STRESS-CORROSION CRACKING OF PIPE STEEL UNDER THE INFLUENCE OF THIN-FILM CORROSION AT CATHODIC POLARIZATION

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The peculiarities of electrochemical behavior and corrosion-mechanical properties of 10G2FB steel under thin-film corrosion in a near neutral pH model soil environment NS4 were investigated. It was found that the limiting diffusion current of oxygen reduction in the soil medium is lower compared to NS4 solution, which satisfactorily correlates with the corrosion rate. At a maximum protective potential of -1.05 V, an increase in the susceptibility to stress-corrosion cracking of 10G2FB steel under thin-film corrosion conditions, estimated by the K_S coefficient from 1.15 to 1.23, was found.

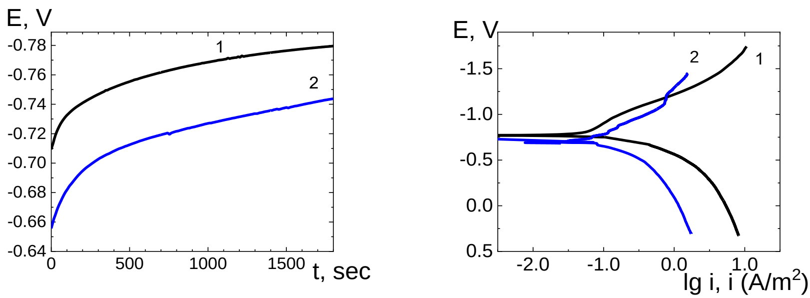
Keywords: pipe steel, slow strain rate tests, voltametry, SEM, stress-corrosion cracking, thning layer corrosion, cathodic polarization

Introduction. Thin-film corrosion is a widespread phenomenon, particularly in the atmosphere and wet soil. The course of corrosion processes in wet soil can be one of the factors of stress-corrosion cracking, which is currently one of the most dangerous phenomena and the cause of accidents in main gas pipelines. Stress-corrosion cracking of main gas pipeline steels under cathodic polarization is presented in the works of specialists of the E.O. Paton Electric Welding Institute [1, 2]. As a follow-up to these works, we have studied stress-corrosion cracking under conditions of thin-film corrosion of 10G2FB steel under cathodic polarization. The aim of this work is to study the features of stress-corrosion cracking of 10G2FB pipe steel at the maximum protective potential during periodic wetting with NS4 solution (50 min in solution and 10 min in air) and under conditions that simulated corrosion in thin electrolyte films.

Research methods. It is known from the literature that the highest corrosion rate is observed at a soil moisture content of 20%, so corrosion and mechanical tests were conducted in an environment of 20% NS4 and 80% sand (hereinafter referred to as the model soil environment). Chemical composition of steel, wt. %: 0.096 C, 0.208 Si, 1.71 Mn, 0.03 Ni, 0.06 V, 0.03 Mo, 0.015 Ti. Mechanical properties: $\sigma_т$ = 440 MPa, σ_B = 590 MPa, δ_5 = 20 %. Composition of NS4 solution, g/l: 0.122 KCl + 0.483 $NaHCO_3$ + 0.181 $CaCl_2$ + 0.131 $MgSO_4$, pH 8.2. Corrosion-mechanical studies were carried out by sloe strain rate tests at a rate of 10^{-6} s^{-1} in a corrosive environment at a polarization potential of -1.05 V. The susceptibility to stress-corrosion cracking was estimated by the K_S

coefficient (the ratio of the relative narrowing ψ of specimens in air to the relative narrowing under the influence of a corrosive factor). Polarization curves were measured on an MTech PGP-550F potentiostat with a potential sweep rate of 1 mV/sec.

Results and discussion. The corrosion potential of 10G2FB steel in NS4 solution is -0.780 mV, in the soil environment it is more positive by 36 mV, namely -0.744 V, Fig. 1, a. The anode slopes of polarization curves (Fig. 1, b) were 0.036 and 0.029 V, indicating some difficulty in the anode reaction under conditions of thin-film corrosion. The limiting diffusion current of oxygen reduction is 0.128 and 0.071 A/m^2 in NS4 solution and in the soil environment, respectively. The decrease in the limiting diffusion current indicates a slowing down of corrosion, presumably due to the difficulty of oxygen delivery to the corroded surface and the removal of corrosion products. The obtained electrochemical data correlate satisfactorily with the results of determining the corrosion rate, which is 0.036 in NS4 solution and 0.029 mm/year in the soil medium.



