



## **DISSOLUTION OF ALUMINUM ELECTRODES IN CHLORIDE SOLUTIONS AT POLARIZATION BY THREE-PHASE CURRENT**

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### **ABSTRACT**

In this paper, process of electrochemical dissolution of aluminum electrodes was studied in a solution of sodium chloride at polarization by three-phase alternating current of frequency of 50 Hz. The effect of current density, concentration of sodium chloride and electrolysis time on the current efficiency of aluminum electrodes dissolution was observed. It was established that with rise of current density at the electrodes upto 2000 A/m<sup>2</sup>, current efficiency of dissolution increases upto 77.0%, and at high current density, current efficiency of dissolving gradually decreases. With rise of concentration of sodium chloride to 300 g/L, the current efficiency of aluminum dissolution decreases, at concentration of NaCl 100 g/L, (-80.6%) and at NaCl concentration 300 g/L (70.4%). It was established that as the result of the electrolysis dispersed aluminum hydroxide Al(OH)<sub>3</sub> formation is observed, the structure of which was identified by X-ray diffraction and electron microscopy.

**Key words:** Three-phase current, Not stationary current, Aluminum, Aluminum hydroxide, polarization.

### **INTRODUCTION**

In recent years, more attention is paid to the use of unsteady currents of different forms, including industrial alternating current with frequency 50 Hz<sup>1-5</sup>. The use of non-stationary electrolysis mode extends the possibility of studying electrode processes and opens up entirely new possibilities in decision of number of problems of applied electrochemistry.

The possibility of targeted processes under the influence of symmetrical alternating

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current of 50 Hz frequency has been doubted for a long time. It was supposed that the processes of deposition or dissolution of the metal should not progress, as with frequent changes of current direction, the amount of metal isolated at cathode half-period must be compensated of metal passed into solution in the form of ions at the anodic half-cycle.

Our investigations conducted over the last 15-20 years show that under certain conditions, we succeeded to carry out the electrolysis under the action of alternating current due to possibility of rectification in one of the half-period.

Decrease of the current in one half-period of the alternating current can cause the formation of oxide, salt or other films, diffusion of ions to the electrode surfaces, the discharge and recharge of the complex anions or cations, crystallization of the metal etc. Altogether this contributes to the fact that symmetrical alternating current in the forward and backward directions created unequal conditions contributing to preferential behavior of one of the process (oxidation or reduction).

Though aluminum has a very negative potential in sulfuric acid and neutral media and does not dissolve. At anodic polarization, aluminum does not dissolve as on the surface a very dense and stable oxide film of  $\text{Al}_2\text{O}_3$  is formed and at its surface, oxygen evolution reaction takes place. We have previously shown<sup>6-8</sup> that at polarization by industrial alternating current of 50 Hz frequency, the dissolution of the aluminum electrode was observed.

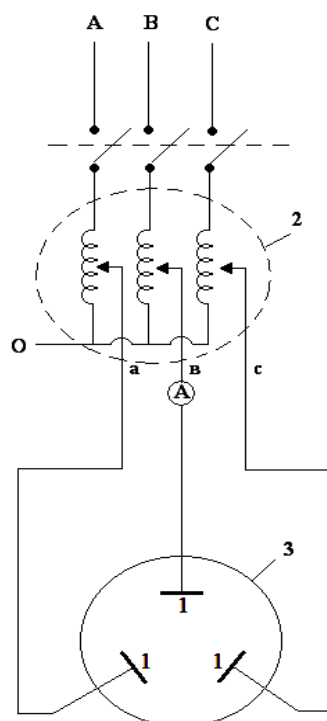
In this paper, process of electrochemical dissolution of aluminum electrodes was studied in a solution of sodium chloride at polarization by three-phase alternating current of frequency of 50 Hz.

## **EXPERIMENTAL**

### **Method**

Experiments were performed in a glass electrolyzer of volume 200 mL. The electrolyte solution of sodium chloride was investigated, and the electrodes-aluminum plates of 99.98% purity were used. Principal scheme of the experimental set is shown in Fig. 1. Amount of current in electrochemical circuit was controlled by three-phase LATR. In the main experiments, the duration of the electrolysis was 0.5 hours. The current efficiency was

calculated on the anodic half-period of alternating current in each phase depending on the weight changes of the electrodes after electrolysis.



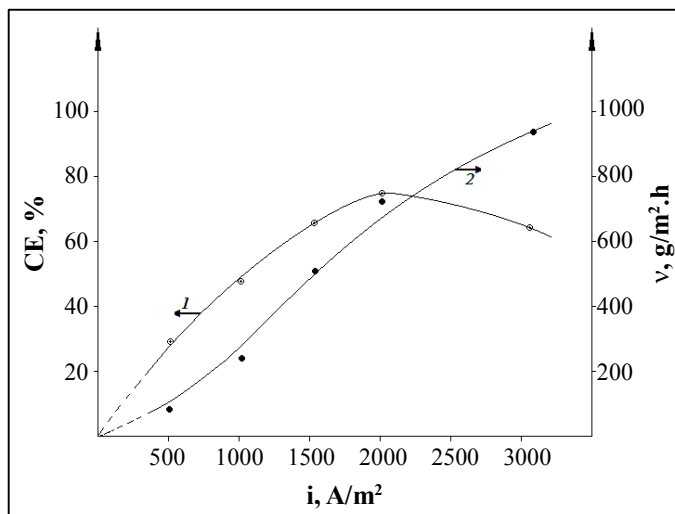
**Fig. 1: Principal scheme of the set for dissolving aluminum by three-phase current**

