Principle of generator HHO hybrid multistack type production technologies to increase HHO gas volume

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Abstract. Hydrogen isclassified as New Energy and also considered as the most promising transportation fuel candidate in the future. Various pilots test of hydrogen fuel cell vehicles by the world's leading automotive industries since the last 50 years have begun to show bright spot in the utilization of hydrogen-based fuel cells as vehicle fuel. The electrolysis process of water (H_2O) would produce H_2 (hydrogen) and O_2 (oxygen). The conventional method resulted in inconsistent volume and quality of HHO gas. However, the current development of HHO gas production through electrolysis process varies in term of materials, production process, design of certain tools, and technical modifications to obtain optimum results. In this research, the Hybrid Multistack TypeHHO generator has been designed and developed by combining two types of dry and wet cell generators. In this study using both cell type generator (wet and dry cell) or called as a hybrid type. Through the process of electrolysis in HHO enclosure space, the HHO gas was produced. The volume of HHO gas obtained from the HHO generator as an alternative fuel is strongly influenced by the electrical current supplied and the concentration of KOH catalyst used. The test was conducted with four stages of catalyst amount from 5.6g/L; 11.2g/L; 16.8g/L; and 22.4g/L. The applied current is linearly increased, with theincreasing HHO gas production. It is proven when with the amount of catalyst used at 22.4g/L, the average HHO gas produced is 230.3mL/min. The author analyzes the performance of the generator in term of current and HHO gas production at a predetermined 12V constant voltage.
Keywords*-Cell generator HHO, HHO Gas, Hybrid Cell Generator, Calibration, Evaluation and optimization*

1. Introduction

The rapid development and technological innovation of transportation drives the need for fossil fuel oil demand. Its effects to global environmental issues demanding government to adopt policies on emissions generated from short, medium and long-term transport on land,

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sea and industry [1,9]. The issue of global warming and the depletion of fossil fuel reserves, encouraging the search for alternative fuels that are renewable, easy to obtain, easy to process, and expected to shift dependency on petroleum and promote environmentally friendly sources.

Energy utilization has been harvested from organic and non organic waste to become a useful source of energy for human. Utilization of water into electrical energy has been widely done with the presence of hydroelectric power. In addition to electricity, water can also be used as energy or fuel vehicles or stoves, through the process of electrolysis by converting water into HHO gas. HHO technology is still considered rare to do and developed, whereas this technology is very effective to suppress the use of fossil fuels. The basic materials for this technology is the water with abundant potential in tropical countries like Indonesia. [2]

HHO gas (Brown's Gas), is the result of electrolysis of water by using a direct electric current, thus splitting water into pure hydrogen and oxygen gaswhich has a high heating value. Until now HHO gas is used as an additional fuel in motor vehicles. By producing HHO gas as much as possible, it is expected to reduce the concern of the Indonesian people against scarcity and fuel price hike.

Until now electrolysis is the most widely usedprocess of producing hydrogen from water. Electrolysis is a process of decomposition of water molecules (H_2O) into hydrogen (H_2) and oxygen (O_2) with reaction-triggering energy in the form of electrical energy [9]. This process can take place when two electrodes are placed in water and direct current is passed between the two electrodes. Hydrogen forms on the cathode, while oxygen at the anode [11]

To increase the production of HHO gas produced from the electrolysis process, it is necessary to add the KOH catalyst dissolved in aquadest water electrolyte. This electrolyte as a catalyst that will reduce the energy required, so that the reaction rate for breaking water molecules become faster through chemical reactions that facilitate the process of decomposition of water into hydrogen and oxygen. It is because the catalyst ion can affect the stability of water molecules into H and OH ions which are more easily electrolysed. [11]

Research the production of oxygen gas through the process of electrolysis of seawater by using graphite as electrode and varying the electrolytes of NaCl and KOH. After research, the fact that the gas is produced in a salinity solution of 35% and a voltage of 13V is the oxygen gas and hydrogen gas. All of these studies produce oxygen gas and hydrogen gas. Production of measured and monitored oxygen is increasing as the voltage is increased. In addition, with increasing levels of electrolytes, increased oxygen gas production is also increasingly evident. KOH solution produces more oxygen gas than NaCl solution. The study states that the type of electrolyte and electric voltage affect the production of HHO gas. [10]

