CORROSION OF STEEL AND ALUMINUM DUE TO AGGRESSIVE COMPONENTS OF THE SOIL ELECTROLYTE

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Corrosion of underground metal structures and the character of destruction depend on the composition of the gaseous phase of the soil and soil electrolyte. The main aggressive components of soil are the products of the vital activity of anaerobic microorganisms, carbon dioxide, mobile forms of iron, manganese, hydrogen sulfide and its compounds, ammonia and its compounds, chlorides, and sulfates.

An extensive literature [1-4] is devoted to the role of these components in the corrosion process occurring in electrolytes, however, the available information is quite contradictory.

The purpose of this work was to establish the role of the ions of chlorine, sulfate, ammonium, sulfide, trivalent iron, and carbon dioxide in the corrosion of aluminum and steel.

The experiments were carried out in solutions containing chlorine ions together with ions of sulfate, ammonium, sulfide, trivalent iron, and carbon dioxide in concentrations corresponding to their content in individual soils. Separate experiments were carried out with solutions of higher concentrations (0.2 g-eq /liter). The specimens were prepared from an aluminum casing (99.3% Al. 0.38% Fe, 0.3% Si, 0.02% Cu) and cable jacket brand MKSAB. The holes of the tubular aluminum specimens were closed by plugs, and the line of separation of the plug-specimen was insulated by a mixture of paraffin with wax. The working surface was 44 cm^2.

The specimens of low-carbon steel cable jacket were plates with a working surface of 63 cm^2. After degreasing, washing in distilled water, and drying for an hour at 100°C, the specimens were weighed (with an accuracy to 0.0001 g) and submerged for 48 h into 3-liter glass vessels.

*Deceased.

