Experimental investigation of HHO gas generation from water as renewable energy source for educational purpose

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Abstract

Energy demand in the world continues to increase as increasing in development and population growth. The need for a cleaner, cheaper and friendlier energy source is on the rise. However, the fossil fuel price is also on the rising trend. The attempt to find alternative renewable energy sources is become urgent need. HHO gas generation from water is one alternative for a renewable energy source. This gas has been used in a lot of different uses, from lighting to industry. It can also be used as a fuel source. Recently, with increasing fossil fuel prices, there has been a lot of interest in using HHO gas in cars as supplement to gas to reduce fuel prices. The aim of this project is to construct a simple prototype of HHO gas generator from water for educational purpose. The effect of the type of water source and auxiliary materials, namely soda (NaHCO\textsubscript{3}) and sodium hydroxide (NaOH) on energy output, current, voltage and efficiency of the system have been selected as main focus on this work. The results demonstrate that the maximum energy output of HHO gas generated when using sodium hydroxide as auxiliary material with concentration of 5 gram in distilled water. Moreover, by using the sodium hydroxide could reduce generation time of HHO gas significantly. It is also found that maximum efficiency is 44\% at auxiliary material type of sodium hydroxide with concentration of 5 gram in distilled water. It is recommended to use sodium hydroxide as auxiliary material with low concentration to generate HHO gas.

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Keywords: HHO gas; renewable energy source; tap water; distilled water; soda; sodium hydroxide; voltage; current; production time; efficiency.

1. Introduction

Hydrocarbon fuels provide the primary source of energy used in the world. These fuels are used for applications such as electrical power generation, heating and transportation. Although hydrocarbon fuels provide energy for our world, they have several very serious side effects. These negative side effects include harmful polluting emissions, increased levels of greenhouse gas and catastrophic disasters such as large scale oil spills. High costs and political instability, due to foreign sources, also are negative side effects. Due to the widespread dependence on hydrocarbon fuels and the difficulty of their replacement, it is not economically feasible to completely eliminate their in the near future. New techniques are needed to significantly reduce the harmful emissions and consumption of hydrocarbon fuels. One possible way to reduce consumption and emissions of hydrocarbon fuels is using hydrogen as a fuel supplement. Many studies have shown that adding a small amount of hydrogen gas to the air intake of a combustion process can reduce the emissions and fuel consumption. These studies have shown that hydrogen is able to improve the flame speed, lean burn ability, and flame quenching distance of hydrocarbon combustion in the cylinder leading to reduced fuel consumption and emissions [1-3].

Production of hydrogen rich gas from the electrolysis of water, at the point of use, could solve many of the potential difficulties of using hydrogen as fuel supplement to improve hydrocarbon combustion. This gas, also referred to as Brown’s gas or HHO (also known as oxyhydrogen), has been shown to exhibit properties that make it a much more reactive gas than

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standard bottled hydrogen. These properties include the ability to melt metals with very high melting temperature but have a relatively cool flame when burned in air [4-6]. Several studies have shown that retrofitting a gasoline/diesel generator or automobile engine with an on-board HHO gas generating system, powered by the engine’s electrical system, can significantly improve engine emissions, performance and fuel efficiency [7-9].

The main objective of this research work is to establish a simple HHO gas generator system for educational purpose and investigate the HHO gas generation related to the type of water source and effect of auxiliary materials, namely soda (NaHCO₃) and sodium hydroxide (NaOH) on energy output, current, voltage and efficiency of the system.

2. Material and methods

In this research work, HHO gas generated from two type of water, namely tap water and distilled water are observed. The effect of auxiliary materials like soda and sodium hydroxide on energy output, current, production time, etc. are also investigated. Table 1 shows the detail of preparation of HHO generation including type of auxiliary materials which are performed in this work.

Table 1. Sample preparation for HHO gas generation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water type</td>
<td></td>
</tr>
<tr>
<td>1. Tap Water</td>
<td>1,500 ml</td>
</tr>
<tr>
<td>2. Distilled Water</td>
<td></td>
</tr>
<tr>
<td>Auxiliary material type</td>
<td></td>
</tr>
<tr>
<td>1. Soda (NaHCO₃)</td>
<td>5, 10, 15g</td>
</tr>
<tr>
<td>2. Sodium hydroxide (NaOH)</td>
<td></td>
</tr>
</tbody>
</table>

The block diagram for HHO gas generation which is performed in this work is shown in Fig. 1, while Fig. 2 shows the actual photograph of the experimental setup of HHO gas generation for this work. From Fig. 2, it can be seen the material/equipment which are used in this work, such as voltage regulator, bridge rectifier, electrolizer, filter, volume gas meter, voltmeter, and dc clamp meter.
HHO Gas generated from water electrolysis using variable ac power supply. The range of ac voltage regulator is 0~250V and rating of current is 30A. The bridge rectifier convert voltage from ac to dc and a heat sink plate is connected on the bridge rectifier to dissipate the heat. Electrolyzer is used to water electrolysis in generating HHO gas process. The Capacity of electrolyzer is 1.5 liter of water and constructed from capacitive cell containing 21 plates of stainless steel at each plate with dimension of 18.3 × 3.8 cm. It has 4 stacks and 20 cells, which constructed from two electrodes; positive and negative. When the current passes the water with auxiliary materials such as soda (NaHCO3) or sodium hydroxide (NaOH), the electrolyzer performs the water electrolysis and then generates HHO gas.

