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Corrosion behaviour of some conventional stainless steels at different temperatures in the electrolyzing process

Eman Nassar[a]*, Amal Nassar[a]

[a]*Mechanical Engineering Department, Higher Technological Institute, Next to Small Industries Complex, Industrial Area, 10th of Ramadan City 11111, Egypt*

Abstract

In this study, attempts were made to find the suitable condition to produce hydrogen gas in the electrolysis process. Some conventional Stainless Steels (S.S. 316, 409, 410 and 430) were used as cathode and as anode in the electrolysis process at different temperatures (60, 70, 80 and 90 °C). Furthermore, the corrosion rate for all the investigated stainless steels was studied. It was observed that the temperature and the amount of nickel content in the electrode effect the amount of generated hydrogen and the rate of electrode corrosion.

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Keywords: Corrosion; behaviour; stainless steels; electrolyzing.

1. Introduction

An electrolysis cell uses electricity to split water molecules (H_2O) into hydrogen (H_2) and oxygen (O_2). In this method, the electrical energy is transformed into chemically bound energy in the hydrogen molecules. Nowadays, electrolytic hydrogen has a share of only 4 % [1,2] in the global production of the most abundant element of the universe [3,4]. Electricity expense constitutes the largest fraction of hydrogen production costs [5].

Hydrogen is probably the preferred energy carrier for a future zero-carbon economy but several research efforts are required in order to supply inexpensive and plentiful amounts of fuel. Although hydrogen is the most abundant

* Corresponding author. Tel.: +2-0100-641-4107; fax: +2-0222-492-4310.
E-mail address: eman.nassar@hti.edu.eg

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element in nature, it is usually found as a compound combined with other elements, and thus, the production of hydrogen always requires energy.

Many researchers studied the optimum condition for the water electrolysis [6–8]), de Souza et al [9] performed a series of experiments on electrode plates made from Nickel, carbon steel ,Molybdenum and Nickel-Molybdenum alloy. The maximum efficiency value of 96% was found at low carbon steel electrodes [7]. Ganley [10] studied the efficiency of the electrolysis process at high temperature and pressure. During the studies, different conditions were used in the experimental work such as: the electrode material, voltage level, current density and temperatures. The results show that a voltage level of 1.8 V was enough to cause a current density of 200 mA cm-2 at 200 °C. This value was only 1.5V when the electrolyte was heated up to 400 °C at the same pressure and current density. Appleby et al.[11] tried to reduce the hydrogen production cost by examining different parameters in conventional electrolyzes. Their results stated that high pressure electrolysis has less power demand for the phase of product compression. Nagai et al. [12] made some experiments to find out the suitable space between electrodes. All experiments were conducted with Ni-Cr-Fe alloy electrodes at ambient pressure. The researchers reported that reducing the distance between the electrodes will decrease the process efficiency.

Many experiments have been pursued in order to examine the effects of using electrodes at different positions on the efficiency of the electrolysis process [12]. The results show that higher efficiency levels can be obtained by placing the electrodes in a vertical position. In our previous work [13] we have studied the effect of chemical composition of the electrode material on the hydrogen generated and on the rate of corrosion. We concluded that the metal composition of the electrode effects the electrolyzing process and the rate of electrode corrosion. In the current research, we studied the effect of temperature on the rate of corrosion and on the amount of hydrogen generated for some conventional stainless steels.

2. Material and Methods

To split water into hydrogen and oxygen (electrolysis process) requires a material with good current connection (conductivity) and good resistance to corrosion. Stainless Steel (S.S) alloy gives superior behaviour in the electrolysis process, in the current study S.S types 316, 409, 410 and 430 (table 1 shows the chemical composition for the selected materials) were used as an anode and as a cathode in the electrolysis process at different temperatures (60,70,80 and 90 ^{0}C).

2.1. Water Electrolysis

A direct current (DC) is applied to maintain the electricity balance and electrons flow from the negative terminal of the DC source to the cathode at which the electrons are consumed by hydrogen ions (protons) to form hydrogen. In order to get a smooth DC voltage, a regulator was used to deliver the required energy to the system. A water electrolysis process was realised by using pipes with a diameter of 19 mm (0.748 inch) and a length of 170 mm (6.69 inch), as shown in figure 1. These pipes will be used as anodes and 5 pipes with a diameter of 22 mm (0.866

Table 1: Chemical composition of each stainless steel type.

Grade	**% from**								
	Ni	**Mo**	**Cr**	**S**	**P**	**Si**	**Mn**	**N**	**C**
316	13	3	17	0.03	0.045	0.75	2	0.1	0.08
409	0.5	0	10.75	0.03	0.045	1	1	0.75	0.08
410	25		12	0.03	0.04	1	1		0.15
430									
430	0.75		17	0.03	0.04	1	1		0.12