The Performance Research and Optimization of Steel Pipeline Coatings in Accelerated Weathering

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Abstract

Considering whether three-layer-polyethylene (3PE) and two-layer fusion bonded epoxy (2FBE) coatings can be used normally under the sunlight, the surface of 3PE coating was added the aluminum foil protection to avoid from the exposure of ultraviolet light. There was a comparative study investigating the anticorrosive performance and surface morphology of rich-zine epoxy antirust paint, 2FBE, 3PE, 3PE+aluminum foil protection in accelerated weathering. The magnitude of impedance modulus for 3PE+aluminum foil protection has always kept on , besides, the surface with the aluminum foil belt protection was flat and smooth, indicating the aluminum foil belt resisted ultraviolet exposure effectively. The magnitude of impedance modulus for 3PE declined two levels after 1200h weathering, and the surface was filled with chalking polyethylene, implying ultraviolet light caused the destruction for 3PE significantly. After 1200h weathering, the magnitude of impedance modulus for 2FBE was almost constant, meanwhile, there was slight chalking and no pin-holes or cracking on the surface, manifesting the 2FBE had fairly stable and great anticorrosive properties; All above results demonstrate that the 3PE+aluminum foil protection has superior corrosion resistance properties than others for the steel pipelines under the sunshine.

Keywords

3PE/2FBE, 3PE+aluminum foil protection, Weathering, EIS.

1. Introduction

The three-layer-polyethylene (3PE) and two-layer fusion bonded epoxy (2FBE) coatings are regarded as the first choice for buried steel pipelines anticorrosion,[1-3] due to the excellent adhesion, cathodic disbonding resistance, chemical resistance, impact resistance and so on. [4-9] However, the 3PE generally are not allowed for the external anti-corrosion of exposed steel pipelines directly,[10-12] in consideration of the poor ultraviolet ray weathering resistance. Meanwhile, there are little documents or reports about whether 3PE and 2FBE coatings can be applied to the exposed steel pipelines normally under the sunlight and the change of anticorrosion property.

Therefore, the 3PE coating was improved into 3PE+aluminum foil belt protection in this comparative study taking the experimental research as the main mode combined with the theoretical basis of electrochemical impedance spectroscopy (EIS) which was most frequently referred evaluation method in anticorrosion coating study.[13-16] The aim of comparative study was to investigate that whether 3PE and 2FBE coatings can be used normally under the sunlight, whether the aluminum foil belt protection can resist the ultraviolet light effectively as well as that the variation trend for performance and morphology about rich-zine epoxy antirust paint, 2FBE, 3PE, 3PE+aluminum foil protection during the artificial accelerated weathering period. The achieved conclusions and recommendations would provide effective guidance for the external anticorrosion coating of the exposed steel pipeline in the future.

2. Experimental

With reference to steel pipeline anticorrosion coating performance index,[10-12] this article puts forward four feasible coating types containing rich-zine epoxy antirust paint, 2FBE, 3PE and 3PE+aluminum foil protection respectively. The artificial accelerated weathering test, electrochemical impedance spectroscopy (EIS) and Scanning electron microscope (SEM) were confirmed as the experimental contents. Finally, there was a whole anticorrosive coating performance evaluation scheme.

2.1 Materials

2.1.1 Experimental Apparatus

Main apparatus in this test are listed in Table 1.

Table 1. Main apparatus

Instruments	Model	Manufacturer	Function
UV accelerated test chamber	LUV-2	Shanghai Pushen Chemical Machinery Co, Ltd	accelerated weathering
electrochemical workstation	PGSTAT302N	The Swiss wantong Co, LTD in China	anticorrosion test
SEM	EVOMA15	American families, roth Co, LTD in China	shape characterization

2.1.2 Coated Specimens Specification

All the coatings are final products made in manufacturers. Metal substrate material is Q235 steel pipeline. The size of anticorrosive coating samples is 10 mm × 10 mm. All specimens possess quality assurances and inspection reports and conform to the requirements of current industry standard. [10-12] Anticorrosion coating sample components are listed in Table 2.

