Station Pipes Inspection Method And Application Based On Damage Modes

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Abstract: Station pipes are important part of the oil and gas delivery system. At present, there are no targeted internal pipeline inspection standards for station pipes. So we can’t inspect the station pipes effectively. According to the characteristics of station pipes, this paper introduce the typical damage modes of station pipes, analyze the applicability of common corrosion inspection technology, weld inspection technology, stress corrosion fatigue inspection technology and fatigue damage inspection technology in the inspection of station pipes, propose an inspection method for the station pipes. The field application shows that this inspection method can inspect station pipes effectively, but due to the particularity of station pipes, the method still has some limitations and shortcomings.

1. Introduction
Station pipelines are generally composed of overhead and underground parts. The current inspection and detection are mainly based on the relevant requirements of “Regulation for Periodic Inspection of In-service Industrial Piping” (Trial) and “Periodical Inspection Regulation for Oil and Gas Pressure Pipeline”. There is still no particular detection standard for station pipelines in China. However, compared with general industrial and long-distance buried pipelines, station pipelines are quite different in working environment, laying methods, operating conditions and pumped medium. This detection method, which is not purposeful, targeted and applicable, is difficult to ensure the intrinsic safety of the whole station pipelines [1, 2].

After determining the damage modes of station pipelines, this paper comprehensively compares the detection accuracy and applicable conditions of various pipeline detection technologies and methods, and puts forward targeted detection methods of station pipelines based on field engineering practice.

2. Typical Damage Modes of Station Pipelines
Typical damage modes of station pipelines mainly include decrease in thickness due to corrosion, welding seam failure, stress corrosion and fatigue damage [3].

(1) Decrease in thickness due to corrosion
Corrosion is divided into external corrosion and internal corrosion. External corrosion mainly occurs in buried pipelines, and the dominant form of corrosion is electrochemical corrosion, which often occurs at the affected areas of external anticorrosive coating, the places with strong soil corrosivity, the places with inadequate cathodic protection and the places with serious stray current. The major forms of
internal corrosion are chemical corrosion, erosion corrosion and electrochemical corrosion of the medium, which mainly occur at places including places with sudden change of velocity such as tee, elbow and transition pipe, dead corner of medium flow (such as dead end), the cluster of liquid water, etc.

(2) Welding seam failure
Due to the limitation of welding technology and site conditions during the construction of the station, there are many original defects in the welding seam, such as incomplete fusion, incomplete penetration, pores, slag inclusion and cracks. The original defects in the welding seam can easily cause failures such as corrosion and cracking.

(3) Stress corrosion
The main failure mode is stress corrosion cracking. It occurs at places such as the pipeline with sulfide, chloride ion and other components that may lead to stress corrosion in the medium, and the pipeline made of high-strength steel. In the actual inspection process, it was found that there were problems such as foundation settlement for some station pipelines, which led to higher stress in the pipeline materials and were more likely to cause stress corrosion.

(4) Fatigue damage
The main failure damage is cracking. It occurs at places such as the inlet and outlet pipelines of the pump and compressor, and the pipelines with vibration.

3. Detection Methods of Pipeline Station

3.1 Corrosion detection

3.1.1 External corrosion detection
(1) Trenchless detection
The detection items include: environmental corrosion detection, trenchless detection of anticorrosive coating, validity check of cathodic protection and insulated joints (flanges) detection [4].

Environmental corrosion detection includes soil corrosion detection and stray current detection. Soil corrosivity detection includes the test of 8 parameters such as soil resistivity, free corrosion potential of pipelines, reduction-oxidation potential, PH value of soil, soil texture, soil moisture content, soil salt content and soil Cl⁻ content. Since there are many pipelines grounded in stations, stray current can be detected and evaluated by detecting the potential fluctuation of pipelines.

Trenchless detection of anticorrosive coating mainly means to detect and evaluate the anticorrosive coating of buried pipelines. Due to the complexity of underground facilities of station pipelines and the grounding of most pipelines, electromagnetic detection method has certain limitations. The overall quality of anticorrosive coating cannot be detected and the main detection content is the detection and location of local failure points of anticorrosive coating. The detection method is ACVG. Before detection, the construction data of station pipelines should be investigated to determine the applicability of the ACVG method. For buried pipelines that ACVG cannot apply to, direct excavation detection method should be adopted to determine the damage and external corrosion of anticorrosive coating.

Validity check of cathodic protection mainly means to detect and evaluate the cathodic protection status of pipelines. According to the characteristics of cathodic protection in the pipeline area of the station, the close interval potential survey (CIPS) detection method and the polarized probe detection method of pipe-to-soil potential of the pipeline can be used for detection, and the influence of IR drop should be considered during detection.

Insulated joints (flanges) can detect the insulation performance through potential method, PCM leakage power reduction method and grounded resistance meter method.

(2) Direct excavation detection
Direct excavation detection is carried out for outliers found in trenchless detection, and pipes that trenchless detection of anticorrosive coating cannot apply to.

Excavation inspection items for external corrosion mainly include:
1) Environmental soil inspection, such as the texture, stratification and humidity;
2) Detection of external anticorrosive coating, such as type, condition, thickness, cohesive property, damage and quality of areas without damage;
3) External corrosion inspection of pipelines, such as the size of corrosion defects, relative position and corrosion appearance;
4) Take the photos required.