HHO generator is a tool that can convert water into hydrogen gas and oxygen. The addition of a HHO generator to a fuel-based engine can improve the combustion efficiency which means it can save fuel to produce the same mechanical energy. In this research has been designed and generated hybrid type HHO which combines two types of HHO cell type and wet cell and dry cell generator. To know the characteristics of the hybrid-type HHO generator, perform function tests and analyze the production volume capability or flow rate of HHO gas in units of milli liters per minute. The test results will be evaluated and validated to determine the performance of the HHO generator. HHO gas generated from HHO generators can be implemented on 1000CC engines up to 2000CC by injecting HHO gas through an air filter inlet without altering the engine's engine settings.

2. Hydrogen Gas Production

Hydrogen gas is known as Brown gas and a form of flammable hydrogen. Use of Brown gas is very broad, depending on the application. This gas can be produced from coal, steam reforming, and water electrolysis.

2.1. Hydrogen Gas from Coal

Coal is a natural wealth that is categorized as fossil energy that is formed from a very long metamorphosis process. The chemical structure of coal is by no means a simple carbon covalent chain. Optically coal is often a high-pitched chunk with varying water content.

2.2. Hydrogen gas from Steam Reforming

Steam Reforming is a method to produce hydrogen, carbon monoxide or other useful products from hydrocarbon fuels such as natural gas. This is achieved in a processing device called a reformer that reacts with steam at high temperatures with a natural material. Renewal of methane vapor is widely used in the industry to make hydrogen.

2.3. Hydrogen gas from Electrolysis

Gases generated from the electrolysis process of water are Hydrogen and Oxygen gas, with a composition of 2 Hydrogen atoms and 1 Oxygen atom. Electrolysis of water is an electrolysis process that is used to break water molecules (H_2O) into Hydrogen (H_2) and Oxygen (O_2). The process of electrolysis of water occurs with half the reaction of acid or alkaline (alkaline electrolysis) or both. In both types of reaction above, Hydrogen gas is also produced on negative electrode (cathode) and Oxygen gas is generated on positive electrode (anode).

The efficiency of electrolysis will increase when the production of hydrogen and oxygen gas is allowed to mix together so that the energy content increases as well. HHO gases should not be stored in high pressure tubes because these gases are highly explosive and can be burned 1000 times faster than gasoline vapor and automatically explode with heat around 570ºC.

Electrolysis of pure water requires excess energy in the form of overvoltage to pass through the activation phase. Without excess energy, there will be no electrolysis at all and if it happens it will be very slow. Reactions that occur in the cathode and anode can be seen in Figure 1.

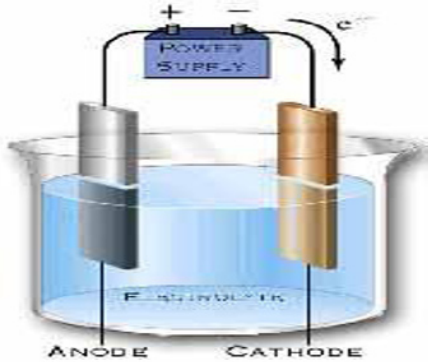


Fig. 1. Electrolysis process

reduction at cathode: $2\,H^+ (aq) + 2e^- \rightarrow H_2 (g)$
oxidation at anode: $2\,H_2O (l) \rightarrow O_2 (g) + 4H^+ (aq) + 4e^-$

3. HHO Generator Concept

The HHO generator is a device that can convert water molecules into HHO molecules. This change uses the concept of electrolysis to get the molecule. Electrolysis is a process of water decomposition (H_2O) into oxygen gas and hydrogen gas caused by the current passed to the water. DC resources are connected to two electrodes or two plates (usually made of inert metal such as platinum, stainless steel or iridium) which are then placed into water. The generator parts consist of:

3.1.Cell Generator

Cell generator serves as a place of electrolysis of separation of H_2O molecules to become HHO gas. This HHO cell generator have various parts that contribute to HHO gasproduction, including:

3.1.1 Electrode Plate

The electrode plate serves as electrical current conductor to the electrolytic water and the site for electrolysis. The electrode consists of anode and cathode plate. The material and extent of the electrode used affects the HHO gas generated from the waterelectrolysis process so that the electrode material must be selected from good electrical conductivity materials with corrosion resistance. Stainless steel type SS 316F, 316L, 316N, 317, 329, and 304 have excellent corrosion resistance in various environments, therefore are suitable as electrode in the waterelectrolysis process to produce HHO gas. In this study, the 316L stainless steel was used as electrode due to its low carbon content.

