Effect of Stainless Steel Duplex Electrode Size on Hydrogen Production through Electrolysis Process

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Abstract: Renewable energy development is the focus of attention at this time, using environmentally friendly energy sources and zero emission by utilizing water to make hydrogen through the electrolysis process. The electrode material is selected from materials that have good electrical conductivity and corrosion resistance. Duplex Stainless Steel (DSS) is a material with a combination of two phases, namely austenite and ferrite. The process includes designing tools, manufacturing, and testing the performance of the electrolyzer against the variation in the cross-sectional area with a voltage of 12V and variations in current and electrolytes used are brackish water with a salinity of 8 ppt. The larger the cross-sectional area, the easier the electron transfer that occurs during the electrolysis process, which causes the charge of electrons to react more, then the resulting current will be more significant, this results in a large amount of power generated, while efficiency is inversely proportional to power. Electrode size is also proportional to the current. Electrode 2 inch is more effective than electrode 1.5 inch because, at current 35 A, an efficiency of 93.33% is obtained with the volume of gas produced is 1.9087 Liters.

1 INTRODUCTION

Electrolysis of water is the decomposition of water compounds (H_2O) into hydrogen gas (H_2) and oxygen (O_2) by using an electric current through water (Ploetz et al., 2016; Rusdianasari et al., 2019). Hydrogen is one of the new renewable energy sources that can reduce exhaust emissions by using water as fuel through the process of electrolysis of water compounds (H_2O) which is converted into its constituent components, namely oxygen and hydrogen (Kassaby et al., 2016; Imperiyka et al., 2017; Irtas et al., 2021; Jannah et al., 2020).

The production of hydrogen gas from seawater containing NaCl can take place quickly because NaCl itself functions as a natural catalyst. The content of the natural catalyst or commonly referred to as salinity, affects the electrolysis process. In the study of electrolysis made from water and seawater based on variations in current and salinity, the salinity used was 0.05 ppt, 15 ppt, and 35 ppt with the best gas conversion at a salinity variation of 35 ppt (Phalakornkule et al., 2020; Purnamasari et al., 2019; Rusdianasari et al., 2020; Rusdianasari et al., 2020).

The production of H_2 gas by electrolysis of water and seawater obtained the highest concentration of H_2 gas formed, namely the electrolysis of aqua DM, which was added with NaCl and NaOH of 4500 ppm. In this study, the concentration of NaOH catalyst was not varied in the electrolysis process (Imperiyka et al., 2017). The results of another study stated that in the production of hydrogen gas with an H_2SO_4 catalyst, the greater the current and the greater the number of electrodes provided with the same sulfuric acid concentration, the greater the concentration of hydrogen gas produced (Syakdani et al., 2019; Bow et al., 2018; Amelia et al., 2021). The greater the concentration of the catalyst, the greater the precipitate formed during the electrolysis process and causes obstruction of the process of forming gas bubbles at the electrode (Hadi, 2020).

A catalyst is a substance that can accelerate the rate of a chemical reaction which at the end of the reaction is obtained in its original state or does not

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react (Sellami and Loudiyi, 2017). In the electrolysis of water, a catalyst is used to facilitate or accelerate the decomposition of water into hydrogen and oxygen because the catalyst ions are able to affect the stability of water molecules into H^+ and OH^- ions which are easier to electrolyze due to a decrease in activation energy (O'Neil et al., 2016).

Research using stainless steel electrodes produced 95.8 ml and 82.6 ml of HHO gas, respectively. The electrolyte used is KOH and electrodes made of Stainless Steel with variations in the cross-sectional area of the electrode with sizes 9 cm x 11 cm and 9 cm x 14 cm (Meier, 2014).

The most important components of the electrolysis process are electrodes and electrolyte solutions (Irena, 2020). One of the raw materials for electrolysis is water. Electrolysis of water which has the chemical formula H_2O is the event of the decomposition of water compounds (H_2O) into its constituent elements, namely hydrogen (H_2) and oxygen (O_2), by using an electric current. Electrolysis is an event that occurs when an electric current is passed through an ionic compound and the compound undergoes a chemical reaction (Abdel-AaL et al., 2020).

Hydrogen gas as the main product and oxygen produced from the electrolysis of water form bubbles at the electrodes and can be collected in a reservoir. This principle is then used to produce hydrogen that can be used as fuel for hydrogen vehicles. Michael Faraday discovered the electrolysis process in 1820. Factors that affect the electrolysis process include the use of a catalyst, the immersed surface area, the nature of the electrode raw material, the concentration of the reactants, and the amount of external voltage (Moulita et al., 2020).

