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Hydrogen Production by Electrolysis of Water: Factors with an Influence on the Corrosion

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Abstract- For a better understanding toward corrosion in metallic electrode of copper and aluminum. Such factors with an influence on the corrosion were investigated via the hydrogen production process by electrolysis of water. The phenomenon of electrode corrosion was studied, and the corrosion is resulted in the appearance of large blisters and a gelatinous alumina gel Al $(OH)_3$. In addition, the measurements tests of reaction mid, used time, deposit, temperature of electrolyte and degree of pH on the metal corrosion regions were also conducted. According to the test results, the corrosion was strongly affected by these factors. Furthermore, the corrosion was necessarily depends on the medium pH value, an increase in temperature greatly increased the corrosion rate and the surface can be covered with a deposit of corrosion products (metal oxide hydrated, insoluble salts). The role of this film can influenced the corrosion was worsening the attack.

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I. Introduction

The water electrolysis to produce hydrogen was the most common and most prized method. Indeed, the use of solar energy in electrolysis processes proved to be the method most cost-effective and protective of environment [1].

H_2 production by electrolysis water is also dependent on factors that directly affect the efficiency of H_2 production [2]. Thus products distribution depends on the environmental conditions. In fact, electrolysis water has received much attention which is easily controlled by different parameters [3]. Because of these unique features, water is employed as a medium for various reactions, and is used for a diverse range of applications.

Here, the corrosion is explained by the materials deterioration of chemical interaction with their environment. In addition, term corrosion is applied to the degradation of concrete and wood.

Although experimental data on the effect of many parameters on corrosion are limited, the studies available to date strongly indicated that the effects were one of the most critical parameters that affect corrosion.

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In fact, the corrosion consequences are varied and the effects of these on the safe, reliable and efficient operation of equipment or structures are often more serious than the simple loss of a mass of metal [4]. Failures of various kinds and the need for expensive replacements may occur even though the amount of metal destroyed is quite small. Some of the major harmful effects of corrosion can be investigated in the present work, when the metal is lost in localized zones. Starting from the study of water electrolysis, the effect of temperature, time, reaction medium, and the deposit are studied.

II. Corrosion Study

The chemical cause due to corrosion was the tendency of the material to return to its original state in the ore. Corrosion was a purely chemical reaction between the surface of the material and a gas or liquid.

The used electrodes in our work to produce hydrogen were based on aluminum (anode) and copper (cathode) Fig. 1. In fact, the metallic electron current contact with the ion current electrolytic contact was on the head corrosion generally.

In order to edit the corrosion mechanism, it is recommended to detail the electrochemical degradation. The type of degradation was an electrochemical corrosion where is an electric current flow to the material surface with aluminum as electrode. The different equations liable to corrosion of aluminum are:

$$Al + 3H_2O \longrightarrow Al(OH)_3 + 3/2H_2\uparrow$$

$$Al \longrightarrow Al^{3+} + 3é$$

$$3H^+ + 3é \longrightarrow 3/2\ H_2\uparrow$$

This phenomenon is encountered particularly aerated solution, in fact in such a medium the oxygen consumption at the metal-electrolyte interface, and then the reaction is limited by the transfer material [5]. This corrosion resulted in the appearance of large blisters and a gelatinous alumina gel Al $(OH)_3$ Fig. 2.

