHO gas volume are qualitatively similar to the theoretical calculation, although quantitatively different due to process efficiency. There is an indication that the effect of applied electric current to the resulted HHO gas volume is proportional. Figure 5 shows that the higher the electric current applied, the more HHO gas volume resulted.

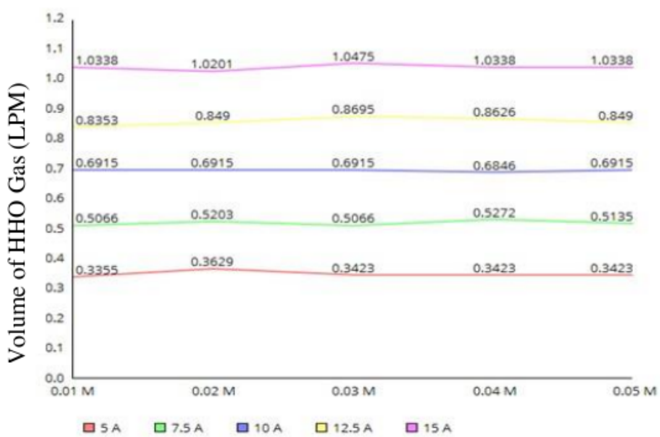

Figure 5. Theoretical Effect of Current to The Resulted Hydrogen Gas Volume

After comparing data result, therefore theoretically in minimum operating condition electrolyte with concentration 0.01 M, HHO gas volume is 0.3355 LPM in 5 A and concentration 0.05 M is 1.0338 LPM for 15 A. This experiment is based on the Faraday concept where the first law states that mathematically the volume of element resulted by electrode proportional with electric current applied to electrolysis.
The current applied to the system is affecting the process of electrolysis. The higher the current applied, the faster bubbles occur on the surface of the electrode. This condition shows that the productivity of hydrogen and oxygen gas is faster and more comfortable. In this research, bubbles will occur when hydrogen generator is given current 12.5 A. However, the bubbles in the surface of the electrode will create instability of electrode and affecting the flow of electric current [16].

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Electric current is used to generate the electrons in the electrode, including material transfer between them through solution's electric current. This condition occurs due to the increment of electrolyte concentration that has the role in incrementing the electric conductivity during electrolysis. Therefore, when the electrolyte condition concentration is 0.03 M - 0.05 M, the resulted HHO gas volume is proportional to the increment of the applied current. In operating condition 10 A, the resulted HHO gas volume is 0.6 LPM, in 12.5 A, the resulted HHO gas volume is 0.75 LPM and in 15 A, the resulted HHO gas volume is 0.925 LPM. The complete result is shown in Figure 6.

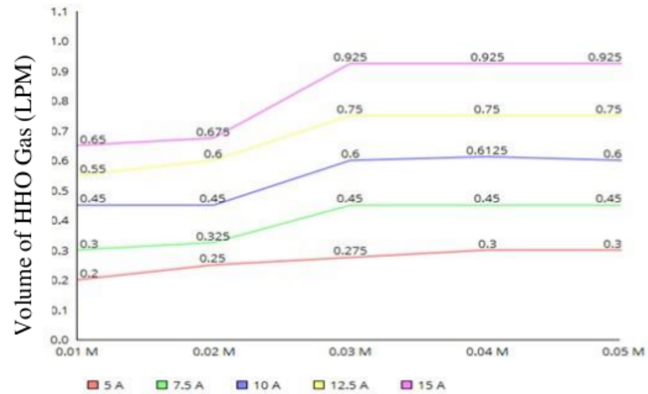

Figure 6. Theoretical effect of current on the resulted hydrogen gas volume

In an ideal condition of electrolysis set up, anode and cathode are set up in a very close distance. This kind of setup decreases the stability of the electrodeposition, due to the occurrence of bubbles on the surface of the electrodes. When this process is disturbed, the instability effect is indicated by the increment of the solution temperature.

4. Conclusions

Based on the result and discussion above, we can conclude that water electrolysis device was designed to produce HHO gas using stainless steel electrode 316 with six stacks, where each stack gas a coupling electrode with surface contact 66 mm^2. The current efficiency of the hydrogen generator is 89.13 %. The highest volume of resulted gas from electrolysis process is 0.9250 LPM at the 0.05 M solution concentration in 15 A. Chromatography gas analysis showed that the average hydrogen content in sample products are 65.432 %; oxygen 33.106%; and nitrogen 1.444 %.

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