Hydrogen as energy vector.
Study of geometry optimization of electrode for processes producing hydrogen by electrolysis of water.

E. F. Cabrera[1], D. Echevarría[1], V. Henríquez[1*], A. Ramos[1] and J. A. Valencia[1]

Department of Process Engineering
E.I.I.C, Las Palmas de Gran Canaria University
Campus of Tafira Baja – Tafira Baja s/n, 35017 Las Palmas (Spain).
[*]phone: +34 928 451490, [1]email: eliana.cabrera101@alu.ulpgc.es, david.echeverria101@alu.ulpgc.es, vicente.henriquez@ulpgc.es, alejandro.ramos@ulpgc.es, jorge.valencia101@alu.ulpgc.es.

Abstract. Hydrogen is presented as a renewable, efficient and clean alternative to traditional energy vectors based on fossil fuels. One method of producing hydrogen is via electrolysis of water, where they play an important role in the efficiency the electrodes used and the electrolyte. This paper focuses on the study of geometry optimization of electrodes electrodes submerged in an electrolyte which does not change. Aluminum cathodes are designed with different shapes of various prototypes and a series of appreciative essays are performed applying selected voltage values. The results are classified using characterization factors focused on quality and behavior of hydrogen bubbles generated, such as the size and homogeneous distribution thereof, getting very good results validating one of the prototypes shaped. Through the behavior observed in tests come to conclusions that are directly related to the geometry and the material of the cathodes, where are fundamental aspects that influence the speed of sliding and rising bubbles, and therefore in the efficiency of process for producing hydrogen.

Key words: Electrodes, Electrolysis, Bubbles, Hydrogen, Geometry.

1. Introduction

The hydrogen economy presents a long-term scene hydrogen production by electrolysis from renewable electricity [1] and its use to meet all kinds of demands, both conventional industry where hydrogen plays a role in various processes reagent, such as energy where it will play its new role as an energy vector. The only emissions that would use hydrogen associated nitrogen oxides would be produced in combustion processes, its use in fuel cells would lead to zero emissions [2]. The vision of the economy of H_2 is based on the expectation that hydrogen can be produced from domestic resources, economically and environmentally acceptable technologies and end-use of hydrogen gain a significant market share. The intention is to introduce and entrench the presence of this renewable energy as a substitute for fossil fuels [3]. To the extent that these expectations are reached, a hydrogen economy will benefit the world by providing greater energy security and improved environmental quality. However, achieving this objective requires overcoming many technical, social and political challenges.

It is important to advance research which focus on the development of new electrocatalysts and effective electrolyte additives, the study of physical / chemical properties of electrodes modifications and proper management of the phenomena of gas bubbles [4,5]. In this line the present study is carried out with the aim of optimizing the electrode geometry processes involved in obtaining H_2 by electrolysis of water. The work focuses on the cathodes being these aluminum. The anode, consisting of a copper terminal is kept constant in all trials performed. The system employed is the electrolysis of water for producing H_2 bubbles, applying different voltage values and a constant value of water conductivity. Five different aluminum electrodes are designed in total. With each test is evaluated the anode behavior based to their resistance to corrosion and generation efficiency. Finally, the importance of geometric conformation is checked, as well as certain aspects of the finish of material.

The objective of this work is to study, examine, obtain and compare equipotential surfaces that increase the useful life of the electrodes. Furthermore, to obtain optimal bubble generation represented by diameter and bubble distribution. Special attention is taken into the finish and geometry of the anodes.

The article is divided into different sections: *Materials and methods*, *Results* and *Conclusions*. In *Materials and methods* are explained the various components used in the study as well as methods in which the same is based. The *Results* are explained and classified under two important aspects as are the voltage values and the behavior of each cathode. Finally, are reached Conclusions as from analysis of trials appreciative gathering common characteristics and behaviors.

2. Materials and methods

A. Materials

In this study aluminum electrodes are used due to it is resistant to corrosion by water material. Three different geometries or electrode models were created:

- *Prototype 1:* Circular cylindrical filled with 220 mm diameter and 110mm height.
- *Prototypes 2, 3 and 4:* Three flat rectangular plates of 575 mm x 430 mm of different thicknesses: 10 mm, 25 mm and 100 mm.
- *Prototype 5:* Cylindrical hollow length 575 mm, diameter of 250 mm and a thickness of 15 mm.