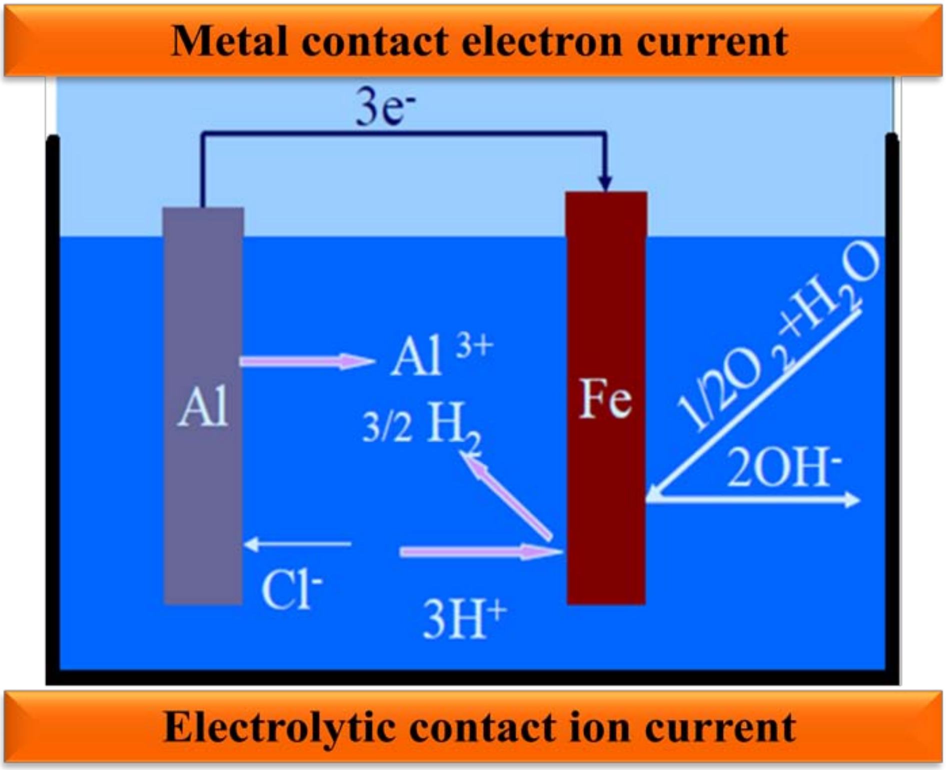

Figure 1 : Different equations occurred during the corrosion

Figure 2 : Voluminous pustules and gelatinous of an alumina gel Al $(OH)_3$

III. Corrosion Phenomenon

Electrochemical corrosion resulted in dissolution of all points constituent of the material surface that is attacked by the corrosive environment. This was done by a micrographic scale globally steady decrease in thickness or weight loss of the material [5]. The metal material (aluminum) was in contact with a liquid electrolyte (presence of ions). Indeed, the attack was the anode regions and the intact was the cathode regions.

In fact, the corrosion phenomenon was the following sequence of steps:

1) Dissociative adsorption of water on the support surface and formation of hydroxyl groups.
2) Migration of OH groups in the carrier surface and transfer to the metal.
3) Adsorption and dissociation of water to the metal surface [6].
4) Desorption of the products.

Also it was shown that in step (1) is kinetically limited and migration of surface hydroxyl groups of the support. Consequently, these reaction medium are strongly influenced the corrosion including how the chemical nature of electrolytes, composition, impurities pH (acidity), temperature, pressure, viscosity, solid deposits and agitation can cause corrosion.

IV. Corrosion Factors

a) Effect of the mid

When the pH deviates from neutrality (4 <pH <9), the corrosion results very quickly by a violent attack. The dissolution between the electrolyte and the electrode may vary depending on the acid or base. Indeed it can be define the dissolution rate by the mass loss of a few micrometers material per year to a few micrometers per day [7]. In neutral environments, general corrosion rate was very low but not zero. All of these results can be explained by the oxygen concentration which usually gives information of an increase or decrease in corrosion rate.

Additionally, in this case it noticed that corrosion necessarily depends on the medium pH value. In fact for most acidic environments found discoloration of the electrolyte, and the current was more intense which confirms the points separation existence of the materials with the electrolyte. The same is observed for pH values lower than 5, a decrease in the deposition solution is observed, it is translated by the absence of the alumina gel which minimizes corrosion [8]. In the range of 7-12 corrosion rate is fairly dependent of pH whereas for basic environment deposit formation is observed Fig.3.

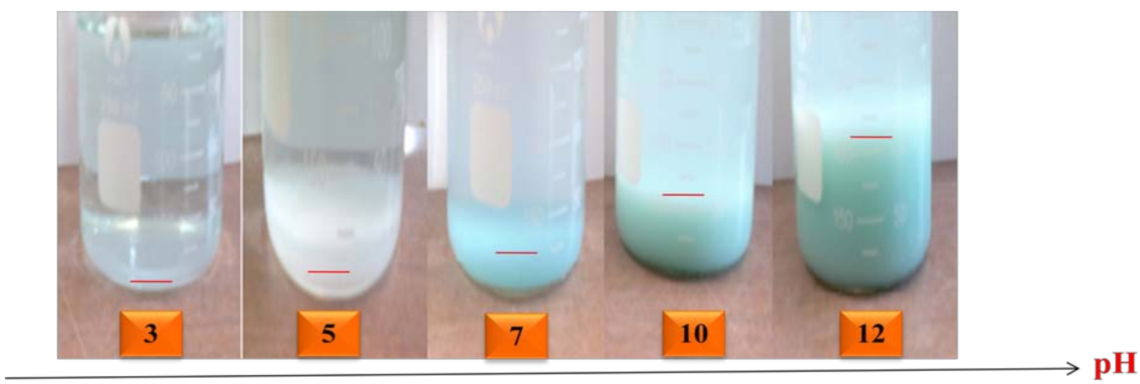

Figure 3 : Evolution of corrosion for different pH

b) Effect of temperature

Generally, an increase in temperature greatly increased the corrosion rate. This phenomenon can be explained by the fact that the anodic process (oxidation of the components of aluminum) and cathode (reduction in acid medium protons) are thermally activated. The exchange resulting current and representing the corrosion rate increased with the temperature.

c) Effect of deposit

When a material (aluminum) undergoes corrosion in an aqueous solution, its surface can be covered with a deposit of corrosion products (metal oxide hydrated, insoluble salts). The role of this film can influenced the corrosion is worsening the attack. A change product specification then allows defining the mechanisms governing the corrosion deposit.