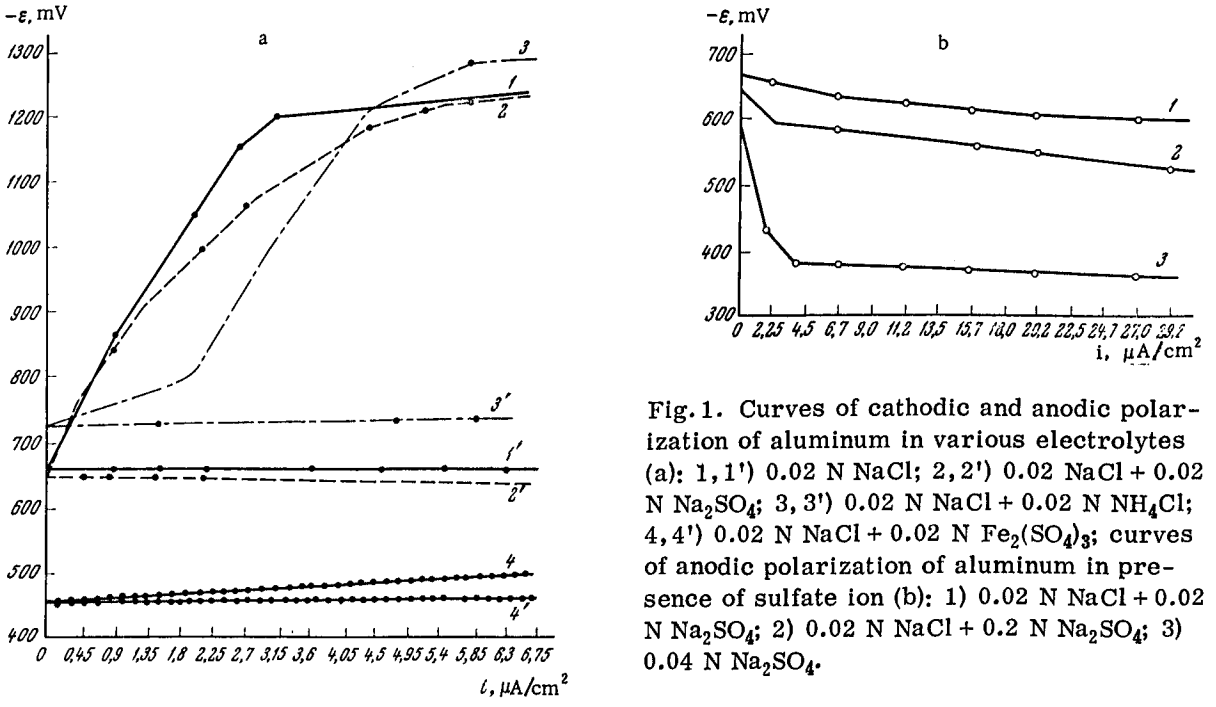

Fig. 1. Curves of cathodic and anodic polarization of aluminum in various electrolytes (a): 1, 1') 0.02 N NaCl; 2, 2') 0.02 NaCl + 0.02 N Na_2SO_4; 3, 3') 0.02 N NaCl + 0.02 N NH_4Cl; 4, 4') 0.02 N NaCl + 0.02 N $Fe_2(SO_4)_3$; curves of anodic polarization of aluminum in presence of sulfate ion (b): 1) 0.02 N NaCl + 0.02 N Na_2SO_4; 2) 0.02 N NaCl + 0.2 N Na_2SO_4; 3) 0.04 N Na_2SO_4.

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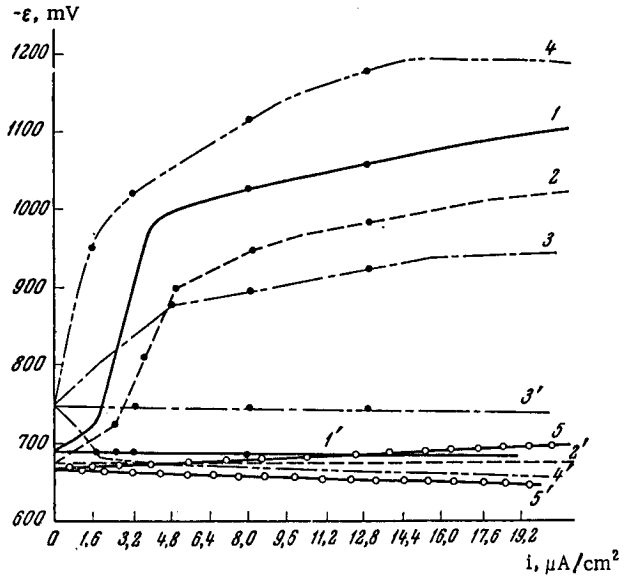

Fig. 2. Curves of cathodic and anodic polarization of steel in different electrolytes. 1, 1') 0.04 N NaCl; 2, 2') 0.02 N NaCl + 0.2 N Na_2SO_4; 3, 3') 0.02 N NaCl + 0.2 N NH_4Cl; 4, 4') 0.02 N NaCl + 0.02 N Na_2S, pH 10.7; 5, 5') 0.02 N NaCl + 0.02 N $Fe_2(SO_4)_3$.

TABLE 1. Potentials and Rates of Corrosion of Aluminum and Steel in Various Electrolytes

