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Effect of spacing between electrodes on the hydrogen generation

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Abstract- Consumption of fossil fuels increases the ambient contamination due to the greenhouse gases. This problem has motivated the search of new sources of energy, such as hydrogen, which are friendly to the environment. Water electrolysis has become in for more usual form hydrogen generation due to its simple mechanism and purity.

In this work, an electrolyzer of 14 plates was built in stainless steel to study the effect of the spacing between electrodes, and temperature and concentration of the electrolyte on the production of hydrogen. Hydrogen production increases with decreasing spacing between the electrodes, due to a decrease in the electrical resistance of the cell given by mass transfer phenomena. Hydrogen generation also increases with increasing electrolyte concentration and cell temperature. In addition, at high temperatures of electrolytic cell, there is low electrical potential in the cell; this indicates high ionic conductivity, low electrical resistance and consequently high efficiency of the electrolysis process.

Keywords- water electrolysis, hydrogen, renewable energy, electrodes.

1. Introduction

Fossil fuel has originated serious problems to our ecosystems, for what one has seen the need to use sources renewables energy [1], which are an alternative to reduce this impact [2]. Emissions of CO_2 come from fossil fuel combustion presented in the cars [3]. By other hand, the high consumption of gasoline, and considerable increase in its Price, have become unsustainable to these fuels, thus encouraging a incessant search of new technologies, to reduce consumption in cars [4-6]; therefore, the hydrogen becomes an option to substitute the oil as a primary energy source, because is the most abundant element of the universe, is clean, safe, and pollution risks are almost non-existent, since the hydrogen energy is given no radioactivity, and its contribution to the greenhouse effect is minimal.

The study of the electrolysis of water, to produce hydrogen registers since ancient times [7-9]. But, it has been in recent years, which have been considered to hydrogen, as one of the best solutions to energy and environmental problems that have been triggered at the global level, so, it has been developing intensively the polymeric membrane of proton exchange for application in fuel cells [10-13], thereby encouraging the development of future applications in electrolyzer, for hydrogen production technologies [5, 14, 15].

Despite all the research that turns around the production hydrogen, only 5% of hydrogen is produced from the electrolysis of water; this is due, to the high consumption of electrical energy required to separate the water molecule, in hydrogen and oxygen, because water is a very stable molecule [9]. The objective of this research will focus on design and built an electrolyzer of 14 plates, in order to study the effect of the spacing between electrodes, temperature and electrolyte concentration on the production of hydrogen.

2. Experimental Procedures

2.1. Materials and electrolyzer

An electrolyzer was designed for water electrolysis by means of electrochemical and thermodynamic fundaments. The electrolyzer of plates was built in stainless steel, gauge 316, which consisted of 14 plates. This electrolyzer has a pipe system to lead the mixture of hydrogen and oxygen. The electrolyzer was connected to a voltage-amperage source, model - HY 1803 D, mark MASTECH, that was fixed, between 0-3 amps amperage. A water bath was used to control the temperature at 40 °C, and for the subsequent collection of hydrogen, was used a beaker of 150 mL, that was submerged upside down, in a square plastic container, of measures 30 x 30 cm. The times of collection of hydrogen, was measured with a stopwatch. As electrolyte was used potassium hydroxide (KOH) by varying the concentrations at 1, 2, 3, and 5 %.

2.2. Experimental procedure to generate hydrogen

A solution of potassium hydroxide at 1% was prepared with distilled water, which feeds the electrolyzer. The electrolyzer is immersed in a maria`s bath at 40 °C and electrolyzer was connected to a power source supplying current (1 A) the electrolyzer. Hydrogen and oxygen generated is collected into a beaker submerged upside down in a bowl that contains water, which allows for determining the volume of gas formed by displacement of water in the beaker. The above procedure is repeated for each concentration, temperature and amperage indicated on the design of the experiment shown in table 1, where a multifactor design was made with two replicas. The factors are temperature, concentration of the electrolyte, and amperage, at the levels indicated in table 1. The dependent variable is the hydrogen mass flow.

Table 1. Experimental Design: factors and levels

Factors	**Levels**				
Spacing between electrodes (mm)	1.5		3.2		
Concentration (% KaOH)	1	2	3	4	5

2.3. Mathematical Model of Electrolyzer

Thermodynamic and electrochemical phenomena were considered to develop the mathematical model of an electrolyzer of 14 plates. These phenomena occurred during

the production of hydrogen and oxygen, to allow calculating the area of the electrode plates. For calculations, it is assumed temperature and pressure of reference of 298.15 K and 1 bar, respectively. Mathematical modeling is detailed in previous investigations [15, 16].

