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Performance Characteristics between Titanium and Stainless Steel Materials as Electrodes on Dry Cell Type HHO Gas Generator

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***Abstract*— *The HHO generator is a device that uses the principle of water electrolysis to produce HHO gas, that is a gas consisting of 2 hydrogen molecules and 1 oxygen molecule. The HHO generator is a technology that can be implemented on an internal combustion engine. In a previous research of a HHO generator with a direct connection system, the electrolyte temperature reached more than 90°C. If the temperature continues to increase, the HHO gas produced will mix with water vapor.*

The electrode material choice in the HHO generator can affect for electrolyte temperature increase, HHO gas production, HHO generator power, and the efficiency of HHO generator. Therefore, a research be conducted about electrode material and the application of neutral plates to the HHO generator Dry cell type. The electrode material that used as object of research is stainless steel 316 and titanium. Titanium material has a higher thermal conductivity value and lower electrical resistance value than stainless steel 316 material. The parameters measured in this research are electric voltage, electric current, electrolyte temperature in the HHO generator, electrolyte temperature in the reservoir tank, HHO gas temperature, and HHO gas production. While the parameters calculated are electrical power requirements of the HHO generator dry cell type, HHO gas rate production, and efficiency of the HHO generator dry cell type.

The results of performance characteristics comparation of HHO generator show that HHO generator with stainless steel 316 electrodes have better performance compared to HHO generator with titanium electrodes.

***Keywords*— *HHO generator dry cell type, stainless steel 316, titanium, performance.*

I. INTRODUCTION

Alternative energy is energy derived from natural elements available in large quantities such as wind, air, sun, plants, and geothermal energy. One of the most economical and widely available alternative energies is air, various types of water utilization technologies as alternative energy, are used by Microhydro, PLTU, PLTA, and HHO Generators [1]. Of the various technologies that use water, HHO generators are the most economical and easy to implement technology for vehicles with internal combustion engines. The HHO generator uses the principle of electrolysis to break down air into two molecules, hydrogen and oxygen, in the form of gas [2].

The use of a neutral plate on the HHO generator type wet cell shows that by adding a neutral plate on the HHO gas generator to the wet cell type, the power of the HHO gas generator used for the electrolysis process of water becomes decreased. So that reduce losses that cause the generator to heat up in previous studies. Addition of neutral plate also causes the rate of production of HHO gas to experience an increase [3]. In the event of electrolysis, the selection of metal as an electrode is very important considering that it can affect the chemical reactions that occur. The flowing electric current plays an important role in producing moles of products from the electrolysis process [4]. Therefore, research will be conducted on the electrode material and the use of neutral electrode plates for the HHO generator, especially in the dry cell type. The research carried out was to compare the characteristics of the HHO Generator's performance in the dry cell type by using different electrodes (cathodes and anodes), as well as the addition of a neutral electrode plate. The electrode material used in this study is stainless steel 316 and titanium. Titanium metal has lower density and resistance, as well as the level of corrosiveness to KOH and lower thermal conductivity compared to stainless steel 316 [5].

II. METHODOLOGY

This research was conducted with an experimental method to determine the characteristics of HHO 316 stainless steel electrode generator performance and HHO titanium electrode generator. The HHO generator consists of 3 anodes, 3 cathodes and 5 neutral plates. The electrolyte used was a mixture of 1 liter of distilled water with 4 grams of KOH. The electric power of the HHO generator is supplied by the battery in charge

HHO generator testing is carried out until the electrolyte temperature reaches 70°C or the test time has reached 20 minutes.

For performance parameters the HHO generator is needed to know the following:

A. HHO Generator Power Consumption

Electric power that enters the HHO generator when supplied by the battery. Formulation to find out the HHO generator power consumption as follows [6]:

$$P = V \times I$$

B. HHO Gas Flowrate Production

The gas produced by the HHO generator as long as the HHO generator is supplied with electricity by the battery. The production of HHO gas is calculated by the flow meter.

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C. Electrolyte Temperature in the HHO Generator

Electrolyte temperature inside the HHO generator during the electrolysis process takes place. Electrolyte temperature is measured by a thermometer.