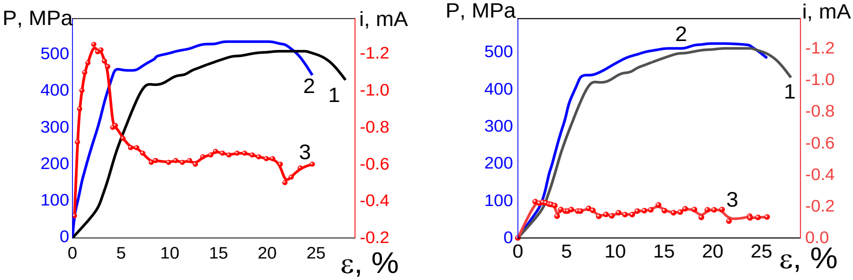
a b

Fig. 1. Corrosion potentials (a) and polarization curves (b) of 10G2FB steel in NS4 solution (1) and in soil environment (2).

After breaking of the specimens in air, signs of ductile fracture were found: the fracture line is smooth, wavy, characterized by tightening near the fracture site and areas that have undergone plastic deformation, Fig. 2, a. The fracture time was 43 hours, the relative elongation was 28 %, and the relative contraction was 72.6 % (Table 1).

After fracture in NS4 solution at a cathodic polarization of -1.05 V, the fracture pattern becomes more brittle, the narrowing of the specimen decreased markedly (Table 1), the fracture line is complex polyline, the steps of the fracture are visible, Fig. 2. b. The tensile strength was 517 MPa, the relative elongation decreased to 25.6 %, and the cross-sectional area, on the contrary, increased to

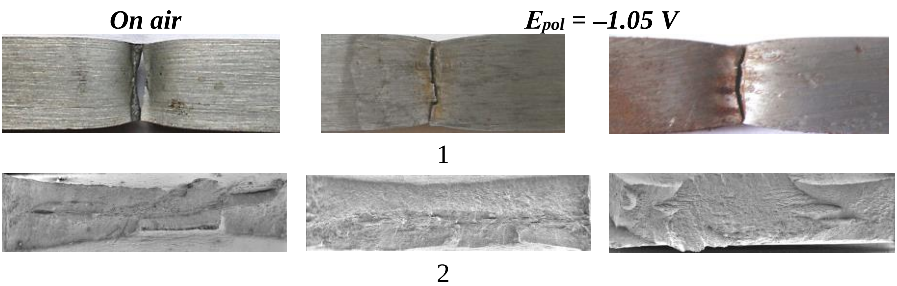
10.41 mm^2, which led to a decrease in the relative narrowing to 65.3 %. The coefficient of susceptibility to stress-corrosion cracking K_S equals to 1.15.



a b

Fig. 2. Fracture diagrams of 10G2FB steel (1, 2) and polarization currents (3) at a potential of -1.05 V: a – NS4; b – soil environment.

After fracture in the soil environment, the nature of fracture is mixed, with both ductile and brittle areas visible on the fracture surface, Fig. 3, a. A decrease in relative elongation to 24.6 % and relative narrowing to 60.6 % was noted compared to the specimen breaking in NS4, Table 1. The coefficient of susceptibility to stress-corrosion cracking K_S was 1.23. The tensile strength was 525 MPa.



a b c

Fig. 3. View of the breaking area (1) and fracture surface (2) of specimens in air (a), in solution (b), and in soil environment (c) at a potential of -1.05 V.

It should be noted that at a potential of -1.05 V, electrolytic hydrogenation of steel occurs, and the concentration of hydrogen capable to penetrate into steel can range from 0.0056 to 0.012 mol/dm^3 [2]. It can be assumed that in soil environment, due to transport complications, the removal of gaseous hydrogen is slower, and conditions are created to facilitate its penetration into steel, causing an increase in the tendency to brittle fracture.

Table 1. Corrosion, electrochemical, and corrosion-mechanical properties of 10G2FB steel in NS4 solution and soil environment at a potential of -1,05 V

Indicator name	Environment		
	Air	NS4	Soil environment
$\tau_{break.}$, hours	43	40	40
δ, %	28.0	25.6	24.6
σUTS, MPa	512	517	525
σ0,2, MPa	417	440	440
S, мм^2	8.23	10.41	11.83
ψ, %	72.6	65.3	60.6
K_S	–	1.15	1.23
v_{corr}, mm/year	–	0.039	0.020
E_{cor}, V	–	-0.780	-0.744
b_a, V	–	0.036	0.029
I_{O2}, A/m^2	–	0.128	0.071
E_{H2}, V	–	-1.00	-1.21
C_H, mol/dm^3	–	0.012	–

Conclusions. It has been established that under conditions of thin-film corrosion, the corrosion potential of 10G2FB steel shifts to more positive values: from -0.780 mV in NS4 solution to -0.744 V in the soil environment. A decrease in the limiting diffusion current of oxygen reduction from 0.128 to 0.071 A/m^2 was also found, which satisfactorily correlates with the corrosion rate in NS4 solution and in the soil environment – 0.036 and 0.029 mm/year.

An increase in the susceptibility to stress-corrosion cracking at a maximum protective potential of -1.05 V under conditions of thin-film corrosion, estimated by the K_S coefficient, from 1.15 to 1.23 was found.

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