Electrode serves aselectrical current conductor from the voltagesource to the water to be electrolyzed. In electrolysis using DC current, the electrode is divided into two valves which are positive as anode and negative as cathode. This study utilized the 316L Stainless Steel type electrode plate and KOH electrolyte dissolved in distilled water. By dissolving the electrolyte in water it will increase the electrical conductivity. Electrolytes as catalysts in the electrolysis process can increase the reaction rate for breaking water molecules faster.

3.1.2 Spacer

Spacer is a series of nonconductive platesin between the stainless steel plate (SS316L) placed on the insulator material made of High Density Polyethylene (HDPE) with 3mm thick that serves as a barrier between the plate and as a leakage prevention electric current. The electrode plate is arranged in a 2x3 plat formation for each generator cell consisting of 6 cell HHO generators.

3.1.3 Gasket

The gasket serves as a barrier on the side portion of the HHO generator casing which serves as a water leak preventer for the gas from the HHO generator. The main requirement for this gasket should be able to close tightly between small gaps so that leakage from the side of the HHO generator frame does not occur. Materials used are rubber type MBR with 2mm thick.

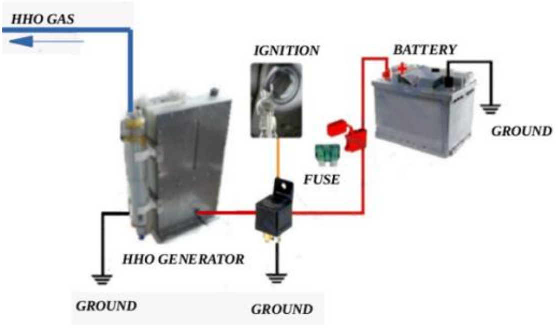


Fig. 2. Schematic diagram HHO generator

3.1.4 Cell Generator Cover

Cover used are from acrylic material. Cover serves as a cell cover generator (spacer) serves to clamp the arrangement of stainless steel plates. The plates on the left and right sides are mounted baud by welding as baud power serves as a current conductor to the anode (+) and cathode (-) electrodes.

3.1.5 Connector

The connector is a part that connects the outer and inner side which serves to fill the distilled water solution which has been mixed with the KOH electrolyte and the HHO gas exit as output. The connector is located on the top of the HHO generator on the left side for the input and the right side for the HHO gas output.

3.2. Type of Generator

3.2.1. Dry Cell Type

A dry cell type HHO generator, in which most of the electrodes are not immersed in electrolytes and the electrolyte only fills the gaps between the electrodes themselves. The advantages of a dry cell HHO generator are:

- Water fills the gap between the plat cells, the electrodes are not completely waterlogged.
- The heat generated is relatively small, because there is always a circulation between hot and cold water inside the HHO generator.
- The used electric current is smaller, because the converted power becomes less heat

3.2.2. Wet Cell Type

The wet cell-type HHO generator, where all the electrodes are submerged in the electrolyte fluid inside a water vessel.

The advantage of a wet cell HHO generator is:

- Generated gas is generally more stable and stable
- Generator maintenance is easier
- Design of making HHO generator easier

In the wet cell type, all areas of the plate electrodes are submerged in water for the electrolysis process to produce HHO gas.

3.2.3. Hybrid Type

Hybrid type generator is a combination of two types of HHO generator that is dry cell and wet cell. The hybrid generator has a formation where the dry cell generator is placed in a vessel containing the electrolyte liquid as in the wet cell type.

The advantages of hybrid type HHO generator are:

- The reservoir is present in a vessel containing an electrolyte water solution
- The electrode of the generator cell is immersed in the water of the electrolyte solution
- The heat generated is relatively small, because the water in the vessel can circulate well, without a water pump.
- The electric current used by the env is smaller, because the power converted becomes less heat
- No PWM electronics required because the working temperature is relatively low

Process flow diagrams are the stages or workflows in a hybrid-type HHO generator (see figue 2). The electrolysis process takes place at the HHO generator, where the water processing into the gas takes place in one vessel integrated in one place. The HHO gas output from the vessel is connected to the bubler tube through the top of the tube, then injected to the machine.

