CORROSION SCIENCE AND TECHNOLOGY, Vol.2, No.3(2003), pp.161~163

The Development and Application of a External Coating for Buried Pipeline Rehabilitation

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With the development of Chinese petroleum and gas industry, about 20,000 km long-distance pipeline and 250,000 km gathering pipeline have been constructed in China. After operating for many years, most of the coatings on buried pipelines have aged so severe that the steel pipes are subject to corrosion environment underground. Focusing on the need of external coating for buried pipeline rehabilitation, a new type of coating has been developed. The development and application of the coatings has been introduced in this paper.

Keywords *: pipeline, corrosion, rehabilitation, solvent-free, coating*

1. Introduction

The pipelines are lifelines of petroleum and natural gas field. With the development of petroleum and gas industry for more than 30 years, about 20,000 km long-distance pipeline and 250,000 km gathering pipeline have been constructed in China. After operating for many years, most of the coatings on buried pipelines have aged so severe that the steel pipes are subject to corrosion environment underground.[1] To solve corrosion problems with the pipeline in the late development period of petroleum industry, a new external coating for rehabilitating buried oil/gas pipelines has been developed to prolong the service life of the used pipeline in the oil field.

2. The development of coating

Because epoxy resin is of excellent anti-corrosion and waterproof properties, it can be selected as membrane in the coating. To satisfy the requirement of rehabilitation in operation, solvent-free coatings were developed to avoid bubbling in the coating during applying and curing. The resins suitable to make solvent-free coatings are low molecule epoxy resins.

The active thinners 5A, 6A, B in commercial were selected to test. Then compared experiments were made with the same composition. The result shown in Table 1 shows that the effects of two active thinners 6A and B are better, but the price of 6A active thinner is expensive. At last the active thinner B of moderate price was selected to test the coating composition.

Table 1. The coating properties of possessing different active thinners

Property item	Thinner		
	5A	6A	B
Flexibility (mm)	1	1	1
Adhesion (scratch ring method) (class)	1	1	1
Impact resistance, cm	50	50	50
Resistance to 95 → water	Perfect after 1000h	Perfect after 1000h	Perfect after 1000h
Package stability of paints	Gelatin after 1 month	No change after 12 months	No change after 12 months

The inert fillers can improve mechanical properties, anti-corrosion properties and adhesion. The dosage of the fillers is one of the key factors of affecting the compactness of the coating, because it can result in the change of water absorption rate, glossiness and anti-corrosion properties of the coating. Not only the contract stress of the system and general physical properties of the coating, but also the adhesion, mechanical and anti-corrosion properties must be considered when the fillers are used in solvent-free epoxy anti-corrosion coatings

Titanium white, talc powder, barite powder, black pigment, iron oxide red, glass flakes and other pigments and fillers were selected to test. The sorts and dosage of pigment and filler were decided after many tests.

Table 2. The physical and chemical properties of the external coating

Test item	Technical specification		Test standards
	Primer	Top coat	
Coating color	Iron red	Grey	
Solid content (%)	◎94	◎94	GB1729
Surface dry (h)	1.3	1.5	SY/T0320
Through dry (h)	24	24	GB1723
Flexibility (mm)	1	1	GB1728
Adhesion (class)	1	1	GB1731
Impact resistance (cm)	50	50	GB1720
Tensile strength (MPa)	>15	>15	GB1732
Shearing strength (MPa)	>9	>11	GB/T1040
Abrasion resistance (1000g,1000r, mass loss, g)	<0.05		SY/T0041
Thermal resistance (150→, 1000h)	Intact		ASTMD4060
Water resistance (100→, 1000h)	Intact		GB1735
Salt fog resistance (1000h)	Intact		GB1733
Water vapor transmission rate ($g/m^2 \cdot 24h \cdot mmHg$)	0.036		GB/T1771
Sea water 3 months immersion	Intact	Intact	SY/T0320
10%HCl 3 months immersion	Intact	Intact	GB/T1763
10%NaOH 3 months immersion	Intact	Intact	GB/T1763
10%NaCl 3 months immersion	Intact	Intact	GB/T1763

3. The physical and chemical properties of the coating

The external coating called EP-94 has been developed for buried pipeline rehabilitation through a lot of screening experiments. It is the air curing coating of two components. The physical and chemical properties of the coating are shown in Table 2.

