ALUMINUM ALLOY CORROSION INHIBITION BY SODIUM ALGINATE IN 0.1% NaCl SOLUTION

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The high efficiency of the environmentally safe polysaccharide sodium alginate as an inhibitor of aluminum alloy corrosion in a 0.1% NaCl solution was established. The protective action of the alginate consists in inhibiting the cathodic reaction of electrochemical corrosion due to the formation of an organic protective film on the surface of intermetallic inclusions of the alloy.

Keywords: aluminum alloy, corrosion inhibition, sodium alginate, potentiodynamic polarization, electrochemical impedance spectroscopy

Introduction. Aluminum alloys are widely used in industry as a structural material with high strength and low specific density. However, due to the presence in them of a strengthening phase - intermetallics - the operational properties of the alloy in corrosive environments are reduced. One of the simplest, technological and effective way of anti-corrosion protection of aluminum alloys is the use of corrosion inhibitors. Today, synthetic inhibitors are mainly used, which contain substances harmful to the environment and humans. The use of environmentally safe inhibitors allows to reduce the negative impact on the environment and human health. Effective components of the inhibitors are ecologically safe products of plant origin, the main advantage of which is cheapness and reproducibility [1, 2]. Promising inhibitory substances can be polysaccharides, in particular sodium alginate, which is obtained from brown algae and used in the food industry and medicine. Therefore, the purpose of this work is to study the effect of sodium alginate on the corrosion of aluminum alloy in a 0.1% solution of sodium chloride.

Materials and methods. Samples of D16T aluminum alloy were used for the research. The corrosive medium was a 0.1% NaCl solution, to which sodium alginate (structural formula $(C_6H_7O_6Na)_n$) was added at concentrations of 0.5 g/l and 1 g/l. Sodium alginate was purchased from Sistema Optimum. The electrochemical behaviour of aluminum alloy samples in an uninhibited corrosive solution and with the addition of polysaccharide was investigated by potentiodynamic polarization and electrochemical impedance spectroscopy methods using a Gill AC potentiostat, a saturated Ag/AgCl reference electrode, and an auxiliary platinum electrode. The working area of the aluminum alloy sample was 1 cm^2. The corrosion current density of the metal was determined from the polarization curves by graph-analytical method. The surface morphology and elemental composition of the surface of the aluminum alloy sample, after it was kept for 168 h in the used solutions, was studied on an EVO-40XVP scanning electron microscope with an INCA Energy 350 microanalysis system.

Results and discussion. The polarization curves of the alloy after 48 h and 168 h of its exposure in a 0.1% NaCl solution with the addition of sodium alginate are shown in Fig. 1. The electrochemical characteristics of the aluminum alloy after 48 h of exposure indicate an increase in its corrosion resistance with an increase in the concentration of polysaccharide up to 1 g/l. The protective effect of the studied composition is also preserved after 168 h of exposure.

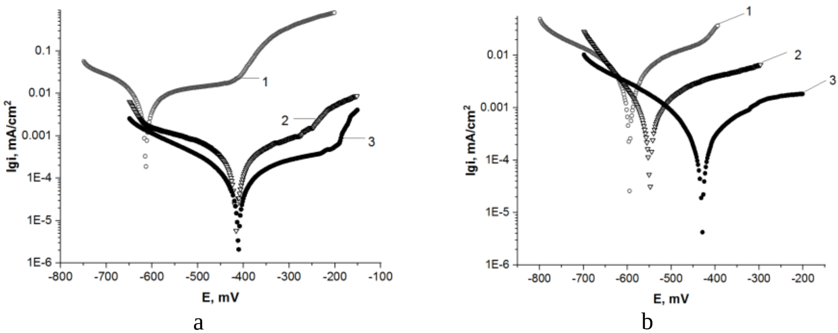


Fig. 1. Polarization curves of the aluminum alloy after exposure for 48 h (a) and 168 h (b) in a 0.1% NaCl solution with the addition of the inhibitor at concentrations: 1–0 g/l, 2–0.5 g/l, 3–1 g/l.

With the addition of sodium alginate $(C_6H_7O_6Na)_n$, the corrosion current density of aluminum alloy significantly decreased (Table 1).

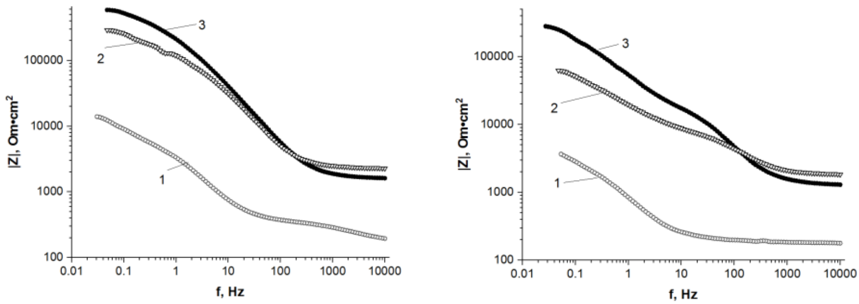
The results of polarization studies of the alloy are consistent with those obtained by the EIS method (Fig. 2, 3). The impedance modulus of the aluminum alloy at a current frequency of 0.1 Hz increases with an increase in the concentration of polysaccharide in the corrosive solution and is maximal at 1 g/l, which can be explained by the formation of an adsorptive organic film on the surface of the metal.