3.3. Catalyst

The catalyst is a material that serves to accelerate the reaction by lowering the activation energy and not changing the reaction equilibrium, and is very specific. The catalyst for water electrolysis uses a strong base electrolyte solution (KOH) to allow electricity to be easily transferred from one cell to another. The strong alkaline based electrolyte solution used is corrosive to metals similar to strong acids.

The concentration of catalyst (electrolyte) in water will affect the conductivity of the solution. The greater the volume of the electrolyte, resulted in greater conductivity of the catalyst molar, indicating that the ability of the solution to conduct electricity is greater or more easily flowing in the solution. The easier it flows at any time, then the solution can produce a larger electric current. Selection of KOH as an electrolyte because KOH easily absorbs water vapor. KOH has a high solubility in water that is 1100g / L.

3.4. Molecular Electrolyte Value.

Molality is the number of particles of solute (mol). Molality can be measured in solid form and can only be measured in mass, not its volume so that it is impossible to be expressed in the form of molarity. In this test, the catalyst used is Potassium Hydroxide or Potassium Hydroxide (KOH). The more catalyst dissolved, the greater the resulting production shown in the table below:

Table 1. Molasity of Potassium Hydroxide (KOH)

m = 0,1; KOH = 5,6g/L			m = 0,2; KOH = 11,2g/L		
v	C (A)	Produksi Hidrogen (ml/m)	v	C (A)	Produksi Hidrogen (ml/m)
12	2,4	100	12	3,2	175
12,5	2,9	125	12,5	3,9	225
13	3,6	175	13	4,7	250
13,5	4,3	225	13,5	5,5	300
14	5	300	14	6,3	325
m = 0,3; KOH =16,8g/L			m = 0,4; KOH = 22,4g/L		
v	C (A)	Produksi Hidrogen (ml/m)	v	C (A)	Produksi Hidrogen (ml/m)
12	3,9	200	12	4,4	250
12,5	4,7	250	12,5	5,3	300
13	5,7	300	13	6,3	375
13,5	6,8	350	13,5	7,3	425
14	7,8	400	14	8,2	450

4. Methodology

The steps taken in this study as follows:

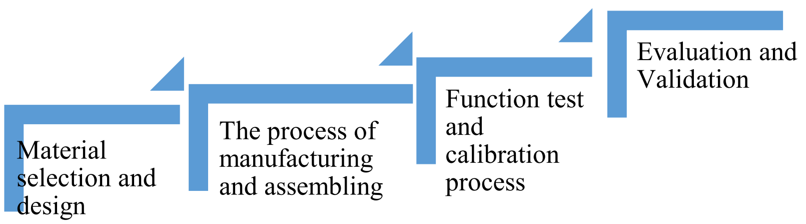


Fig. 3. Research Methodology Process

4.1 HHO Generator Manufacturing Process

Manufacturing process can be seen in the following flow diagram, where the work process starting from the design process, material preparation and testing are presented in detail.

4.2 MultistackCell Generator Design

HHO multistack generator design consists of 6 5x5cm stainless steel plate in each cell. The plates are arranged in parallel with the aim of obtaining more HHO gas production volumes with lower electric current intake than single stack models. To prevent electrical leakage, each plate is coated with a gasket. In the generator cells should be coated gaskets that serve as a barrier between the plate and as a leakage prevention electric current. The material used is HDPE with 1mm thick.

4.3 HHO Generator Case Design

HHO generator case is made from HDPE material with 80mm thick while cover is used from acrylic material. The cover acts as a cover or flank of stainless steel plates with surrounding bolts, and two bolts serve as a current conductor to the anode (+) and cathode (-) electrodes.