This HHO gas flows from electrolyzer to filter through plastic pipe. This filter containing water which filtering gas from water vapor of water and at the same time working as a protective device for Electrolyzer from back fire. The gas output from filter is pure HHO gas.

The volume of HHO gas generated from output of the filter was measured using volume gas meter. In this research work, a constant volume of HHO gas (100ml) was used. The production time of HHO gas was measured using a stop watch. A dc clamp meter (Megger DCM2000P) and voltmeter (Atten ATW830L) for measuring the input voltage and current of the system were also employed. The currents and production time of HHO gas were measured for different voltage range from 6 to 22 volt. Each process was repeated for three times. From the experimental results, output energy (MMW; millilitre /min./watt) and efficiency of the system were performed.

3. Results and discussion

The effect of different type and concentration of auxiliary materials, namely soda (NaHCO3) and sodium hydroxide (NaOH) on tap and distilled water were investigated in this research work. The results are as following.

3.1. Output energy (MMW)

The output energy (MMW; millilitre/minute/watt) for HHO gas generation is calculated according to equation (1).

\[
MMW = \frac{\text{Vol (ml) } \times \text{Time (Sec.)}}{\text(V (volt)} \times \text{I (Amp.))} \times 60
\]

(1)

where MMW is output energy (millilitre/minute/watt), Vol is volume of water (ml), V is input voltage (volt), and I is current.

Fig. 3 shows the characteristics of MMW against voltage for different concentration of auxiliary materials. As clearly seen from Fig. 3(a), the maximum MMW is 3.74 at 14 volt of voltage application for distilled water with 5g of sodium hydroxide concentration, while for tap water with 5g of soda, the maximum value of MMW is 2.65 at 18 volt of voltage application. For the distilled water with 10g of sodium hydroxide concentration, the maximum MMW is 3.9 at 10.3 volt of voltage application, while for tap water with 10g of soda, the maximum value of MMW is 2.7 at 20 volt of voltage application as shown in Fig. 3(b).

For the distilled water with 15g of sodium hydroxide concentration, the maximum MMW is 2.3 at 9 volt of voltage application, while for the tap water with soda MMW is 2.7 at 16 volt of voltage application, as shown in Fig. 3(c). Note that the range of voltage application with sodium hydroxide is smaller than that of soda.

3.2. HHO gas production time (t)

Fig. 4 shows the characteristics of 100ml HHO gas production time against voltage for different concentration of auxiliary materials. As clearly seen from the figure, the production time for water with sodium hydroxide is much smaller compared with soda for same voltage of application. It is found that by increasing the concentration of auxiliary materials; reduce the production time of HHO gas. Sodium hydroxide could reduce the production time 5~6 times compared with soda for same voltage of application. It is also found that there is no significance difference between types of water with regard to production time of HHO gas.
Fig. 3. Characteristic of MMW against voltage for different concentration of auxiliary materials; (a) 5g, (b) 10g, (c) 15g.

Fig. 4. Characteristic of HHO gas production time against voltage for different concentration of auxiliary materials; (a) 5g, (b) 10g, (c) 15g.
3.3. Current of the system (I)

Fig. 5 shows the characteristics of current generated in the system against voltage of application for different concentration of auxiliary materials. As clearly seen from Fig. 5(a), the water with 5g of sodium hydroxide, the generated current in the system is very high (above 30 A in max) compared with 5g of water with soda (about 15A in max) for same voltage of application. It is also found that effect of water types is not significantly observed in this experimental work. Similarly, for water with 10g of sodium hydroxide, it is obviously found that the current generated in system much more higher compared with water added with soda as shown in Fig. 5(b). There is also no significance effect of water type was observed for this state. Furthermore, for distilled water with 15g of sodium hydroxide, the current generated in system much higher compared with water added with soda as shown in Fig. 5(c). The difference between two cases sodium hydroxide and soda is larger than the previous cases. Note that the range of application voltage is smaller by adding sodium hydroxide concentration.