- 1 - Aluminum electrodes; 2 - Three-phase laboratory autotransformer (LATR);  
3 - Electrolyzer

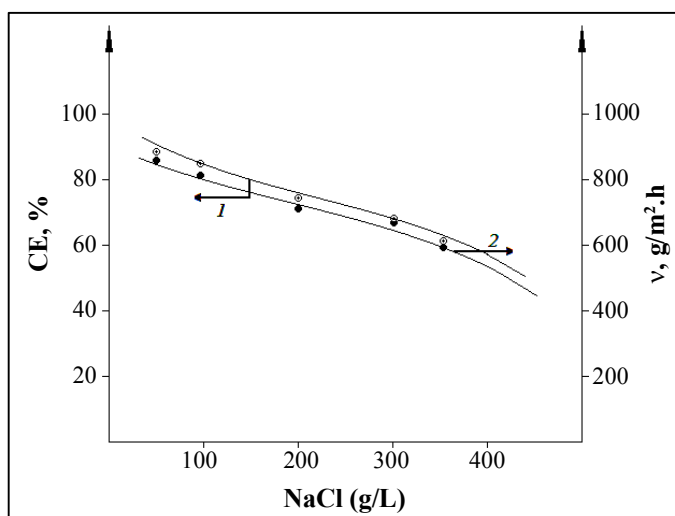
## RESULTS AND DISCUSSION

Preliminary experiments showed that the aluminum in the solution of sodium chloride does not dissolve anodically (at polarization by direct current).

At rise of current density at the electrodes upto  $2000 \text{ A/m}^2$ , current efficiency of dissolution of aluminum increases reaching 77.0% (Fig. 2, curve 1), and at more high current density, current efficiency of metal dissolving gradually decreases that can be explained by formation of oxide film ( $\text{Al}_2\text{O}_3$ ) at anodic half-period of alternating current. As the current density at the electrodes naturally increases, the dissolution rate of aluminum also increases (Fig. 2, curve 2).

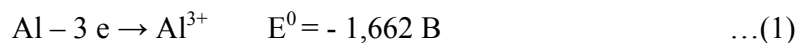


**Fig. 2:** Effect of current density at the electrode on current efficiency (1) and the speed of dissolution of the metal (2) ( $C_{\text{NaCl}} = 200$  g/L;  $\tau = 0.5$  hour)



**Fig. 3:** Effect of sodium chloride concentration on the current efficiency (1) and the metal dissolution rate (2) ( $i_{\text{Al}} = 2000$  A/m<sup>2</sup>;  $\tau = 0.5$  hour)

Dissolution of the aluminum electrodes at polarization by alternating current can be explained as follows: during staying of the aluminum electrodes at anodic half-period of alternating current, they are oxidized by the reaction:



At cathodic half-period, water molecule is reduced to form hydrogen and thus, the pH of the solution increases:

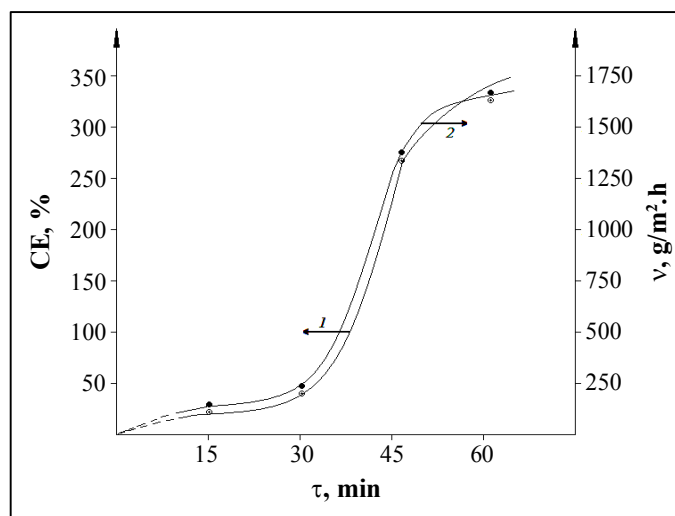


As the result of interaction of the aluminum ions and hydroxide ions in the bulk solution, sparingly soluble compounds  $\text{Al}(\text{OH})_3$  were formed:



It was established that as the result of the electrolysis, dispersed aluminum hydroxide formation is observed, the structure of which is identified by X-ray diffraction and electron microscopy (particle size equal to 80-90 nm).

With rise of concentration of sodium chloride to 300 g/L, the current efficiency of aluminum dissolution decreases, at concentration of NaCl 100 g/L (80.6%) and at NaCl concentration 300 g/L (70.4%) (Fig. 3). This is explained by the fact that in concentrated solution of sodium chloride, the electrode surface is partially passivated by oxide or salt films.



**Fig. 4: Effect of electrolysis time on current efficiency (1) and the rate of the metal dissolution (2) ( $C_{\text{NaCl}} = 200 \text{ g/L}$ ;  $i = 1000 \text{ A/m}^2$ )**

With rise of the duration of the electrolysis, current efficiency of dissolution of aluminum electrodes increases (Fig. 4). As it has been shown in the course of time, pH of

solution is increased in this regard, chemical dissolution of the aluminum electrodes is enhanced.

## CONCLUSION

So at the first time, electrochemical dissolution of aluminum electrodes at polarization with alternating three-phase current has been investigated. It is shown that soluble aluminum electrodes are dissolved with formation of aluminum hydroxide with high current efficiency.

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