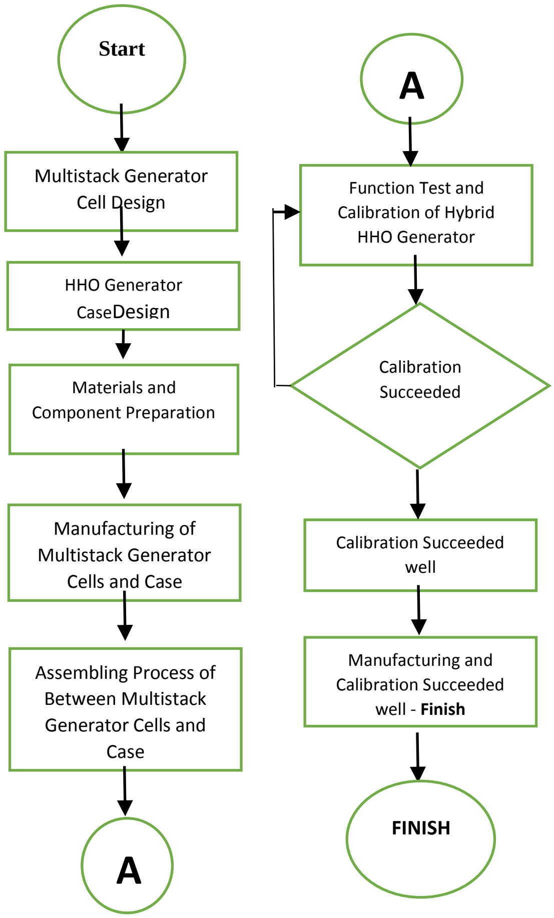


Figure 4. Flowchart of Manufacturing Process

4.4 Test Material Preparation

Materials to be used in designing HHO Generator, such as HDPE 80mm, HDPE 3mm, HDPE 1mm, 316L Stainless steel Plate, Amplas 1000, Acrylic Cuter, Bolt, Bubbler, NBR Rubber, Hose, and Niples.

5. Testing and Calibration

Before calibration of the HHO generator, first perform a function test on the device itself to determine the ability of the device in operation.

5.1 Function Test

The function test stage is performed to ensure that the HHO generator works properly and can know if there is leakage of electrolyte solution on the HHO generator case.

The next stage, carried out the calibration on the HHO generator in the following way:

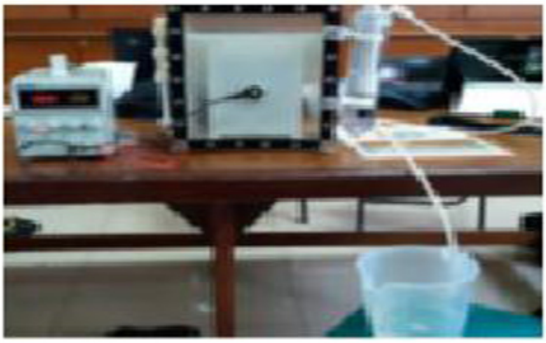


Fig. 5. Testing and Calibration Process

5.2 Calibration Tool

The calibration tools used consist of Power Supply, ampere clamp, Flow meter and stopwatch.

5.3 Calibration Process

Calibration is done in the following way:

1. Turn on the HHO generator that has filled the catalyst solution with the first 5gram electrolyte and left for 10 minutes, then the HHO gas output through the bubler tube is measured using a gas flow meter.
2. Add 5gram electrolyte for every 10 minutes and measure the flow of HHO gas, until the number of electrolytes reaches 50gram.
3. This process is repeated three times in the same way.

5.4 Measurement Result Data

Measurement Data Result is the measured value of HHO gas output (liter per minute). This data is a large electric current relationship (Ampere) due to the addition of the amount of catalyst (gram) that is incorporated into the HHO generator vessel.

The calibration data is needed to know the accuracy of the HHO generator in generating HHO gas against standards stating the relation of electric current, the amount of electrolyte and the volume of HHO gas production.

Furthermore, the results of data processing compared with standard data as a reference that will be displayed in the form of tables and graphs. The data of calibration measurement can be seen in appendix 1.

6. Result and Discussion

6.1 HHO Generator Design Results

The result of HHO generator design is shown in Figure 6, is a series of HHO generator making process starting from the provision of ss316L plate material until assembling process becomes HHO generator cell. The next process combines the generator cell with the casing to become a functional HHO generator, shown in Fig. 6.