The main product, hydrogen in the water electrolysis process, is highly flammable and will burn at a concentration of 4% in free air. The enthalpy of combustion of hydrogen gas is -286 kJ/mol (Yunsari et al., 2019). Based on this, safety is needed when burning hydrogen gas. The arrestor is a tool component that reduces the risk of work accidents such as explosions due to flashback fires during the hydrogen gas flame test (Bow et al., 2020). In this study, electrolysis was carried out using a prototype electrolysis reactor equipped with an arrestor in terms of the effect of the size of Duplex Stainless Steel on hydrogen production through the electrolysis process.

2 METHODOLOGY

The material used in this study is water with a salinity of 8 ppt which was taken according to seawater sampling standards (SNI 6964.8:2015). After knowing the salinity that produces hydrogen gas optimally, variations in the size of the stainless steel duplex electrode are carried out. The seawater electrolysis prototype consists of five main units, namely, feed tank, electrolyzer tube, electrodes, H_2 and O_2 gas cylinders, flashback arrestor, and control panel. The system is equipped with measuring instruments, namely digital pressure detectors, digital temperature detectors, H_2 smart sensors, and O_2 smart sensors. The electrolysis equipment used can be seen in Figure 1.

Figure 1: Electrolyzer Prototype.

The electrolysis process is carried out using the Hydrogen Generator Using Water Electrolysis Process method based on ISO 22734-1:2008 with adjustments to the design and condition of the tool. The electrolysis process in the electrolysis reactor used is that the feed is pumped into the electrolyzer as much as 17 liters. The electrolysis process is carried out with a certain current. The electrolysis results obtained are in the form of hydrogen and oxygen gas in the electrolyzer, which will then be temporarily accommodated in the gas holding tank. During the electrolysis process, data is collected every 2 minutes in the form of operational condition data in the form of pressure, temperature, and voltage. After hydrogen gas is obtained, then temperature data is taken on the arrestor every 2 minutes.

3 RESULT AND DISCUSSION

In this study, we want to get the effect of Duplex Stainless Steel as an electrode and the electrolyte used is brackish water on the production of hydrogen gas produced. The prototype for making hydrogen was carried out by varying the size of the electrode with the respective electrode diameters (2 inches and 1.5 inches), the thickness was 0.33 mm, and the electrode height was 40 cm, and the current variation with a voltage of 12 Volts for 480 seconds and using an electrolyte, namely water. brackish with a salinity of 8 ppt. The production of hydrogen gas produced by varying the size of the electrodes can be seen in Table 1.

Table 1: Hydrogen production based on electrode cross-sectional area.

Electrode Size	I (A)	V (Volt)	H_2 Gas Volume (Liter)	P (Watt)	η (%)
Electrode I (D= 2 inch, t= 40cm)	15	11.9	0.8512	178.5	99.17
	20	11.7	1.1251	234	97.50
	25	11.6	1.3877	290	96.67
	30	11.6	1.6538	348	96.67
	35	11.5	1.8719	402.5	95.83
Electrode II (D= 1,5 inch, t=40cm)	15	11.6	0.8539	174	96.67
	20	11.5	1.1407	230	95.83
	25	11.5	1.4179	287.5	95.83
	30	11.3	1.6769	339	94.17
	35	11.2	1.9087	392	93.33

3.1 Effect of Current and Electrode Size on the Volume of Hydrogen Produced

The formation of hydrogen gas in the electrolysis process has a directly proportional relationship between gas yield, time, and current strength. The results of measuring the volume of hydrogen gas produced at different electric currents and the cross-sectional area of the duplex stainless steel electrodes used during the electrolysis process can be seen in Figure 2.

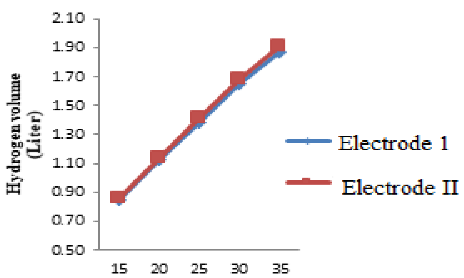

Figure 2: The volume of hydrogen gas produced is based on the curren t and the size of the electrode.