Table 2. Anticorrosion coating sample components

Types	Rich-Zine Epoxy Antirust Paint	2fbe	3pe	3pe+Aluminum Foil
Undercoat	Rich-Zine Epoxy Antirust	Fbe	Fbe	Fbe
Interlayer	None	None	Copolymer Adhesive	Copolymer Adhesive
Outerlayer	Yellow Mixed Paint	Plastic Fbe	Pe	Pe
Protection	None	None	None	Aluminum Foil Belt

2.2 Experimental methods

The accelerated weathering is to shorten the weathering test cycle through simulation of natural environment and its effect on samples regarding factors like light, moisture and temperature based on the reinforcement of mentioned variates in a single or collective way [17,18]. Studies have shown that after the weathering time of 1200h, coating has the most significant changes in mechanical properties such as tensile strength, cohesive force.[19-21]

There are three 313nm-peak wavelength uv lamps, heating tank, sample frame and control and record the operation time and temperature of the system, test parameter is set to the temperature of 60 ℃

EIS measurements get the evaluation of anticorrosive performance by researching the electrochemical behaviors, for example the modulus of coating impedance, the size of the impedance loop. [22-24] The measured impedance data are given as typical Nyquist plots and Bode plots allowing for an easy calculation of the corrosion elements.[25] Tait put forward those conclusions: the magnitude of impedance modulus for coating is proportional to the coating corrosion impedance through the electrochemical impedance spectroscopy (EIS) measurements.[26,27] What's more, if the impedance modulus of organic coating is up to , that means the coating has an exceptional anticorrosive property to the steel substrate.

In this article, after weathering on a regular basis, rich-zine epoxy antirust paint, 2FBE, 3PE, 3PE+aluminum foil protection were performed in the solution 3.5% neutral NaCl by a three-electrode system that a steel substrate, a platinum wire, and a saturated (3 M) Ag/AgCl electrode were used as working, auxiliary, and reference electrodes, respectively. The open circuit potential (OCP) was obtained by immersing the working electrode (the coated specimen) in the test for 30 min. Then, electrochemical impedance spectroscopy (EIS) measurements were carried out for the frequency ranging from 100 kHz-10 mHz, with a 20 mV amplitude of waveform.

3. Results and Discussion

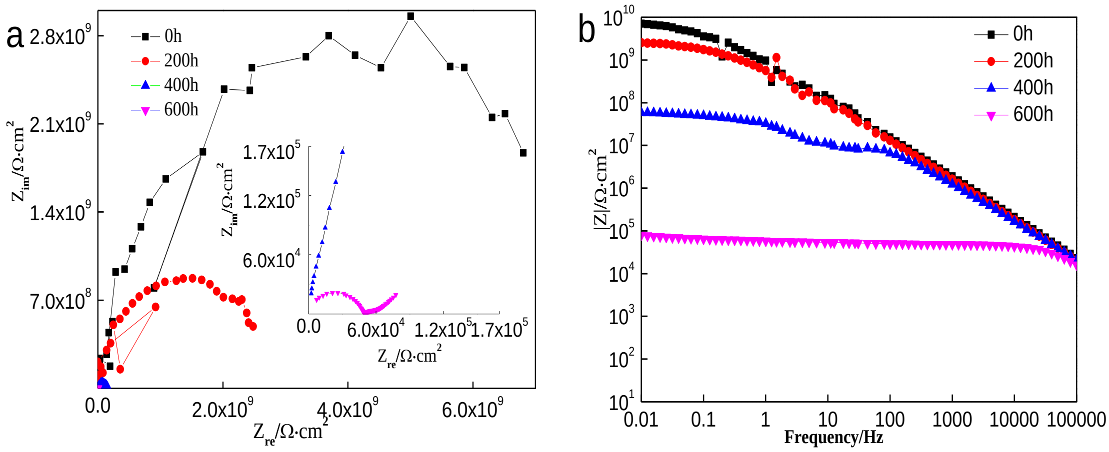
The measured impedance data was showed in Fig.2. The impedance plots for same type anticorrosive coating in the different accelerated weathering stage, in particular, the Nyquist plots of rich-zine epoxy antirust paint, 2FBE and 3PE coatings have partial enlargement.

