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# A Comparison of Hydrogen Production by Electrolysis Method Using Water Electrolyte with Stainless Steel and Copper Electrodes

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**ABSTRACT**

This experiment focuses on the production of hydrogen gas ($H_2$) using the electrolysis method. The electrolysis method converts water ($H_2O$) into the combustible compound $H_2$ and $O_2$, which aids in the combustion process. Hydrogen gas ($H_2$) is an important renewable energy source. Therefore, research is needed to explore and optimize alternative and renewable energy sources, one of which is hydrogen gas. The objective of this experiment was to find the optimal variation between stainless steel and copper in producing the highest hydrogen gas pressure. In this experiment, a power source of $12\ V\ 20\ A$ was used, along with a salt solution of $1500\ mL$ with a concentration of $0.167\ gr/mL$. Two different types of cathodes were used, stainless steel and copper. The experiment involved variations in the number of plates, namely 3, 5, and 7, and testing durations of 5, 10, and 15 minutes. The test results indicated that the hydrogen gas pressure increased with the increasing number of plates and electrolysis time. The highest pressure was achieved using copper plates with 7 plates and an electrolysis time of 15 minutes. Under these conditions, the hydrogen gas pressure reached $439.677\ Pa$

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## INTRODUCTION

The need for energy is increasing in accordance with the time, both for daily activities and production. One of the energy consumptions is the use of petroleum (conventional energy) for transportation, power generation, and other purposes. The dependence on conventional energy can lead to an energy crisis and greenhouse effect. Therefore, there is a need for new and renewable alternative energy sources. One example of renewable energy is hydrogen gas. Hydrogen gas is combustible and explosive under certain conditions. However, hydrogen cannot be found directly in nature as it is bound with water or other compounds. One method used to separate hydrogen is through the process of electrolysis (Fazlunnazar et al., 2020). Electrolysis is an electrochemical process that uses electrical energy flowing through a cathode and an anode in a container containing an electrolyte. Two electrodes are required to connect the electric current from the current source for a chemical reaction to occur, with the positive electrode called an anode and the negative electrode called a cathode (Siregar et al., 2020). Water electrolysis is the process of separating water ($H_2O$) into hydrogen ($H_2$) and oxygen ($O_2$) using an electric current flowing through the water. The working principle is that the electric current flows from the current source through the electrical conductor to the cathode, where hydrogen is formed, while oxygen is formed at the anode.

Hydrogen is the simplest element, consisting of one proton and one electron. Most of the hydrogen on Earth is found in the form of water. Hydrogen makes up about 11.2% of the mass of water, making it very abundant on the Earth's surface. However, the content of free hydrogen in the atmosphere is very small, less than 0.001%. Hydrogen gas is the lightest among all gases. This gas can burn with a colorless flame and produce a very large amount of heat. The combustion of hydrogen gas produces a large amount of energy, so it can be used as a fuel (Astuti, 2016).

Stainless steel (SS) is a metal alloy composed of several elements with a specific composition, which gives the metal new properties that are stronger, corrosion-resistant, and have other superior qualities. Stainless steel is an iron compound that contains at least 10.5% chromium (Cr) to prevent the process of corrosion of the metal (Astuti, 2016). Copper is a metal found as a single element or associated with copper and silver. Copper is widely found and obtained during the separation process from its core during electrolysis and copper refining. Copper (Cu) is a transition metal (group IB) with atomic number 29, atomic mass 63.546, melting point 1083 °C, and boiling point 2310 °C. Copper has a reddish color, is easily bent, and is malleable. Copper is toxic to living organisms. An electrode is an electrical conductor connected to an electrolyte solution in an electrical circuit. In an electrochemical cell, the electrode can act as an anode during the oxidation process or as a cathode during the redox process (Hamid et al., 2017).

Numerous studies have been conducted on the production of hydrogen gas using electrolysis. In Bow et al., (2020) research on the comparison of hydrogen gas production with different electrodes, the gas pressure produced by stainless steel electrodes was higher compared to electrodes made of aluminum and copper, and the closer the distance between the electrodes, the higher the gas pressure produced. The highest hydrogen gas pressure was measured at the stainless-steel electrode at 9733 Pa. Meanwhile, at the aluminum electrode on the cathode side, the hydrogen pressure was 9246.8 Pa, and the lowest hydrogen pressure was measured at the copper electrode at 6034 Pa (Bow et al., 2020). In Reinaldi's 2022 research on the comparison of hydrogen gas production using aluminum electrodes, by analyzing the effect of the number of electrode plates and electrolysis time, it was found that the gas pressure produced by a variation of 5 plates with electrolysis times of 1, 2, and 3 minutes separately were 0.441 Pa; 1.274 Pa; and 2.695 Pa. The gas pressures produced by a variation of 6 plates with electrolysis times of 1, 2, and 3 minutes consecutively were 0.548 Pa; 1.401 Pa; and 2.812 Pa. The gas pressures produced by a variation of 7 plates with electrolysis times of 1, 2, and 3 minutes consecutively were 0.637 Pa; 1.568 Pa; 2.881 Pa (Manurung et al., 2022).