In the presence of polysaccharide, the peak of the phase angle of the aluminum alloy shifted towards higher frequencies of alternating current and its maximum increased, which indicates the formation of a protective film on the metal.

After 168 h of exposure of the alloy in corrosive environments, its surface morphology and chemical composition were investigated. It is shown that the surface of the alloy after exposure to an environment without the presence of polysaccharide is completely covered with corrosion products, in particular aluminum oxides and hydroxides (Fig. 4, a).

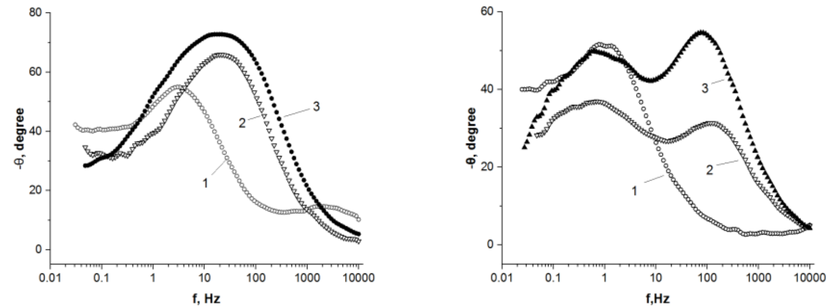
Table 1. Electrochemical characteristics of the D16T alloy after exposure to a 0.1% NaCl solution inhibited by sodium alginate

Exposition	48 h			168 h		
C, g/l	E_{corr}, V	i_{corr}, mA/cm^2	Z, %	E_{corr}, V	i_{corr}, mA/cm^2	Z, %
0	512.38	$8.6 \cdot 10^{-3}$	-	224.54	$36.9 \cdot 10^{-4}$	-
0.5	152.66	$1.79 \cdot 10^{-4}$	97.91	215.94	$3.1 \cdot 10^{-4}$	91.5
1	168.82	$7.06 \cdot 10^{-5}$	99.17	207.52	$3.06 \cdot 10^{-4}$	91.7



a b

Fig. 2. Impedance dependences for D16T alloy after 3 h (a) and 48 h (b) exposure in 0.1% NaCl solution at inhibitor concentrations: 1 – 0 g/l, 2 – 0.5 g/l, 3 – 1 g/l.

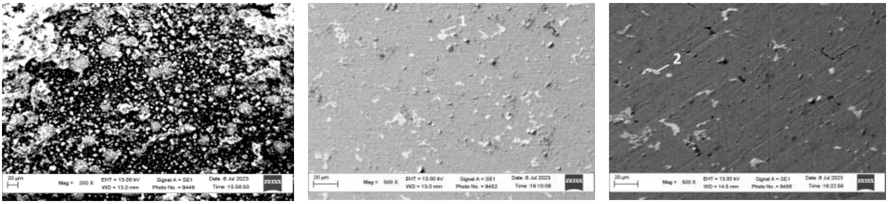


a b

Fig. 3. Dependencies of the phase angle on the frequency for the D16T alloy after 3 h (a) and 48 h (b) exposure in a 0.1% NaCl solution at inhibitor concentrations: 1 – 0 g/l, 2 – 0.5 g/l, 3 – 1 g/l.

Chlorine content was also detected in certain areas. The addition of sodium alginate of various concentrations to the medium contributes to the formation of a protective film on the surface of the aluminum alloy (Fig. 4 b, c).

Already with a content of 0.5 g/l of sodium alginate on the surface, the amount of corrosion products significantly decreases and clear localized protective films are found in the area of intermetallic inclusions (Table 2). This state of the surface probably indicates the blocking of the cathodic reaction by sodium alginate. This trend persists at an inhibitor concentration of 1 g/l.



a b c

Fig. 4. The surface of the D16T alloy after 168 h of exposure in a 0.1% NaCl solution at different concentrations of sodium alginate: a (0 g/l), b (0.5 g/l), c (1 g/l).

Table 2. Chemical composition of the surface of the D16T alloy after 168 h of exposure in a 0.1% NaCl solution at different concentrations of sodium alginate

C, g/l	Area	Content, wt %				
		Al	C	O	Mg	Cu
0.5	1	82.68	9.92	1.58	1.51	4.32
1	2	89.53	4.38	0.76	1.46	3.87

Conclusions. Therefore, based on conducted research, the environmentally safe polysaccharide sodium alginate can effectively inhibit the corrosion of aluminum alloy in a 0.1% NaCl solution. The mechanism of corrosion inhibition probably consists in blocking the cathodic reaction on aluminum alloy due to the formation of protective film on its intermetallic inclusions.

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