Figure 2 shows that the transfer of electrons during electrolysis results in an increase in the production rate of hydrogen gas produced. This is indicated by an increase in current and a different size of the electrode. The size of electrode I (2 inches) is obtained with a current of 35A, the volume of gas produced is 1.8719 liters, while the size of the electrode II (1.5 inches) is that the volume of gas produced is 1.9087 liters. The increase in the volume of gas produced at different electrode sizes is not significant, this occurs because the electrode sizes are 2 inches and 1.5 inches respectively, with the same electrode height. The increase in current and voltage causes the electrolysis process to occur quickly because the movement of the molecules is also increasing. The temperature in this process also increases due to the faster movement of electrons during the electrolysis process (Ploetz, R. Rusdianasari and Eviliana, 2016).

3.2 Effect of Current and Electrode Size on the Electric Power Generated

The relationship between current and power generated by using different sizes of electrodes can be seen in Figure 3.

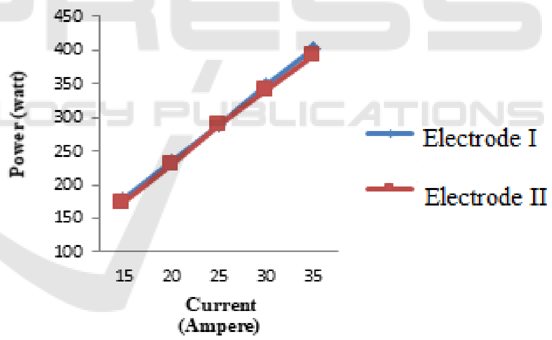

Figure 3: The electric power generated is based on the current and the size of the electrode.

Figure 3 shows that the relationship between the current and the supplied power is less significant for different electrode sizes, this happens because the electrode sizes are 2 inches and 1.5 inches, respectively with the same electrode height. At the size of the electrode I obtained with a current of 35A, the power supplied was 402.5 Watts, while the size of the electrode II obtained a power supply of 392 Watts. However, if the cross-sectional area affects the power supply, the larger the size of the electrode, the easier it will be for the transfer of electrons that occurs during the electrolysis process, causing more electrons to react, so the current generated will be even greater, this results in a large amount of power being generated directly proportional to the current (Purnamasari, I., Yerizam, M., Hasan, A., Junaidi, R., 2019).

3.3 Electrolyzer Efficiency

The performance of the electrolyzer prototype that converts seawater into hydrogen gas with variations in electric current and different sizes of stainless steel duplex electrodes can be seen in Figure 4.

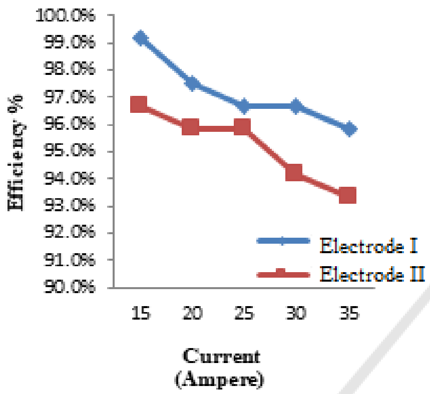

Figure 4: Electrolysis efficiency based on the electrode size.

Figure 4 shows that the greater the electric current, the greater the power produced because power is directly proportional to current, while efficiency is inversely proportional to power. So that the highest efficiency obtained at electrode I is 99.17% with an electrode size of 2 inches at a current of 15A, while the lowest efficiency obtained at electrode II is 93.33% with an electrode size of 1.5 inches at a current of 35A. The relationship between current and efficiency generated, this happens, when an increase in current occurs, the power generated is more significant and the efficiency of the electrolyzer is getting smaller. The efficiency of the electrolyzer is not only affected by the increase in current and power but is also affected by the heat energy produced, which is directly proportional to hydrogen gas. The type of electrode greatly affects the efficiency of the electrolyzer. The electrode used is Duplex Stainless Steel. Besides being able to produce a larger current, this type also reacts and produces a constant and relatively large gas in the long term.

4 CONCLUSIONS

The production of hydrogen has been carried out by the electrolysis method using a prototype electrolyzer which has an electrolysis cell with a capacity of 15-20 liters. The electrodes used are Duplex Stainless Steel with varying diameter sizes, namely 1.5 inches and 2 inches with a height of 40 cm and an electrode thickness of 0.3 mm. In this process, the highest volume of gas produced with different electrode sizes is found in the size of electrode II (D = 1.5 inches, t = 40cm) at a current of 35A of 1.9087 Liters. The power generated is more significant because the power is directly proportional to the current so that the highest power is obtained at 402.5 Watt with a current of 35A at the electrode size I (D = 2 inches, t = 40cm). The highest efficiency was obtained at the size of the electrode I (D = 2 inches, t = 40cm) with a current of 15A of 99.17%.

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