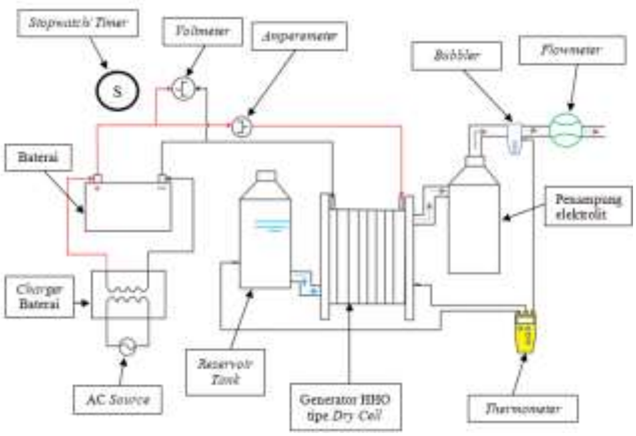

Fig. 1. HHO generator testing scheme

D. HHO Gas Temperature

HHO gas temperature produced by the HHO generator. HHO gas temperature is measured by a thermometer.

E. HHO Gas Mass Flowrate Production

The main product of the electrolysis process of water is HHO gas. The mass flowrate of HHO gas production is directly proportional to the flowrate of HHO gas production. To calculate the mass flowrate of HHO gas production use the following equation [7]:

$$\dot{m} = Q \times \rho$$

wherein:

$\dot{m}$ = HHO gas mass flowrate production (kg/s)
Q = HHO gas flowrate production (m^3/s)
ρ = HHO mass (kg/m^3).

F. HHO Generator Efficiency

Calculation of the efficiency of a HHO generator is a comparison between the energy needed by an HHO generator to work (input) with the energy produced by the output HHO generator (output). The energy produced at the HHO generator is HHO gas which can be used to increase the energy from the combustion process on the combustion motor.

In water electrolysis reactions:

$H_2O(l) \rightarrow H_2(g) + 0,5\ O_2(g)$ = +285,8 KJ/mol is an endothermic reaction that produces the enthalpy energy needed to break H_2O molecules into H_2 and O_2 positive (+). The enthalpy energy produced is:

$$\Delta h = +285,84 \times 10^3 \frac{J}{mol}$$

While the bond energy needed is through the reduction of the ideal gas equation under STP conditions [8]:

$$pv = n\bar{R}T$$

wherein:

p = Ideal gas pressure (atm)
v = Measured gas volume (L)
n = Molarity of compounds (mol)
$\bar{R}$ = Universal gas constant (L.atm/mol.K)
T = Gas temperature (K)

Bond energy is defined as the energy needed to break 1 mole of bonds from a molecule in the form of gas. Bond energy is expressed in kilojoules per mole (kJ mol-1).

To eliminate the value per mole of enthalpy and equalize the input value of the power in watts (J / s), then the volume of gas and moles is given per unit time. The compound molarity equation per unit time and the formula for efficiency of HHO generators according to Silaen and Kawano in 2014 are as follows:

$$pv = \dot{n}\bar{R}T$$

obtained:

$$\dot{n} = \frac{p \times \dot{v}}{\bar{R} \times T}$$

wherein:

$\dot{v}$ = Volume per unit time (Liter/s)
$\dot{n}$ = Molarity of compounds per unit time (mol/s)

then [9],

$$\eta = \frac{\text{Theorytical energy used for electrolysis}}{\text{Actual energy needed by a HHO generator}} \times 100\%$$

$$= \frac{\Delta h \times \dot{n}}{(V \times I)} \times 100\% .$$

III. Results and Analysis

A. HHO Generator Power Consumption

After testing and processing data, the graph of power consumption with time is obtained as follows:

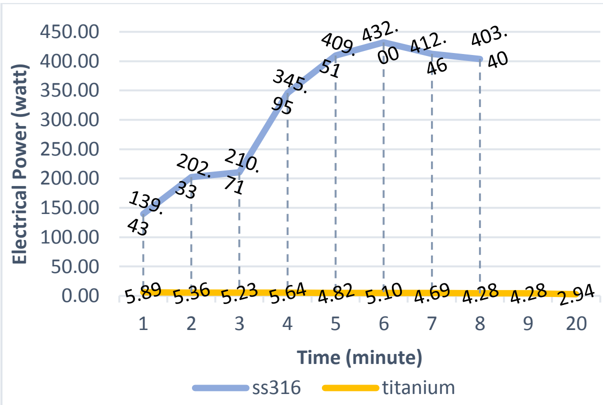

Fig. 2. Graph of power consumption with time

The highest electrical power consumption of HHO generators with 316 stainless steel electrodes is 431.99 watts in the 6th minute and the lowest electrical power consumption in the HHO generator is 139.42 watts in the 1st minute, while the highest electrical power consumption in the HHO generator is titanium electroada is 5.89 watts in the 1st minute and the lowest electric power consumption in the HHO generator is 2.93 watts in the 20th minute.