3.1.2 Internal corrosion detection
The commonly used internal corrosion detection methods include guided wave detection technology, electromagnetic detection technology, ultrasonic detection technology and eddy current detection technology, etc. [6] Based on the characteristics of the above-mentioned detection technology, the combined detection technology can be adopted for the internal corrosion detection of station pipelines[7, 8]:

(1) For long-distance straight sections of overhead pipelines, the detection combination of low-frequency guided wave + magnetic leakage/low-frequency electromagnetic/remote field eddy current + ultrasonic thickness measurement/C-Scanning can be adopted;
(2) High-frequency guided wave detection technology is adopted for the crossing section, wall-penetrating section and sections entering and leaving the ground of pipelines.
(3) Ultrasonic thickness measurement/C-Scanning detection technology is adopted for pipe fittings such as tee, elbow and transition pipe that may have internal corrosion.

3.2 Welding seam detection
The main detection technologies include ultrasonic, radiographic, magnetic particle, penetration, eddy current, TOFD and phased array detection technologies, of which ultrasonic, radiographic, TOFD and phased array mainly detect internal defects, and magnetic particle, penetration and eddy current detection technologies mainly detect surface or near-surface defects.

Due to the portability and high detection efficiency of common ultrasonic detection equipment, as well as low quantitative accuracy of defects, ultrasonic detection can be used to comprehensively detect the internal defects of the welding seam first, and radiography, TOFD or phased array technology can be used to recheck the outliers found.

3.3 Stress corrosion detection
For pipelines that may have stress corrosion, hardness testing and nondestructive testing can be used for the pipeline detection. In addition, X-ray stress detector is used to quantitatively detect the stress inside the material for the parts suspected of stress concentration inside the pipeline.

3.4 Fatigue damage detection
For cyclic loading cases and vibrating pipelines, macro detection and non-destructive detection methods are used for detection of cracking.

4. Engineering Application
In the substation of a long-distance pipeline company, pipelines are divided into overhead and underground parts, with a pipe diameter of Ф114 ~Ф 529mm. The station was put into operation in 2002, with crude oil as the medium, operating pressure of 3.0 ~ 5.0 MPa and operating temperature of 40 ℃. According to the previous data investigation, the main failure modes of the station are internal and external corrosion and welding seam failure.

4.1 External corrosion detection
A total of 16 suspected failure points of anticorrosive coating are found during trenchless detection. Cathodic protection potential of pipeline (V_{OFF}) is between-900 mV and -1050mV, and the pipeline achieves effective cathodic protection; the soil corrosivity is at the moderate level; no obvious stray
current interference is found; and the insulated joint has good performance.

Five failure points found by trenchless detection are excavated, and it is found that one of them is sacrificial anode, and the other four are damage of anticorrosive coating. The pipeline is corroded at the affected area of the anticorrosive coating. In one of them, intensive corrosion pits appear in the pipe body of the exploration pit, with the deepest pits being 2.2 mm, the pipe specifications being Ø 168 × 6 mm, and the wall thickness around the external corrosion point being 5.6 mm, as shown in Figure 1.

4.2 Internal corrosion detection

For long-distance straight pipe sections, the combined corrosion detection of low-frequency guided wave + magnetic leakage + ultrasonic thickness measurement is carried out. For straight pipelines that cannot meet the conditions of guided wave detection, the combined corrosion detection of magnetic leakage + ultrasonic thickness measurement is carried out, and the conventional ultrasonic wall thickness detection is carried out for tee, elbows and transition pipes. A total of 12 guided wave tests are carried out on the station pipelines, and one pipeline is found to be abnormal. Guided wave signal analysis diagram is shown in Figure 2. In the figure, there are 3 abnormal signals at abnormal wave crests 1, 2 and 3, and other wave crests are echo signals of the welding seam. In the figure, the blue curve is the signal peak value of the welding seam, and other curves come from this curve. The red curve represents 26% cross sectional area loss, the green curve represents 9% cross sectional area loss, and the dotted line represents 9% noise level which is 6 dB below the loss line.

The pipeline specification is Ø 325 × 8 mm. Three outliers are detected by magnetic leakage detection technology, and the areas of magnetic leakage alarm are marked. Ultrasonic intensive detection shall be carried out on the magnetic leakage alarm areas and the parts where magnetic leakage cannot be detected, such as elbows and both sides of the welding seam. The detection results are shown in Table 1.
Table 1 Ultrasonic wall thickness test results

| Number | Test results                                      |
|--------|---------------------------------------------------|
| Defect 1 | 2 thinning points, the wall thickness is 3.25mm, 3.85mm. |
| Defect 2 | 2 thinning points, the wall thickness is 4.18mm, 5.49mm, 3.10mm. |
| Defect 3 | 5 thinning points, the wall thickness is 3.94mm, 3.84mm, 4.56mm, 4.07mm, 5.30mm |

Ultrasonic wall thickness detection is carried out on 519 pipe fittings of the station. It is found that there is localized corrosion with varying degrees in the pipes.

4.3 Welding seam detection
Ultrasonic and permeation detection methods are adopted for welding seams, and the defects found by ultrasonic waves are rechecked by radiography. A total of 398 welding seams are detected, and one welding seam is found to have defects of incomplete penetration, with the incomplete penetration length of 100 mm and the depth of 1.5 mm.

5. Concluding Remarks
According to the characteristics of station pipelines, the detection method proposed in this paper gives full play to the advantages of different detection technology and can effectively improve the detection efficiency and defect detection rate. However, for trenchless detection of external corrosion of buried pipelines, due to the complexity of underground facilities of station pipelines, ACVG at some grounding points is too intensive or the position near sacrificial anodes is severely disrupted. The detection rate and effectiveness of failure points of anticorrosive coating need to be further improved.

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