3. Results and Discussion

3.1. Effect of Spacing between electrodes on the Hydrogen Generation

Figure 1 shows the effect of spacing between electrodes on the hydrogen generation at different amperages and an electrolyte concentration of 1%. The hydrogen generation increases with decreasing the spacing between electrodes, due to the reduction of electrical resistance (R). This behavior is according to the equation $R = \rho l/A$ [14], where ρ is the material resistivity, A is the electrode area, and l is the longitude of current trajectory or distance between electrodes. Mazloomi et al. [14] studied the effect of gap between electrodes on the hydrogen generation and they obtained similar behavior to our work, hydrogen generation increases with decreasing the spacing between electrodes. However, high reduction in the spacing between electrodes would reduce the hydrogen generation due to high formation of bubbles that avoid the electron flow between electrodes. Results above mentioned were observed for all electrolyte concentrations.

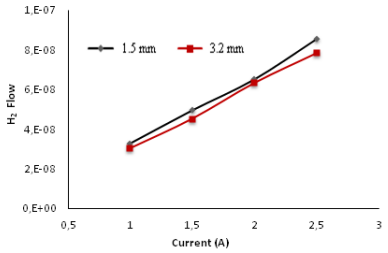

Fig 1. Effect of amperage on the hydrogen generation at different spacing between electrodes

3.2. Effect of Electrolyte Concentration on the cell voltage

Figures 2, 3, 4 and 5 show variation of voltage with respect to amperage at spacing between electrodes of 1.5 and 3.2 mm. Voltage of electrolytic cell decreases with increasing the electrolyte concentration, because the solute (KOH) increases the electrolyte conductivity, which increases the mobility of electrons. This behavior was observed in [5, 15, 16]. Also, voltage increases with decreasing the spacing between electrodes due to the reduction of electrical resistance.

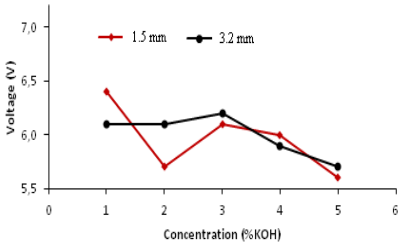

Fig 2. Effect of electrolyte concentration on the cell voltage at 1 amperage and different spacing between electrodes.

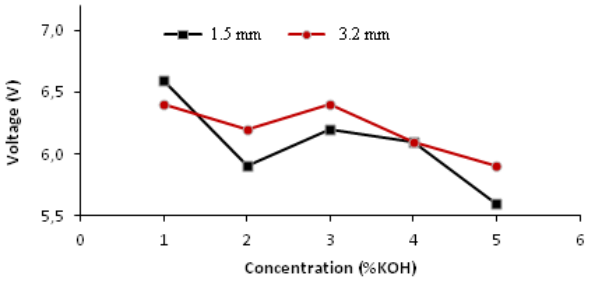

Fig 3. Effect of electrolyte concentration on the cell voltage at 1.5 amperage and different spacing between electrodes.

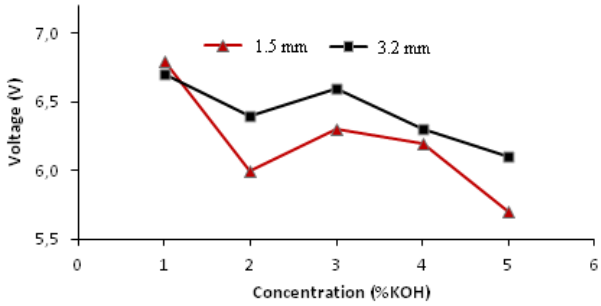

Fig 4. Effect of electrolyte concentration on the cell voltage at 2 amperage and different spacing between electrodes.

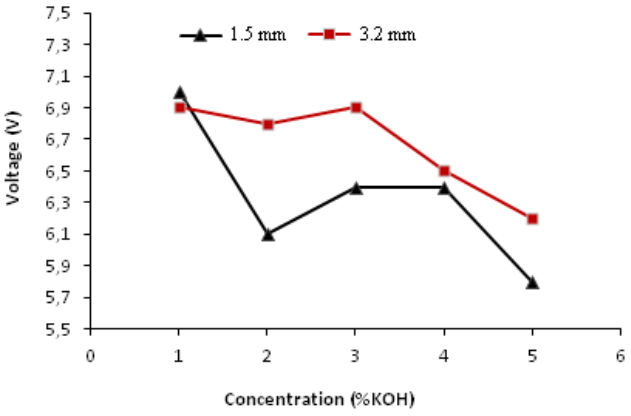

Fig 5. Effect of electrolyte concentration on the cell voltage at 2.5 amperage and different spacing between electrodes.

4. Conclusions

Electrolyzer of 14 plates constructed in stainless steel generates hydrogen, which increases with decreasing the spacing between electrodes. Furthermore, voltage decreases with increasing the electrolyte concentration due to the reduction of electrical resistance. Both phenomenons, mentioned above, are according with *Ohm's* law.

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