Based on previous research, further investigation is needed regarding the comparison of hydrogen production through electrolysis using stainless steel and copper electrodes with varying plate numbers. This is done because there is no direct comparison yet between the impact of the number of plates in stainless steel and copper electrodes. It is hoped that the results of this study can be useful for the development of hydrogen gas production.

## METHOD

The independent variables used in this study were the variation in the number of electrode plates and the electrolysis time. This research was conducted from April to May and took place in South Lampung, at the Energy Conversion Laboratory of the Mechanical Engineering Department, Sumatra Institute of Technology.

The tools and materials used in this electrolysis experiment were a jar as the electrolysis container, a $12\ V\ 20\ A$ power supply as the source of electric current, copper and stainless steel plates 1 mm thick as electrodes, alligator clip cables as current conductors, 2 used bottles as reaction tubes, rubber tubing as an air conductor from the reaction tube to the gas container, plastic as a gas container, small hose clamps as hose locks, bolts and nuts as electrode locks, hot glue as an adhesive, and a U-manometer as a pressure measuring device.

The process of making the apparatus begins with cutting the copper and stainless steel into 14 pieces each, with dimensions of $1\ mm\ x\ 14\ mm\ x\ 50\ mm$. The remainder of the stainless-steel plate was cut into 2 pieces with dimensions of $100\ mm\ x\ 20\ mm$. Then, a $5\ mm$ diameter hole was made at one end of each previously cut metal. Next, both used bottles were cut into 2 parts and the bottle caps were drilled to the diameter of the rubber hose. Then, 2 holes were made in the jar lid to the diameter of the rubber hose. The apparatus was then assembled as shown in the image below:

Figure 1. Electrolysis scheme.

The bottom of the jar was drilled with dimensions of $1\ mm\ x\ 20\ mm$ right below each reaction tube, then a stainless-steel size of $100\ mm\ x\ 20\ mm$ is inserted $30\ mm$ into the jar from that hole to act as a support as well as an electrical conductor to the electrode. The hole was sealed using hot glue from inside and outside the jar to prevent water leakage. Then, bolts were installed on the electrode support and copper metal was arranged on each support, three pieces as electrodes, and then locked with nuts.

The experimental setup involves filling a jar with $1500\ mL$ of water and $250\ g$ of NaCl (sodium chloride), which was then dissolved. The jar was tightly sealed while positioning the reaction tubes directly above the electrodes. One rubber hose was connected to a U-shaped manometer, and another hose was connected to a plastic gas container. An alligator clip was attached to the power supply, and then to the electrode support. The negative pole was connected to the electrode linked to the manometer U, while the positive pole was connected to the electrode linked to the plastic container. The power supply was turned on, and bubbles will form on both sides of the electrode.

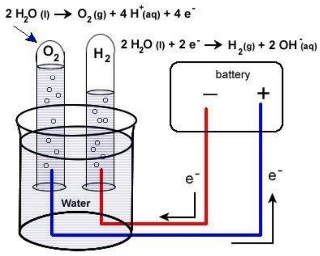


Figure 2. Electorlysis process

In this research, the pressure measurement of the produced $H_2$ gas is carried out using a U-manometer that uses the following equation:

$$P = \rho\ g\ h \tag{1}$$

Where:

$P$ : Hydrogen gas pressure ($Pa$)

$\rho$ : Density of water ($997\,\frac{kg}{m^3}$)

$g$ : Acceleration due to gravity ($9{,}8\,\frac{m}{s}$)

$h$ : Height difference ($m$)

**RESULT AND DISCUSSION**

Based on the experiment activities that have been conducted, the resulting data obtained include the amount of time ($minutes$), height ($mm$), and pressure ($Pa$) using a U-manometer. Then, the height values were used to calculate the pressure values ($Pa$) in the electrolysis reaction using the existing formula. The following Table 1 summarizes the test data and pressure calculations.