4. The study on coating system

Because the solvent-free coating can be applied to form thicker film at one time, we hope to try our best to depress the cost of the project but not to affect the coating properties. A series of the coating system have been designed. At first the coupons were made, then put them in the artificial sea water (100℃) to accelerate corrosion test. The anti-corrosion properties and rules of different coating systems have been conformed. The results are showed in Table 3.

Table 3. Artificial sea water resistance of different coating systems

Coating system	The results of the artificial sea water immersion
Phosphate surface: 1 layer EP-94 top coat	A lot of bubbles
Rust cleaning surface: 1 layer EP-94 top coat	Some bubbles
Rust cleaning surface:	Intact
Rust cleaning surface: 1 layer primer + 2 layers EP-94 top coat	Intact
Rust cleaning surface: 1 layer primer + 1 layer EP-94 top coat+1 layer glass cloth + 1 layer EP-94 top coat	A few pits, no rust

The anti-corrosion performance tests of different coating systems have shown following results.

1) The blast cleaning on the steel surface can form definite anchor pattern, so that it is fit for adhesion and coherence of the coating and steel surface. The surface treated with phosphate is smoother, so it is not propitious to adhesion of the coating and steel surface. Therefore, the blasted steel surface is better than the surface with phosphate film for improving the anti-corrosion property.

2) As a general rule, the anti-corrosion effect of coating is primarily achieved through the coating physical barrier between corrosion medium and steel. In the definite range, when increasing the thickness of coating, the coating screening effect can be enhanced, and the deficiencies of coating can be reduced, such as micro-crack, pinhole etc. So the anti-corrosion properties of the coating have been enhanced with the increase of coating thickness.

3) The glass fiber cloth can improve the mechanical performance of coating system, but has not obvious effect on the anti-corrosion performance of coating.

5. The application in site

When the ultimate prescription of the coating is confirmed, it is time for us to process the coating extensively. Every property of the coating can meet the designing demands when tested, and it is also good enough to meet the construction demands. In 1999, EP-94 epoxy solvent-free heavy anticorrosion coating, the pipeline outer-surface repair material, was used on the 150 km oil transmission pipeline in operation. The oil transportation pipeline with diameter of 273 mm was originally constructed in 1987.

After digging the pipeline ditch and removing the aged coating, we used the EP-94 epoxy solvent-free anti-corrosion coating to rehabilitate the pipeline.

When the depth of the corrosion area on steel surface is less than 0.5 mm, if the area of the corrosion area is less than 1 cm^2, the anticorrosion insulating-layer can be repaired directly without filling the corrosion pit. And if the corrosion area is more than 1 cm^2, it needs smearing flat using anticorrosion solvent-free repair materials, then go along the repair.

When the depth of the corrosion place is between 0.5 and 2 mm, special polymer alloy repair material can be filled, or spot welding repair be used on condition that the area of corrosion place is less than 1 cm^2. And if the area is more than 1 cm^2, it can be adopted in the following two methods: 1) Special polymer alloy repair materials were filled in and smeared flat, then three layers coatings and two layers glass fiber cloth were made with anticorrosion solvent-free repair materials and glass fiber cloth. 2) Fill in anticorrosion solvent-free repair materials, then go along the steel plate welding.

When the depth of the corrosion area is more than 2 mm, the anticorrosion solvent-free repair materials were filled firstly, then reinforce weld was carried out adopting two methods: 1) A piece of machined steel plate was reinforcing welded on the area. 2) Wrap the area being repair in the manner of nipping the sleeve.

The coating system is applied in strengthening grade anticorrosion layer: primer--top coating--glass fiber cloth--top coating--glass fiber cloth--top coating, and the total thickness of the coating system is no less than 450 um. After running for 2 years, the pipeline is perfect in service. Therefore, it can be believed that the pipeline coating is of excellent anticorrosion performance.

6. Summary

There are about 2000-3000 km various pipelines to be replaced or to be abandoned every year because of corrosion in onshore oil field in our country and the amount of the pipelines is probably increasing in coming years. These pipelines can be externally rehabilitated with special repair coatings and cost 50% less than new pipeline construction. The service life of rehabilitated pipelines expects to be more than 15 years and gathering production is not affected.

References

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