Precipitation of corrosion products on the surface of a metal which corrodes is linked to a local solubility problem. The solubility limit is by experience, rarely achieved in all of the liquid; it is only at a liquid layer on the surface of the metal as corrosion product may precipitate. In other words, the precipitation of corrosion products involved initially because the cation diffusion in the liquid phase does not dissipate the flow of metal ion-induced corrosion. This effect can lead to corrosion with a possibility of pitting.

d) Effect of material nature

It was shown that the composition, processing, metallurgical, (thermal and mechanical treatments) impurities additions were most important to the corrosion state of such material. The aluminum was an amphoteric metal, it can be dissolved both in acid medium (Al^{3+}). The resistance of aluminum alloys is limited to neutral environments or very close to neutral (4 <pH <9) [5]. At low pH (acidic water) or in the presence of high concentrations of chloride copper tends to dissolve. However in our case, we note that the electrode corrodes aluminum of trying to time while watching a thickness reduction which controls the corrosion rate Fig.4.

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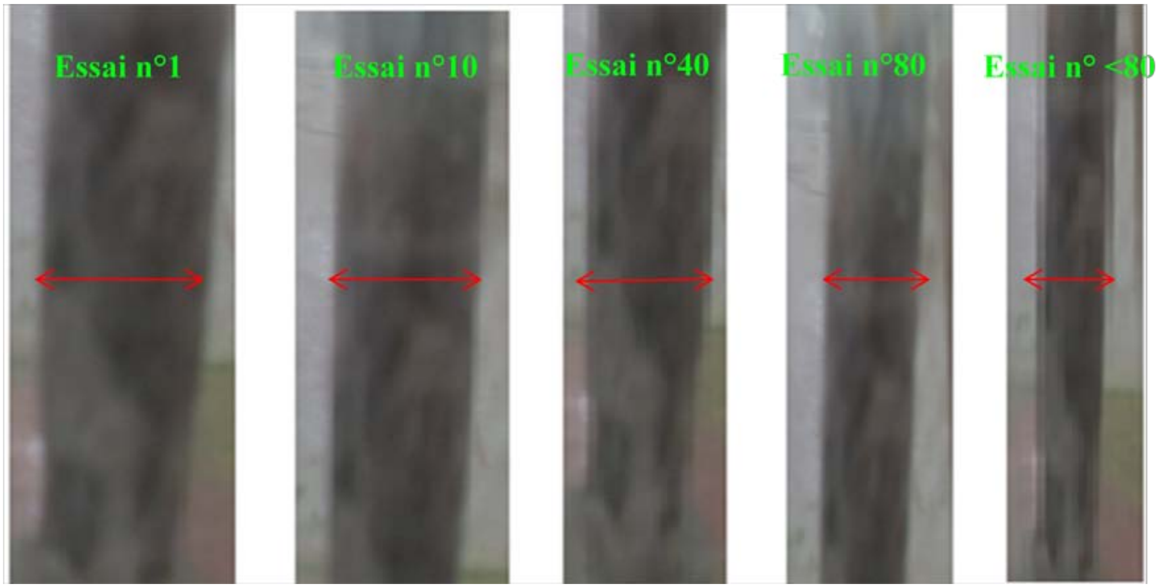

Figure 4 : Change in thickness of the aluminum electrode for different handling

e) Effect of Electrolyte concentration

For our experimental study allows us to control the corrosion rate of deposit formation at the level of the electrolyte. Therefore it is found that corrosion increased with the increase of the mass concentration of the liquid Fig. 5. The resistance of aluminum alloys is therefore limited to neutral media or very close to neutral (4 <pH <9).