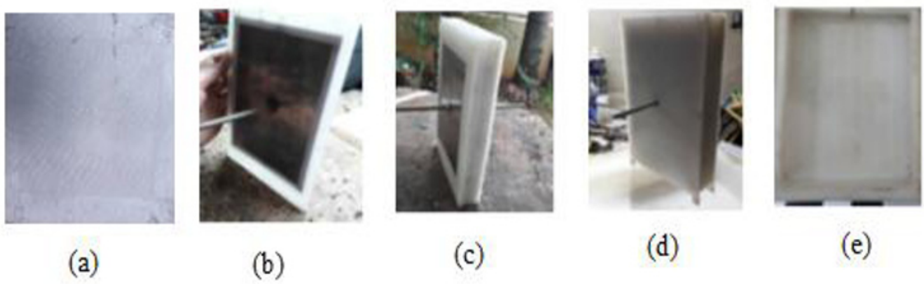


Figure 6. Asembling process of HHO generator cell; a. Pieces of SS316L plate, b. Preparation of Spacer (cell generator), c. Power Plate on Cell Generator, d. Cover Cell Generator, e. Frame generator HHO HDPE 80mm

After preparing the elements of the HHO generator, the next step is to combine these elements with the casing and complete it with the various accessories required. Figure 7 shows a hybrid-type HHO generator complete and ready to operate.

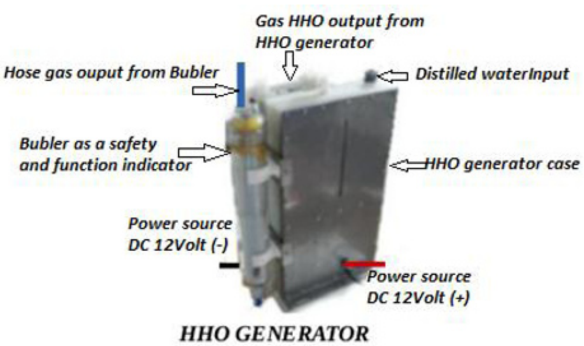


Figure 7. Generator HHO tipe Hybrid

6.2 Graph of Flow Relation and HHO Gas Production on Voltage

The following test results data on the HHO generator in the form of graphs. Testing done three times.

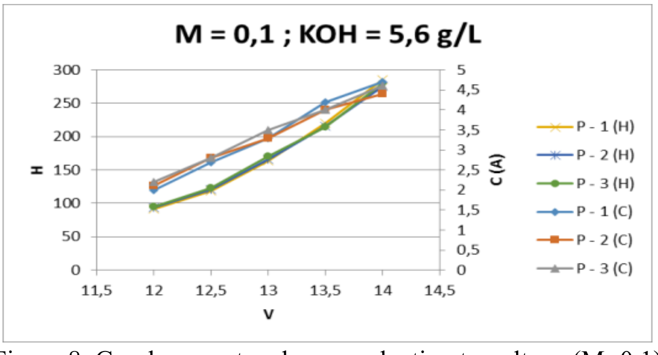


Figure 8. Graph current and gas production to voltage (M=0.1)

In the graphic Figure M = 0.1 shows the effect of voltage applied to the generator on the current and the production of gas produced with molarity =0.1; KOH catalyst content of 5.6gram/L. The graph shows the non-linear relationship to the standard on the number of 5.6gram/L catalysts caused by the unstable HHO generator because the electrolytic chemical process causing the change of resistance can affect the current change. Judging from the first test data up to the third test, the HHO generator tends to be more stable. When a voltage of 12V is applied, the current generated at the first test is 2A, the second test is 2.1A, and the third test is 2.2A, while the HHO gas produced at the first test is 92mL/menit, the second test is 94mL/menit, and the test third of 95mL /menit.

The other graphs in the second and third tests can be seen in Appendix 2 and the results in Table 2.

Table 2. Gas production on molarity to the resulting current

V	C (A)			
	M = 0,1	M = 0,2	M = 0,3	M = 0,4
	X1 (C)	X2 (C)	X3 (C)	X4 (C)
12	2,1	3,4	3,7	4,0
12,5	2,8	3,7	4,3	4,9
13	3,4	4,4	5,3	5,9
13,5	4,1	5,0	6,4	7,1
14	4,6	5,5	7,4	7,8

In Figure 9. Shows the average gas production generated by HHO generator from the three tests on each molarity, among others described in Table 3. Figure 10. Graph C (A) shows the average current generated by the HHO generator from all three tests on each molarity.