3.4. Efficiency of the system

The efficiency of HHO gas generation system is calculated according to the following equation. Electrolysis of water:

\[ \text{H}_2\text{O} \rightarrow \text{H}_2 + \frac{1}{2} \text{O}_2 \]  

(2)

where 1 mole (water) is 1 mole (H\textsubscript{2}) + 0.5 mole (O\textsubscript{2}) and 1 mole (water) is 1.5 mole (HHO) gas. This process is presumed to be at 298K and one atmosphere of pressure, and the relevant values are taken from the table of thermodynamic properties as shown in Table 2.

![Figure 5: Characteristic of current against voltage of application for different concentration of auxiliary materials; (a) 5g, (b) 10g, (c) 15g.](image)

| Table 2. Thermodynamic properties [10] |
|---------------------------|----------------|----------------|----------------|----------------|
| Quantity     | H\textsubscript{2}O | H\textsubscript{2} | 0.5 O\textsubscript{2} | Change |
| Enthalpy     | 515            | 166            | 59.6          | 0.79         |
| Entropy      | 69.91 J/K      | 130.68 J/K     | 0.5 x 205.14 J/K | T\Delta S = 48.7 kJ |
The molar volume is the volume occupied by one mole of ideal gas at standard temperature and pressure (STP). Its value is 22.4 liters/mole. One atmosphere pressure = 101.3 kPa. Molar volume = volume of one mole of gas at STP = 22.4 L.

\[ W = (101.3 \times 103 \text{ Pa})(1.5 \text{ mol})(22.4 \times 10^{-3} \text{ m}^3/\text{mol})(298\text{K}/273\text{K}) = 3715 \text{ J} \]  

(3)

Since the enthalpy \( H = U + PV \), \( \Delta U = \Delta H - P\Delta V = 285.83 \text{ kJ} - 3.72 \text{ kJ} = 282.1 \text{ kJ} \) and \( \Delta G = \Delta H - T\Delta S = 285.83 \text{ kJ} - 48.7 \text{ kJ} = 237.1 \text{ kJ} \). where \( W \) is work to expand gases produced, \( P \) is pressure, \( V \) is volume, \( \Delta G \) is electrical energy input, \( \Delta H \) is energy exchange processes for one mole of water. 237.1kJ=65.8611 (watt-hour). One mole of ideal gas at standard conditions is 22.4 Liters. So, to get 1.5*22.4=33.6 L of HHO gas. Therefore, it requires (65.8611/33.6) =1.96 Watt to generate 1 liter of HHO Gas (Ideal Value).

\[ \text{Input Energy (w.h/L)} = (V*I *\text{Time}/3600)/1L \]  

(4)

Efficiency (%) = (Ideal factor/input energy)*100%  

(5)

Efficiency (%) = (1.96/Input energy)*100%  

(6)

Fig. 6 shows the characteristics of efficiency in HHO gas generation in system against voltage of application for different concentration of auxiliary materials. It is obviously found that the maximum efficiency is 44% at 14 volt of application voltage for distilled water with 5g of sodium hydroxide, while using the tap water with 5g of soda; the maximum value of efficiency is 32% at 18 volt of application voltage as shown in Fig. 6(a). For distilled water with 10g of sodium hydroxide, the maximum efficiency is 34% at 10.3 volt of application voltage, while it is 31% for tap water with 10g of soda at 20 volt of application voltage as shown in Fig 6(b). Notes that the range of application voltage for water with sodium hydroxide is much smaller than that of water with soda. However, when adding 15g of sodium hydroxide, the maximum efficiency is 32% at 8 volt of application voltage in tap water, while 31.5 of maximum efficiency with 15g of soda with tap water at 18volt of application voltage as shown in Fig. 6(c).

Fig. 6. Characteristic of efficiency against voltage for different concentration of auxiliary materials; (a) 5g, (b) 10g, (c) 15g.
This is due to sodium hydroxide (NaOH) is a strong base material which has high conducting abilities [10]. Therefore, if a water-soluble electrolyte is added, the conductivity of the water rises considerably. This is indicating by increasing of current of the system much higher in sodium hydroxide compared with soda.

4. Conclusion

The prototype of HHO gas generator for educational purpose has been performed in this research work. The effect of water type and difference concentration of auxiliary materials, namely sodium hydroxide (NaOH) and soda (NaHCO3) on output energy, production time of HHO gas, voltage and current of the system and efficiency are investigated.

The result revealed that the maximum efficiency value (44%) of HHO gas generated when using sodium hydroxide as auxiliary material with concentration of 5g in the distilled water. At the same voltage of application, the production time of HHO gas much smaller for distilled water with sodium hydroxide compared with tap water with soda. By using the NaOH decrease the time consuming. It is recommended to use sodium hydroxide as auxiliary material with low concentration to generate HHO gas.

![Fig. 7. Overall relation of HHO gas generation efficiency against different concentration of auxiliary materials.](image)

References