From the Fig.2. (a-b), it can be seen from the 0-200h that the rich-zine epoxy antirust paint coating exhibited capacitive behavior, indicating good protective properties for the steel substrate. However, the rapid decrease in impedance after accelerated weathering 400h was attributed to the entry of water into the coating polymer and the permeation the interface coating /metal substrate, as the solution did not come into contact with the metal substrate, the protective properties of coating still existed. After 600h ageing, there was serious blister as well as a small amount of rust on the surface of rich-zine epoxy antirust paint coating. What's worse, the impedance plot with Warburg and the magnitude of impedance modulus dropped to , manifesting the coating was lost the function to protect the steel substrate which has begun to be corroded.

From the Fig.2. (c-d) the impedance plot of 2FBE coating, the modulus of impedance barely dropped after accelerated 1200h weathering, simultaneously, the Nyquist plot presented the feature of impedance loop during the weathering test, indicating the great and stable anticorrosive properties.

From the Fig.2. (e-f) the impedance spectrum of 3PE coating, after 1200h ageing, the impedance spectra had two time constant and the magnitude of impedance modulus of 3PE dropped 2 levels. All above phenomena suggested that the solution got through the 3PE outer polyethylene and reached to the undercoat via a small holes and material defects on the microcosmic level. After 1200h ageing, on account of the resistance of FBE undercoat, the impedance loop size of the coating basically remained changeless.

From the Fig.2. (g-h), the impedance plots of all 3PE + aluminum foil belt protection coatings kept linear characteristic that there were two capacitive loops in high frequency and middle frequency respectively during the whole period of artificial accelerated weathering. With the weathering time going by, the modulus of impedance had little change and kept the magnitude of , showing that the coating had the excellent blocking and stability.