Table 1. Data Results of Electrolysis Experiment with Copper Electrode

| Number of Copper Plate | Time (minute) | Height (mm) | Pressure (Pa) |
|---|---|---|---|
| 3 | 5 | 10 | 97.706 |
| | 10 | 19 | 185.641 |
| | 15 | 21 | 205.183 |
| 5 | 5 | 12 | 117.247 |
| | 10 | 19 | 185.641 |
| | 15 | 23 | 224.724 |
| 7 | 5 | 25 | 244.265 |
| | 10 | 42 | 410.365 |
| | 15 | 45 | 439.677 |

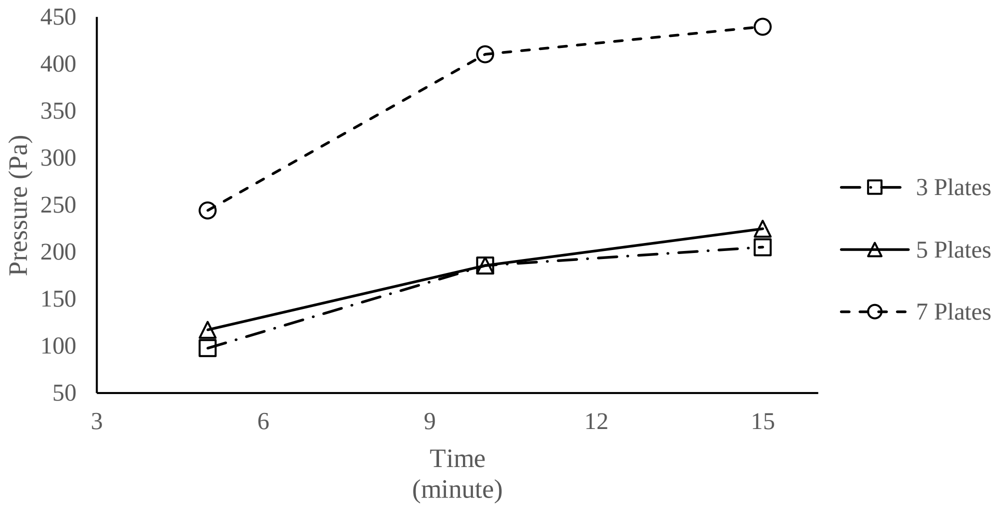


Figure 3. Graph of pressure comparison over time on copper plate

Figure 3 shows an increasing trend as time progresses, and also the greater number of plates increases the pressure produced. This indicates that the pressure produced is directly proportional to the electrolysis time and the number of copper plates. This result is reinforced by the research conducted by Manurung et al., (2022) who performed electrolysis testing on aluminum plates with variations in time and number of plates, where he obtained an increasing pressure trend as the electrolysis time and number of aluminum plates increased. The highest-pressure value was obtained with a variation of 7 plates, with a pressure value of 439.677 Pa, and the lowest pressure value was found in a variation of 3 plates, with a pressure value of 97.706 Pa.

Table 2. Data Results of Electrolysis Experiment with SS Electrode

| Number of SS Plate | Time (minute) | Height (mm) | Pressure (Pa) |
|---|---|---|---|
| 3 | 5 | 5 | 48.853 |
| | 10 | 15 | 146.559 |
| | 15 | 19 | 185.641 |
| 5 | 5 | 8 | 78.165 |
| | 10 | 14 | 136.788 |
| | 15 | 20 | 195.412 |
| 7 | 5 | 10 | 97.706 |
| | 10 | 17 | 166.1 |
| | 15 | 21 | 205.183 |