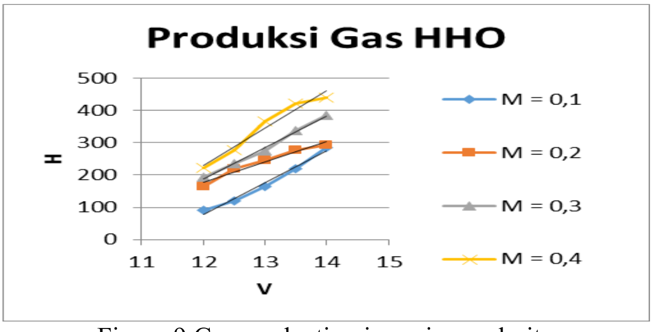


Figure 9 Gas production in varian molarity

Table 3. Molarity Catalyst on the volume of HHO gasproduced

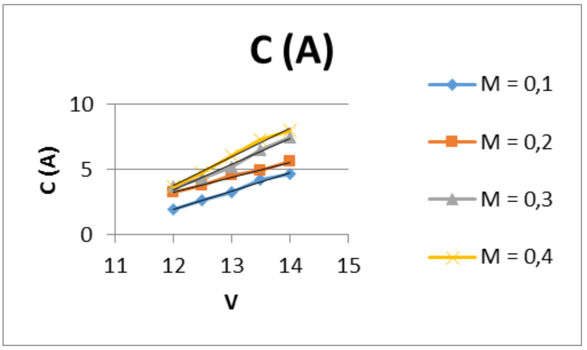
V	Gas HHO			
	M = 0,1	M = 0,2	M = 0,3	M = 0,4
	X1 (HHO)	X2 (HHO)	X3 (HHO)	X4 (HHO)
12	93,7	167,3	193,3	230,3
12,5	121,0	217,0	236,0	279,7
13	167,0	238,0	278,7	358,7
13,5	216,7	277,0	332,0	414,7
14	280,0	292,3	380,0	434,7

Figure 10. Average electric current from all three measurements

The results of the current on the HHO generator test with 0.1 molarity large voltage 12V is 2.1A while the current according to the standard (literature) of 2.4A. Can be determined error by using the equation:

Measurement error against standard:

$$x = \frac{\text{HHO current} - \text{standard current}}{\text{HHO current}} \; x\ 100\%$$



(1)

An error of reference value (default) with M = 0.1, voltage = 12V and current HHO = 2,1A, has a reference error of 0.14%.

The result of HHO gas production on HHO generator test with molarity 0.1 with 12V voltage is 93,7 mL / min while HHO gas production standard is 100 mL / min. Can be determined error by using the equation:

Standard value error:

$$x = \frac{\text{production of HHO gas} - \text{Standar of production of HHO gas}}{\text{production of HHO gas}} \; x\ 100\% \tag{2}$$

An error of standard value with M = 0.1 voltage = 12V and
HHO gas production of 93.7mL / min, has an error with a default value of 0.07%.

7. Conclusions

The results of this study can be summarized as follows:

1. HHO Type Hybrid Multistack generator was designed by combining two types of wet and dry cell type HHO generator shows good results with maximum error at current of 0.14% and on HHO gas production of 0.07% against standard.
2. With a constant voltage of 12V there is a different molarity variant to the electric current in the HHO generator. With a mean molarity of 0.1 the resulting current is 2.1A. For 0.2 molarity of 3.4A, 0.3 molarity of 3.7A, and 0.4 molarity by 4.0A.
3. The greater the molarity of the catalyst is given, the greater the HHO gas output rises at a constant voltage of 12Volt. The average molarity of 0.1 HHO gas

produced were 93.7mL/min, 0.2 molarity of 167.3mL/min, 0.3 molarity of 193.3mL/min, 0.4 molarity of 230.3mL/min.

4. For all tests, the error against the standard (literature) for each test on the resulting electric current and the resulting HHO gas is less than 1%.

In connection with the above results, the design of HHO multistack generator can reduce the electrical current and working temperature and provide accurate measurement value of HHO gas production volume of 1%.

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