Composition of solution	pH of solution	Investigated metal	Potential, mV*			Corrosion rate,† g /cm²·day·10⁻⁶
			initial	after 24 h	after 48 h	
0,04 N NaCl	6	Aluminum	—700	—660	—660	28,6
		Steel	—630	—690	—710	353,0
0,02 N NaCl+	6	"	—590	—610	—610	66,2
+0,02 N. Na_2SO_4		"	—580	—690	—715	607,0
0,02 N NaCl+	6	"	—625	—600	—610	10,4
+0,2 N Na_2SO_4		"	—630	—715	—745	500,0
0,04 N Na_2SO_4	6	"	—500	—615	—690	0
		"	—635	—730	—735	327,0
0,02 N NaCl+	5,9	"	—660	—600	—600	105,5
+0,02 N NH_4Cl		"	—675	—725	—745	640,0
0,02 N NaCl+	5,85	"	—715	—710	—700	148,0
+0,2 N NH_4Cl		"	—700	—745	—745	729,0
0,02 N. NaCl+	10,95	"	—1510	—1520	—1490	2025,0
+ 0,02 N. Na_2S		"	—610	—565	—665	33
0,02 N NaCl+NaOH	10,95	"	—1425	—1385	—1490	463,0
		"	—380	—490	—510	275,0
0,02 N NaCl+	11,7	"	—1555	—1515	—1535	35000,0
+0,2 N Na_2S		"	—655	—670	—690	22,7
0,02 N NaCl+NaOH	11,7	"	—1500	—1425	—1425	14980,0
		"	—375	—560	—560	240,0
0,02 N NaCl+	2,3	"	—435	—365	—435	309,0
+0,02 N $Fe_2(SO_4)_3$		"	—650	—665	—620	2420,0
0,02 N NaCl+H_2SO_4	2,3	"	—625	—740	—760	235,0
		"	—600	—610	—645	2010,0
0,02 N NaCl+	1,7	"	—600	—620	—630	6750,0
+0,02 N. $Fe_2(SO_4)_3$		"	—580	—630	—655	18950,0
0,02 N NaCl+H_2SO_4	1,7	"	—750	—755	—750	241,0
		"	—590	—590	—590	2790,0
0,01 N. NaCl+CO_2 (satur.)	4	Aluminum	725	—	—	37,0

* Potentials measured relative to saturated calomel electrode.

†Each value is the average of three measurements.

During the experiment the specimens were rotated at a speed of 2 rpm. To remove the corrosion products, the aluminum specimens were treated in a solution of 20% H_3PO_4 + 8% CrO_3 for 30 min at 20°. The steel specimens were held in 5% NaOH + Zn at 85° for 30 min.

In all the investigated solutions the aluminum corroded much more slowly than the steel. When sulfate was added to the 0.02 N solution of sodium chloride the rate of corrosion of aluminum greatly increased (see Table 1).

A further increase of the sulfate concentration inhibited dissolution, and the corrosion of aluminum in a 0.04 N solution of sodium sulfate during the test was virtually absent. All other investigated components intensified the corrosion of aluminum. In all solutions (with the exception of sulfate) pitting was observed on the surface of the aluminum specimens. Additions of the ions of sulfate, ammonium, sulfide, and trivalent iron to the sodium chloride solution affect the corrosion of steel to about the same extent as the corrosion of aluminum. However, the presence of sulfides in an alkaline medium caused a drop of the rate of corrosion of steel. Pitting appeared by the end of the test on steel specimens in solutions containing the ions of chlorine, sulfate (0.02 N), ammonium, and trivalent iron.

In the chloride solutions the aluminum is characterized by a low anodic polarizability (Fig. 1). The addition of sulfate leads to some acceleration of the cathodic process and a slowing down of the anodic process. When the sulfate concentration is increased anodic polarization greatly increases, with which is related, evidently, an inhibition of the corrosion of aluminum in the presence of sulfate ions. On the curve of cathodic polarization of aluminum in the presence of ammonium ions, the regions of oxygen reduction and evolution of hydrogen are more clearly defined than in the pure solution of sodium chloride. Like aluminum, steel has a low anodic polarizability in chloride solutions (Fig. 2). The addition of sulfate and ammonium chloride lowers the hydrogen overvoltage on steel. Sulfate has almost no effect on the anodic process.

LITERATURE CITED

1. G. V. Akimov and E. N. Paleolog, Inst. Fiz. Khimii, AN SSSR, No. 7 (1951).
2. I. L. Rozenfel'd and V. P. Maksimchuk, Transactions of the All-Union Interinstitute Scientific Conference on Problems of Corrosion Control [in Russian], Gostoptekhizdat, Moscow (1962).
3. I. S. Shklovskii, in: Investigations into Metal Corrosion [in Russian], No. 1, Izd. AN SSSR (1951), p. 241.
4. E. M. Zaretskii, in: Corrosion and Protection of Aluminum Alloys [in Russian], Oborongiz, Moscow (1949), p. 84.