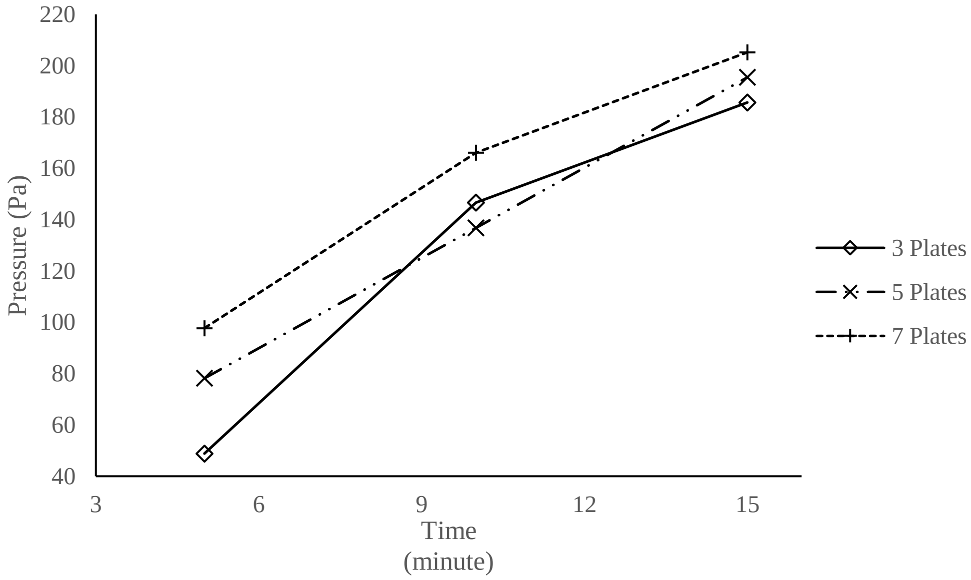


Figure 4. Graph of pressure comparison over time on SS plate

Figure 4 shows an increasing trend with the passage of time, and also the greater number of plates increases the pressure produced. This indicates a pattern similar to the copper plate testing (Figure 3) in terms of the same increasing trend with the passage of time and number of plates. This suggests that the pressure produced is directly proportional to the electrolysis time and the number of stainless-steel plates. The highest-pressure value was obtained with a variation of 7 stainless steel plates, with a pressure value of 205.183 Pa, and the lowest pressure value was found with 3 stainless steel plates, with a pressure value of 48.853 Pa.

Table 3. Data Results of Electrolysis Experiment with Copper and Stainless Steel Electrodes

| Number of Plate | Average Pressure (Pa) | |
|---|---|---|
| | Copper | SS |
| 3 | 162.843 | 127.018 |
| 5 | 175.871 | 136.788 |
| 7 | 364.769 | 156.330 |

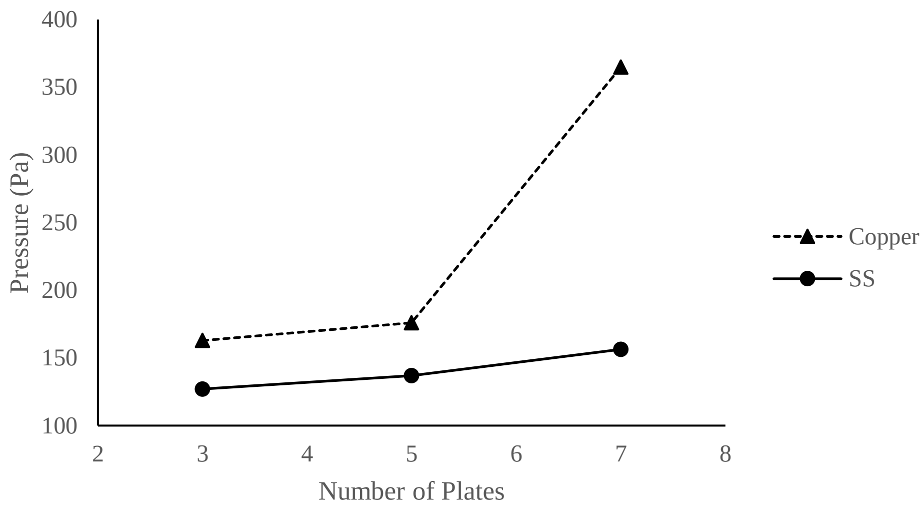


Figure 5. Graph of Pressure Comparison Relative to the Number of Copper & Stainless Steel Plates

The graph above shows that there is an increase in gas pressure as the number of copper or stainless-steel plates increase. This proves that the gas pressure is directly proportional to the number of plates. However, there is a data deviation (outlier) in the Copper data, where the average gas pressure with 7 copper metal plates produced is very skewed compared to the test data of stainless-steel metal. This can occur due to several factors, such as a lack of precision when reading the U-manometer measurements and the manometer's condition, which is difficult to calibrate

**CONCLUSION**

The electrolysis experiment with copper and stainless-steel plates with varying the number of plates and electrolysis time, was successfully conducted. The hydrogen gas pressure produced in the copper and stainless-steel tests are directly proportional to the electrolysis time and the number of plates. For copper, the highest-pressure value obtained for each plate variation was achieved by the variation of 7 plates and a time of 15 minutes with a pressure value of 439.677 Pa. The lowest pressure value was found with 3 plates and a time of 5 minutes with a pressure value of 97.706 Pa. For stainless steel, the highest-pressure value obtained for each plate variation was achieved by the variation of 7 plates and a time of 15 minutes with a pressure value of 205.183 Pa, and the lowest pressure value was on 3 plates and a time of 5 minutes with a pressure value of 48.853 Pa. The greatest hydrogen gas pressure from all the tests was obtained by the copper plate test with 7 plates and a time of 15 minutes, which is 439.677 Pa. This proves that copper plates are better compared to stainless steel plates in terms of producing hydrogen gas by electrolysis.

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