The cause of the HHO generator electrical power of the titanium electrode drops because the longer the test time, the electrode plate there is an increasingly thickened precipitate. Whereas, the cause of the low electric power consumption of HHO generator titanium electrodes in this study is because there are thick precipitates which cover the positive electrode plate when the electrolysis process takes place. The longer the

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test time, the deposits on the positive electrode plate are thicker, so the HHO generator's electrical power consumption of titanium electrodes decreases.

B. HHO Gas Flowrate Production

After testing, the HHO gas flowrate production graph is obtained for the following time:

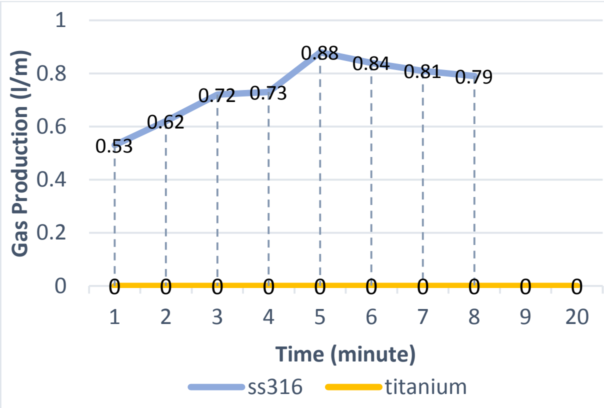

Fig. 3. Graph of HHO gas flowrate production with time

The HHO stainless steel 316 electrode generator produces a higher HHO gas production flowrate which reaches 0.88 liters / minute than the HHO generator titanium electrode whose HHO gas production flowrate is zero. It can be seen that the production of HHO gas in HHO generators is not directly proportional to the amount of electric power, possibly due to energy losses.

C. Electrolyte Temperature in the HHO Generator

After testing, the electrolyte temperature graph in the HHO generator is obtained for the time, as follows:

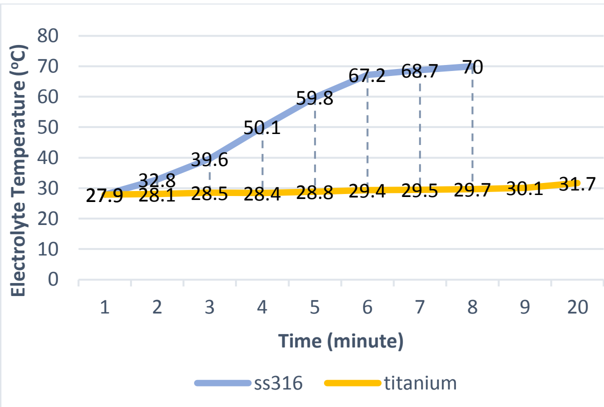

Fig. 4. Graph of electrolyte temperature with time

Electrolyte temperature in stainless steel 316 HHO generator electrode and titanium HHO generator electrode tends to increase with increasing testing time. Electrolytes in HHO generator 316 stainless steel electrodes reach a temperature of 70 ^{o}C in 8 minutes. While the temperature of the HHO generator electrolyte titanium electrode only rose from 27.9 ^{o}C to 31.7 ^{o}C after testing for 20 minutes.

D. HHO Gas Temperature

After testing, the electrolyte HHO gas temperature graph is obtained for the following time:

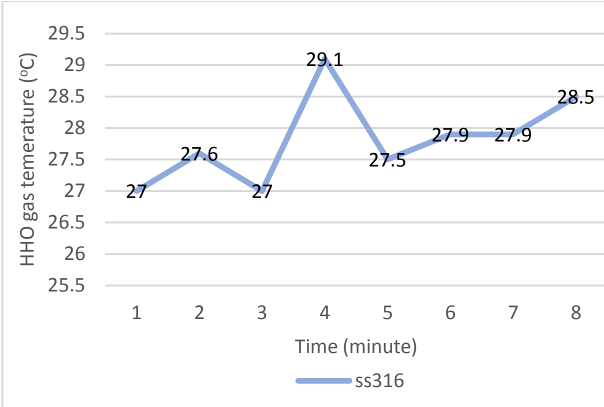

Fig. 5. Graph of HHO gas temperature with time

HHO gas temperature on HHO generator stainless steel 316 electrodes tends to fluctuate during the test, which is between 27 ^{o}C to 29 ^{o}C. Meanwhile, the HHO gas temperature on the HHO generator titanium electrode is zero, because the generator cannot produce HHO gas.

