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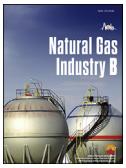

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Research Article

Electrochemical corrosion behaviors of the X90 linepipe steel in NS4 solution☆

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Abstract

Oil and gas line pipes are laid underground and run through different areas in the laying process, so they will be subjected to different degrees of corrosion and even crack, leading to enormous casualties and economic losses. In order to guarantee the safe operation of line pipes, therefore, it is significant to investigate the electrochemical corrosion behaviors of pipe steel in a simulated soil environment. In this paper, the electrochemical corrosion behaviors of the base metals and welding materials of API 5L X90 steel longitudinally submerged arc welding pipes in near-neutral simulated soil solution (NS4) were studied by means of the electrochemical impedance spectroscopy (EIS) and the potentiodynamic polarization testing technology. It is shown that the typical characteristic of anodic dissolution is presented but with no passivation phenomenon when X90 linepipe steel is put in NS4 solution. The base material is thermodynamically more stable than the seam weld material. The base material and seam weld samples were polarized under −850 mV polarization potential for different durations. It is demonstrated that with the proceeding of polarization, the polarization resistance and the corrosion resistance increase while the corrosion current density decreases. And the corrosion resistance of base material is better than that of seam weld material.

Keywords: API 5L X90 linepipe steel; Base metal; Welding seam; NS4 solution; Anodic dissolution; Thermodynamic stability; Electrochemical impedance spectroscopy (EIS); Corrosion resistance

Application of high-strength linepipe steel is beneficial to improving the transportation capacity of long-distance gas pipelines, but a higher requirement is made for its strength [1–3]. In recent years, X90 linepipe steel has been the new research focus at home and abroad [4–8]. At present, global research on X90 linepipe steel mainly focuses on its development and trial production [9–11], as well as its microstructure and mechanical properties [12–14]. And there is rare report on the electrochemical corrosion behaviors of X90 linepipe steel. The authors study the effect of polarization duration on the electrochemical corrosion behaviors of the base metals and welding materials of X90 steel longitudinally-submerged arc welding pipes in near-neutral simulated soil solution (NS4) by means of electrochemical impedance spectroscopy (EIS) and electrochemical testing method, and

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then summarizes the electrochemical corrosion laws of X90 linepipe steel in NS4 solution.

1. Electrochemical corrosion test

1.1. Testing materials

The X90 steel longitudinally-submerged arc welding pipe produced by one domestic steel pipe factory is taken as testing materials, and its specification is 1219 mm × 19.6 mm. The chemical compositions of the base metal are shown in Table 1.

Table 1
Chemical compositions of base metals and welding materials of X90 steel longitudinally-submerged arc welding pipes[a].

Composition	C	Si	Mn	P	S	Mo	Nb	Ti	Cr	Al	Cu	Fe
Base metal	0.056%	0.21%	1.92%	0.010%	0.0018%	0.21%	0.081%	0.012%	0.33%	0.029%	0.220%	Residual
Welding material	0.060%	0.25%	1.73%	0.014%	0.0034%	0.28%	0.045%	0.011%	0.19%	0.013%	0.140%	Residual

[a] Chemical compositions are presented in mol fraction.

1.2. Testing method

Near-neutral simulated soil solution (NS4 solution) is used as test solution and its pH is about 7. It is prepared by using distilled water and analytical pure chemical reagent.

The base metals and welding materials of X90 steel longitudinally-submerged arc welding pipes are processed into electrochemical samples with an area of 1 cm^2. The back of samples is welded with Cu conductors and the non-working surface is sealed with epoxy resin so as to isolate them from corrosive medium. Before the test is conducted, it is necessary to polish the working electrode with No. 100–1000 abrasive paper and then remove the greasy dirty at the surface of the samples with deionized water and alcohol. During the potentiodynamic polarization test, the standard three-electrode system is adopted by taking the X90 linepipe steel as the working electrode, the saturated calomel electrode (SCE) as the reference electrode and the Pt electrode as the auxiliary electrode. PARSTAT 2273 electrochemical testing set is used for electrochemical test. And its scanning speed is 1 mV/s and alternating current impedance spectrum is scanned in the range of 100 kHz–5 MHz. Each test is performed three times to calculate the average. Alternating current impedance spectrum is analyzed by using ZsimpWin software. Then the equivalent circuit and electrochemical parameters in the process of electrochemical corrosion is acquired. Potentiostatic polarization is performed by using the PS-168 electrochemical measurement system to apply the polarization potential of −850 mV (SCE) for 0, 2 and 10 h. Before electrochemical test is carried out, N_2, the fineness of which is 99.5%, is injected into the solution for 2-h oxygen removal. And in the process of test, the mixed gas of 95% N_2 + 5% CO_2 is injected continuously. All tests are performed at room temperature.

In the polarization process controlled by the controlled potential, the relation between the polarization potential of working electrode and its polarization current density is expressed by the following electrode dynamics equation [15].

$$I = i_{corr}\left\{\exp\left[\frac{2.303(E-E_{corr})}{b_a}\right] - \exp\left[\frac{2.303(E_{corr}-E)}{b_c}\right]\right\} \quad (1)$$

Where, E is the polarization potential when it is polarized, mV. I is the corresponding net current density, μA/cm^2. E_{corr} is the self-corrosion potential of corrosion systems, mV. i_{corr} is the self-corrosion current density, μA/cm^2. And b_a and b_c are the constant of anodic Tafel and the cathodic Tafel respectively, mV/dec.

When it is in the potential range of weak polarization with potential difference $\eta = |E - E_{corr}| < 50$ mV, b_a, b_c and i_{corr} can be calculated based on Equation (1) by the iterative fitting method.

2. Test results and discussion

2.1. Open-circuit potential

Fig. 1 shows the relation between open-circuit potential (E_{op}) and testing duration when the base metal and welding material samples of X90 steel longitudinally-submerged arc welding pipes are put in NS4 solution. It is indicated that the open-circuit potential E_{op} of the samples decreases quickly in the first 0–0.5 h of the test and then the decline rate slows

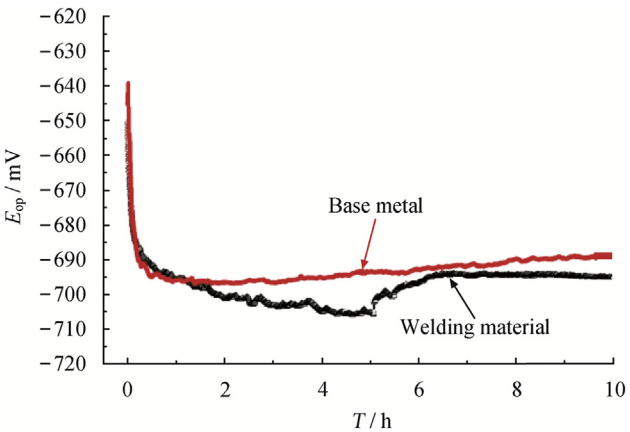

Fig. 1. Relation between open-circuit potential and test duration of the base metal and welding material samples of X90 steel longitudinally-submerged arc welding pipes in NS4 solution.

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