A METHOD FOR THE EVALUATION OF PROTECTIVE PROPERTIES OF COATINGS IN CORROSIVE MEDIA IN THE PRESENCE OF PROPAGATING CRACKS

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We studied the influence of the state of the specimen surface on the electrochemical conditions at the tip of a corrosion fatigue crack and cyclic corrosion crack-growth resistance of 20 steel in distilled water. It was discovered that aluminum-zinc and zinc coatings protect the specimen surface against local anodic dissolution at the tip of the corrosion-fatigue crack and, hence, significantly increase the cyclic corrosion crack-growth resistance of the specimens as compared to the value typical of the specimens without coatings, although the intensity of hydrogen depolarization and, consequently, the probability of hydrogen embrittlement increase in this case. We propose a procedure and electrochemical parameters for the evaluation of the efficiency of protection of the tip of a propagating corrosion-fatigue crack by metallic coatings.

Application of organic and inorganic coatings is one of the most popular methods for protection against corrosion. The efficiency of protecting coatings is largely determined by the proper choice of their components under given operating conditions.

At present, there are no reliable and effective methods for the choice of protecting coatings and evaluation of their efficiency. This can be explained, e.g., by the extremely complicated kinetics of electrode processes on painted surfaces (as compared to metal-medium systems), which makes the determination of the actual mechanism of corrosion quite complicated. A similar situation is also observed in the case where the surface is covered with inorganic materials and, first of all, by such metals as zinc, aluminum, and their alloys.

The well-known methods for the evaluation of the efficiency of protective coatings are mainly based on the estimation of their corrosion resistance in the unloaded state and there are practically no data on protective properties of coatings damaged by corrosion-fatigue cracks.

In what follows, we propose a procedure for the evaluation of the efficiency of protective coatings in the presence of corrosion-fatigue cracks based on the use of the results of the experimental investigations of the influence of zinc and aluminum-zinc sprayed coatings on the cyclic corrosion crack-growth resistance of 20 steel in distilled water and on the electrochemical conditions at the tip of the corrosion-fatigue crack.

Experimental Procedure

To measure cyclic corrosion crack-growth resistance and electrochemical conditions at the tip of a corrosion-fatigue crack, 20-steel specimens 10 × 20 × 150 mm in size without coatings and with zinc or aluminum-zinc coatings were subjected to tests by pure bending. For this purpose, a part of the specimens was covered (by a manual metal sprayer) with coatings 0.1–0.2 mm in thickness prior to drilling holes for measuring capillaries and initiation of a fatigue crack in air.

The tests were carried out according to a special procedure described in [1] in distilled water, at a frequency of repeated-stress cycles of 0.33 Hz, and at an ambient temperature of 25°C. The specimens subjected to test had initial lateral cracks 2.2–2.4 mm in length. For comparison, the specimens without coating were also tested in air.

In the course of the tests, parallel with the parameters of crack growth (the length of the crack \( l \) and the corresponding number of loading cycles \( N \)), we recorded the pH value of the medium and the value of the electrode potential of the metal \( (E) \) on the specimen surface \( (pH_s \text{ and } E_s) \) and at the tip of the corrosion-fatigue crack \( (pH_t \text{ and } E_t) \). The values of \( E \) were measured relative to the silver-chloride reference electrode.

The stress intensity factor (SIF) \( K \) was determined for the specimens under investigation by the well-known formula [2] corrected to take into account the effect of holes for measuring capillaries.

Some segments of the noninvariant diagrams of cyclic corrosion crack-growth resistance were described by the formula \( v_e = CK^m \) whose coefficients \( C \) and \( m \) were determined by the method of least squares. The results of the tests carried out in air were processed as prescribed by the methodical instructions presented in [2].

![Diagram](image)

**Fig. 1.** Dependences of the pH value of the medium \( \text{pH}_t \) at the tip of the corrosion-fatigue crack (a) and of the electrode potential of the metal \( E_t \) at the tip of the crack (b, solid lines) and on the surface \( E_s \) (b, dashed lines) on the length of the crack \( l \): (1) specimens without coating, (2) with aluminum-zinc coating, (3) with zinc coating.

**Experimental Results**

For uncoated specimens in distilled water, the pH value \( \text{pH}_t \) (which is much greater than \( \text{pH}_s \)) first rapidly decreases as the length of the corrosion-fatigue crack increases and then stabilizes at a certain level for sufficiently long cracks (Fig. 1a, curve 1). The behavior of the specimens with aluminum-zinc coating is similar (curve 2) but stabilization is observed for somewhat lower values of \( \text{pH}_t \) and greater values of crack length. For specimens with zinc coating, the value of \( \text{pH}_t \) also decreases and, up to a certain crack length, it is greater than the relevant values for uncoated specimens (curve 3).

For uncoated specimens in distilled water, the electrode potential \( E_t \) is a monotonically decreasing function of the length of the corrosion-fatigue crack (Fig. 1b, curve 1). The behavior of the potential \( E_s \) is similar but its values...