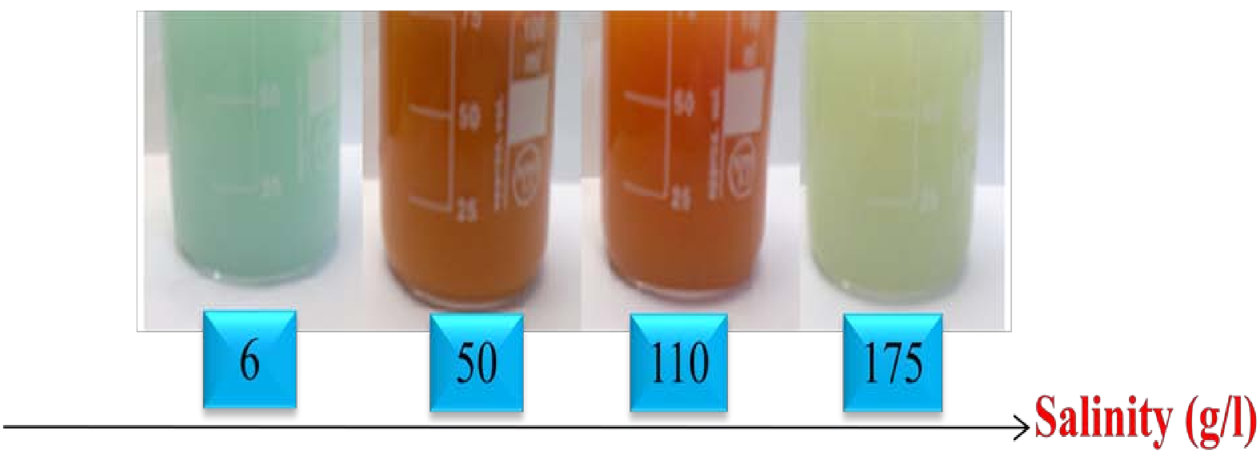

Figure 5 : Variation of the coloration of the electrolyte in function of the concentration

f) Effect of time

Aging structure, changing tension and temperature depend on the duration of use. Fig.6 shows that increasing the time cause the corrosion, in fact increasing the time minimizing the flow of hydrogen where the corrosion of the material was produce.

Here, the production duration are strong influenced on the corrosion and aging of the material structure using the deposit as corrosion controller.

Figure 6 : Evolution of the corrosive condition of the electrodes

i. *Effect of the conception*

The surface condition, shape, assembly and contact with the medium, (partial or total immersion) are elements that affected the corrosion of materials Fig 7.

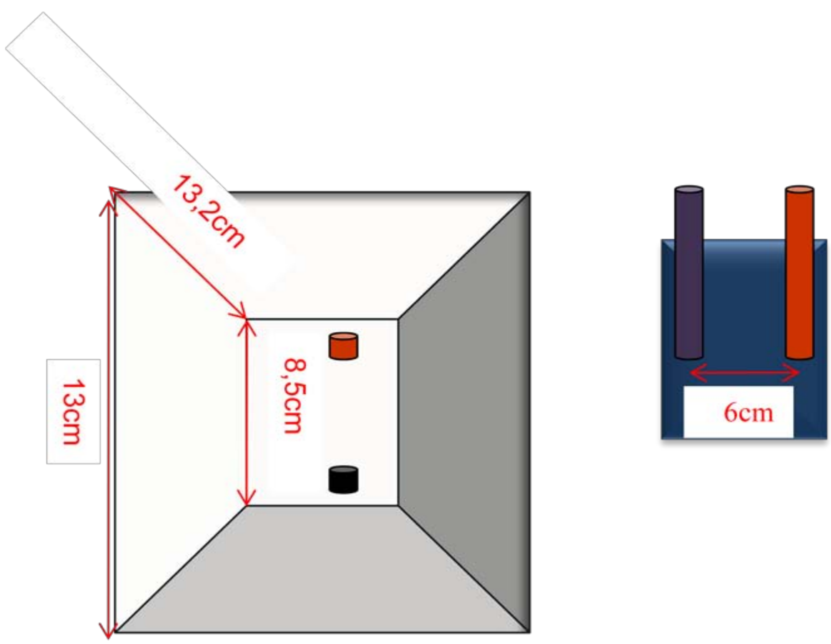

Figure 7 : Parameterization of the electrolyzer surface

g) *Effect of the deposit*

The most common form of corrosion is expressed by The uniform dissolution of the metal surface in contact with the corrosive agent. The metal to active controllable by weight loss measurements or decrease in thickness of the metal. The corrosion rate can be controlled by the amount of precipitate that persists for different electrolytes, indeed in our case note that the deposit increases in acid-base medium, while it decreases in a neutral medium and for close pH values neutrality Fig 8.

Figure 8 : pH influence on the corrosion rate

V. Conclusion

The corrosion behavior of aluminum/cooper electrodes and the electrolyte were studied using the production of hydrogen by the water electrolysis. Current experimental results are new and important to specify the corrosion by different factors which affected. Indeed, the nature and used time of electrode, electrolyte temperature, reaction mid, showed strongly corrosion in simulated water electrolysis environment.

From a comprehensive consideration, the study of the hydrogen production by water electrolysis, and forming the deposition were carried out in this study. The variation of their factors evidently, the media reaction nature, including any examination of the results, shows that current density is higher in acid-base environments.

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