Each electrode is welded with tin an electrical lead, with the final purpose being connected to the power source. To close the circuit is used an other electric cable that is coupled to a terminal of copper. As studio environment is used a beaker of 2000 ml, where the corresponding electrode is introduced into each test. For obtaining a real value of the voltage applied to the corresponding electrode is used a multimeter.

B. Methods

By applying voltage to each electrode the water electrolysis process occurs generating hydrogen bubbles. It is important to have adequate conductivity in the water to ensure the efficiency of electrolysis. For this purpose water conductivity is increased by adding sodium chloride. The conductivity value remains constant for each test being this 32.7 µS. Quantification and comparison is performed by quality of bubble generated, as well as the amount of bubbles, diameter and distribution thereof in the studio environment. To each of the different electrode geometries are applied voltage values of 2, 4, 6, 8, 10 and 12 V. It must be ensured distribution and bubble diameter uniforms, the electrode surfaces are polished with the aim of minimize as much as possible imperfections present in the aluminum, such as scratches, swarf, etc. And in the case of the flat rectangular sheet of smaller thickness and the hollow cylinder its upper end is sharpened obtaining a conical shape, to facilitate sliding of the bubbles along the wall of the electrode.

3. Results

The water conductivity increased by the addition of sodium chloride, is a value that is constant for each test electrode. The results are grouped mainly in two aspects: voltage values to which process efficiency is optimal and the behavior of each cathode.

1) *Voltage values.* A voltage values 2 and 4V, shown a curtain of bubbles dense and uniform, well as bubbles diameters larger than 1mm. However, a value of 6V shows that the bubble generation produced by each electrode is constant and uniform, and also the diameter thereof is 1 mm, lower compared to the values first. The tests values 8, 10 and 12 V, let see a clouding in the bubble curtain which results in an uneven distribution. Table I shows the voltage applied to each test are collected and which ones are have better results.

TABLE I.- Voltages ratio in tests

Power source (V)	Multimeter (V)	Prot. 1	Prot. 2	Prot. 3	Prot. 4	Prot. 5
2	3,1	✓	✓	✓	✓	✓
4	4,9	✓	✓	✓	✓	✓
6	6,68	✓	✓	✓	✓	✓
8	8,56	-	-	-	-	-
10	10,36	-	-	-	-	-

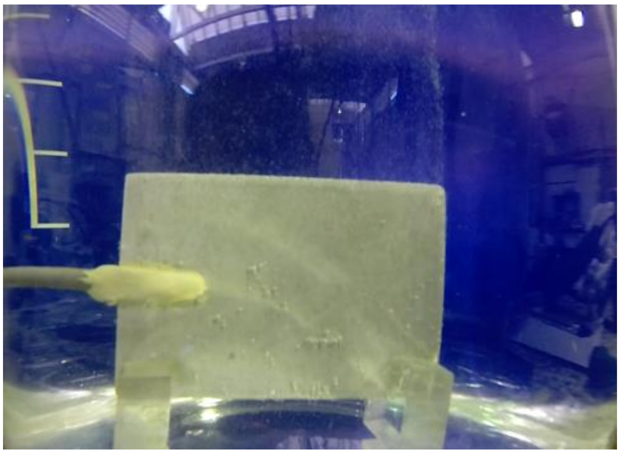

Fig 1. Flat rectangular geometry thickness 10 mm, subjected to a voltage of 6 V.

2) *Behavior of each cathode.* Certain differences between each model are appreciated. In the filled cylindrical geometry bubbles is limited at the edges of the electrode limits. It is produced accumulation which results in disparate diameters bubbles. Thicker lamina exhibit the same behavior, accumulation of bubbles at the longitudinal edges of the electrode. However, it is observed that lower thick lamina at a voltaje

of 6 V produce bubbles of small diameter and uniform, as a homogeneous distribution and no accumulation, as reflected in Fig. 1. As discussed in the previous paragraph, the same lamina when subjected to 12V the output speed of the bubbles increases, resulting in a nonuniform distribution (Fig. 2).