E. HHO Gas Mass Flowrate Production

After testing and processing data, the graph of the HHO gas mass flowrate production for the time is as follows:

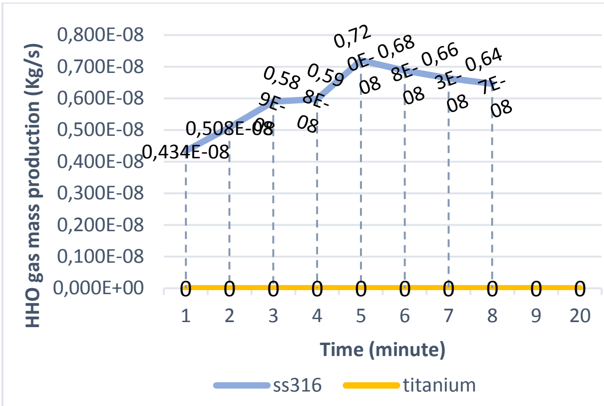

Fig. 6. Graph of HHO gas mass flowrate production with time

The characteristic of HHO Gas Mass Flowrate Production is directly proportional to the HHO Gas Flowrate Production. In the graph above, it can be seen that the characteristics of the rate of production of HHO gas in the HHO generator with 316 stainless steel electrodes showed an increase in the 1st minute to the 5th minute, then decreased after the 5th minute. The highest HHO gas production rate in this study was 7.2 x 10-6 Kg / s. Meanwhile, the characteristics of the rate of production of HHO gas in the HHO generator with titanium electrodes is zero and does not change for 20 minutes the electrolysis process takes place. This is because the HHO gas discharge on the HHO generator titanium electrode is also zero.

F. HHO Generator Efficiency

After testing and processing the data, the graph of the HHO generator efficiency for the time is as follows:

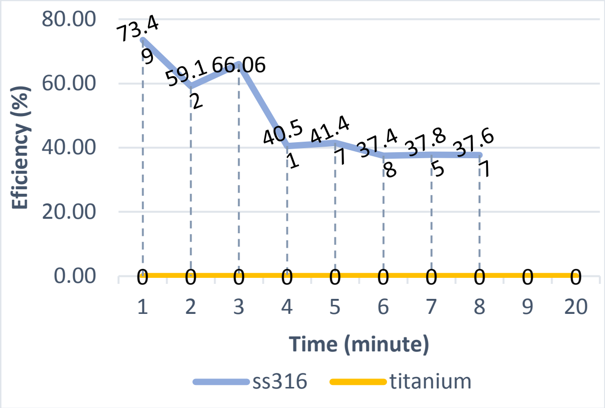

Fig. 7. HHO generator efficiency with time

The efficiency of stainless steel 316 electrode HHO generators tends to decrease with increasing testing time, with the highest efficiency being 73.49% in the 1st minute. While the efficiency of HHO generator titanium electrodes is zero during the testing process, because the HHO gas generator discharge is zero.

IV. CONCLUSION

After researching the HHO generator, conclusions can be obtained as follows:

A. The HHO generator with stainless steel 316 electrodes has the characteristics of electrical power consumption which tends to increase, while the consumption characteristics of HHO generator titanium electrodes tend to continue to decrease with increasing testing time.

B. The HHO generator of stainless steel 316 electrodes produces a higher gas discharge than the HHO generator of titanium electrodes.

C. Electrolyte temperature in stainless steel 316 electrode HHO generator and HHO titanium electrode generator tends to increase with increasing testing time.

D. Temperature HHO gas in HHO generators 316 stainless steel electrodes tends to fluctuate during the test, whereas, the HHO gas temperature at the HHO generator electrode is of no value.

E. The characteristics of the rate of production of HHO gas in the HHO generator stainless steel 316 electrode are the same as the characteristics of the gas discharge. While the rate of production of HHO gas in the HHO generator titanium electrode is zero.

F. The efficiency of the HHO 316 stainless steel electrode generator tends to decrease with increasing testing time, while the efficiency of the HHO generator titanium electrode is zero.

G. The comparative results of the performance characteristics of the HHO stainless steel 316 generator with HHO generators of titanium electrodes show that the HHO 316 stainless steel electrode generator is far better in performance, with a much greater HHO gas production efficiency and efficiency.

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