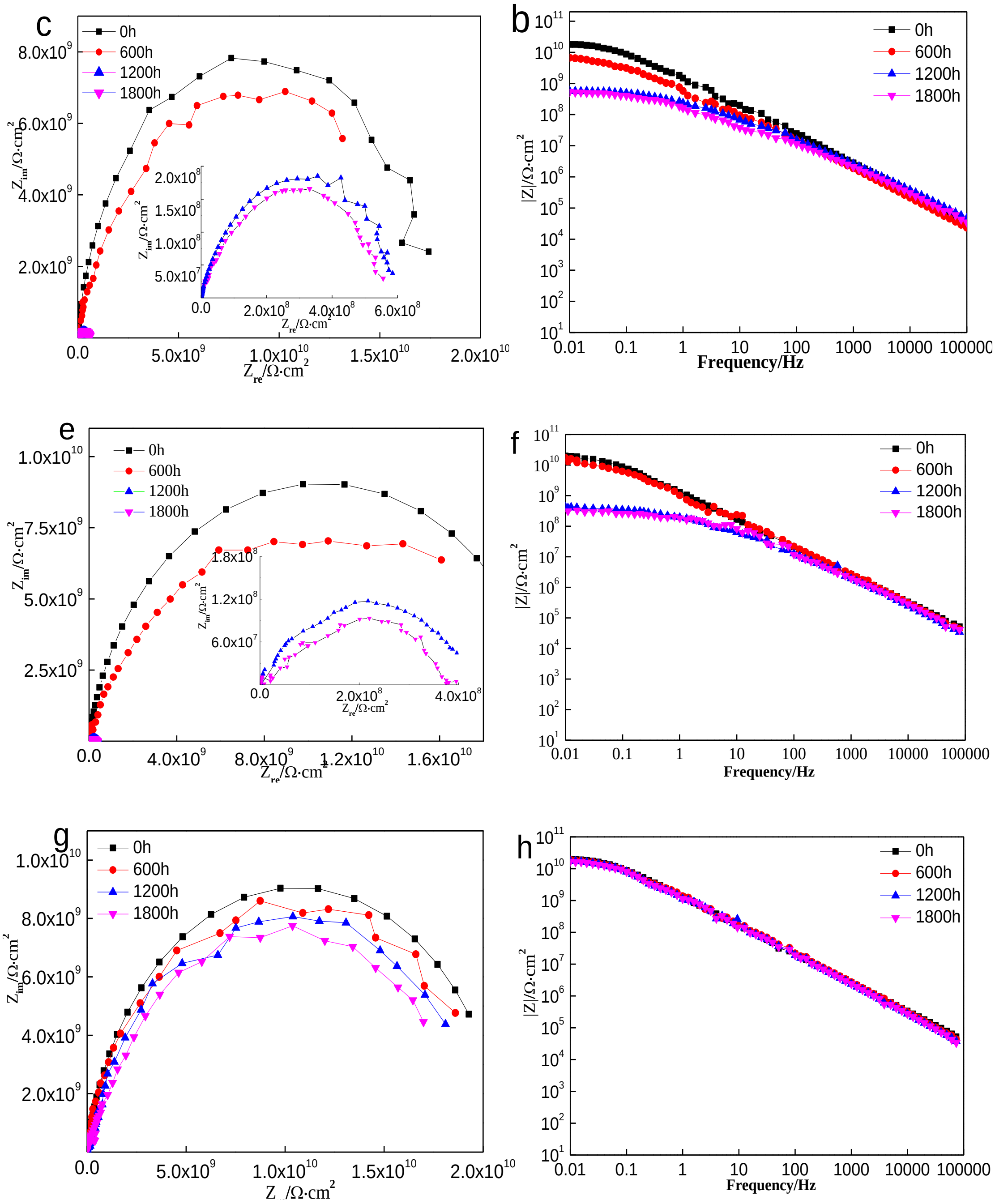


Fig.2. The impedance plots of (a-b) rich-zine epoxy antirust paint, (c-d) 2FBE, (e-f) 3PE, (g-h) 3PE+aluminum foil protection.

4. Conclusion

In present work, the comparative study has been studied by Electrochemical impedance spectrum (EIS)and Scanning electron microscope (SEM) to investigate the anticorrosive performance and surface morphology of rich-zine epoxy antirust paint, 2FBE, 3PE, 3PE+aluminum foil protection in accelerated weathering. The magnitude of impedance modulus for 3PE+aluminum foil belt protection has been keeping on during the study. Besides, the 3PE surface with the protection of aluminum foil belt was flat and smooth. Obviously, the aluminum foil belt resists the ultraviolet light effectively. The magnitude of impedance modulus for 3PE declined two levels after 1200h weathering, and the surface was filled with chalking polyethylene, implying ultraviolet light caused the destruction for 3PE significantly. After 1200h weathering, the magnitude of impedance modulus for 2FBE was almost constant, what's more, there was just slight chalking and no pin-holes or cracking on the surface. That means 2FBE has the fairly stable anticorrosive property. The rich-zine epoxy antirust paint coating is unsuited for the external anti-corrosion of exposed steel pipelines because of the poorer corrosion resistance as well as the shorter service time. In accelerated weathering, the anticorrosive properties are strengthened by the turn of rich-zine epoxy antirust paint, 2FBE, 3PE, 3PE+aluminum foil protection. Especially, the corrosion resistance of 3PE+aluminum foil protection is the most effective for the steel pipelines under the sunshine.

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