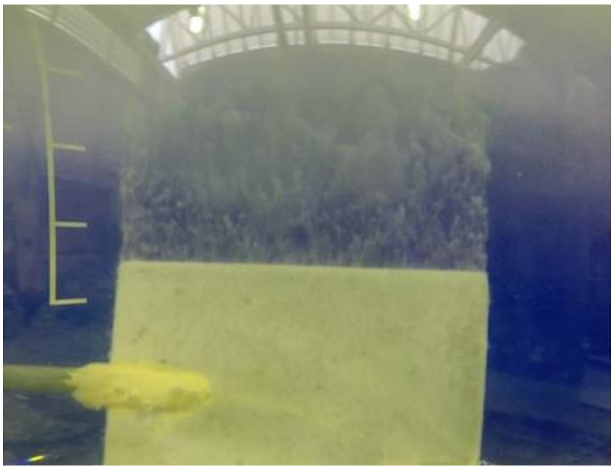

Fig. 2. Flat rectangular geometry thickness 10 mm, subjected to a voltage of 12 V.

The cathode of hollow cylindrical geometry also responds with good results with 6 V (Fig. 3), optimum sliding bubble this affects diametre and distribution. When the hollow cylinder is tested at 12V, results a high output speed bubbles creating a turbulent flow (Fig. 4.).

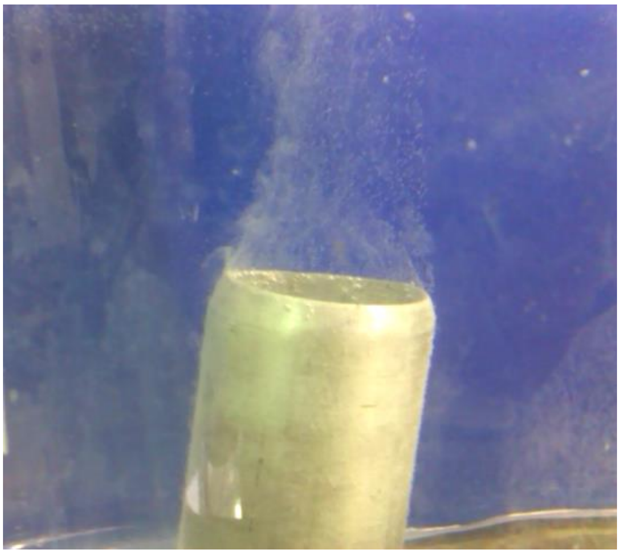

Fig. 3. Model hollow cylinder geometric shape subjected to a voltage of 6 V.

It´s important say that none of the cathodes suffers corrosion, therefore be deduced that the choice of electrode material has been correct.

Fig. 4. Model hollow cylinder geometric shape subjected to a voltage of 12 V.

4. Conclusions

According to observations, it concludes that there is significant influence of the geometry of the electrodes in the generation of H2, by relating terms as sliding resistance and the sliding speed and ejection of bubble.

The lower the resistance to sliding find the bubble less will be chance to accumulate and form bubbles of non-uniform diameters. This is achieved by polishing the cathode surface eliminating material imperfections. The lower the resistance, higher will be the speed of sliding and bubble bubble acquires greater output speed. The thinner the electrode or its ends are faced, higher will be the speed off the bubble, facilitating a homogeneous distribution of the bubbles.

The cathode has shown better results is the prototype 5 of hollow cylindrical shape, with that obtained balanced relation of quality and balanced distribution of bubbles. It must be emphasized that the electrodes at the end of the realization of all tests not present corrosión damage. This indicates that the choice of material has been accepted.

Electrodes have been characterized so that the width of the prototypes 2, 3 and 4 coincides with the height of the prototype 5, resulting in the optimum operating voltage for all of 6V.

In conclusion, put on record the importance of continuity and initiation of new researches related to physical / chemical modifications of the electrodes, allowing the continuous development of better technologies for the efficient production of H2 as a renewable and clean energy, with positive impacts on society, the economy and the environment.

6. References

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