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Corrosion failure cause analysis and evaluation of corrosion inhibitors of Ma Huining oil pipeline

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ABSTRACT

The corrosion failure cause analysis of Ma Huining ×52 oil pipeline has been investigated in the present study. The morphology and composition of the corrosion products are characterized by scanning electron microscopy, energy-dispersive spectroscopy and water quality analysis. The static and dynamic weight loss experiment is conducted to estimate corrosion rate of ×52 pipeline steel with different inhibitors. With the addition of electrochemical impedance test and polarization curve method, the inhibitors aimed at corrosion of Ma Huining oil pipeline have been evaluated. Results show that corrosion of ×52 pipeline steel is mainly induced by oxygen corrosion and SRB. Non-metallic inclusions are MnS and Al_2O_3. The inhibitor made up of oleic acid imidazoline amide and sodium sulfite at 80 ppm was optimal for corrosion of Ma Huining oil pipeline.

1. Introduction

As a conventional energy, oil plays an important role in the development of global economy [1]. The safe and reliable operation of oil pipeline has become the focus of the world [2]. With the development of oil exploitation, the depth of oil well and the total water cut rate is increasing [3]. On account of the pipeline corrosion, many major problems existing in the course of the oil-gas field development, which imposes a great threat to the safe operation and also causes huge economic losses [4]. The common corrosion forms include uniform corrosion, localized corrosion, pitting corrosion and crevice corrosion and so on [5–7]. The length of Ma Huining oil pipeline, consisted of Ma Hui pipeline and Hui Ning pipeline, is 270 km from Quzi (Gansu) to Shikong (Ningxia). What's more, the corrosion of pipeline is mainly effected by CO_2, H_2S, SO_2, dissolved oxygen, SRB, which are contained in oil [8]. According to pipeline accident statistics of Changqing Oilfield Company, the most serious corrosion is within the range of 12 km in Quzi station. Moreover, corrosion perforation had been existed for 63 times from 1991 to 2004, which would lead to pipeline failure more easily.

In the current work, the corrosion cause analysis of pipe which was used in the Ma Huining oil pipelines has been investigated by scanning electron microscope (SEM) and energy-dispersive spectroscopy (EDS). Additionally, several corrosion inhibitors used in the Ma Huining oil pipelines have been evaluated through the weight loss experiments and electrochemical tests.

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2. Materials and methods

2.1. Background of failure

The material of Ma Huining oil pipeline was ×52, and the pipe specification was Φ325 mm × 7 mm, and crude oil was the transported medium in the pipeline. The temperature of oil in Ma Huining from Quzi station was 65 °C in winter. In summer, the temperature was maintained at 34 °C from Quzi station, while it was 24 °C in Huianbao station.

2.2. Organisms and testing medium

The water samples were collected at storage tank. The bacteria consortium used in this study from water samples obtained from pipeline of Quzi station. As shown in Table 1, the pH value was neutral, which was suitable for the growth of SRB, and high conductivity was advantageous to the electrochemical corrosion process. The high concentrations of chloride reached 10^4–10^5 mg/L exacerbated corrosion; while the metal elements can form protective membrane (MnS and Al_2O_3) to slow down the corrosion rate. The water contained SO_4^{2-} and little oxygen, which was suitable for the growth of SRB with the addition of appropriate temperature and pH [9], and the bacteria test of water samples from Quzi station was presented in Table 2.

2.3. Characterization

Using a Photoelectric Direct Reading Spectrometry (4460, Switzerland) analyzed the chemical composition of the pipe on the basis of GB/T9711–2011. EDS (Tecnai G220, America), XRD (X'Pert PRO, Holland), and SEM (XL30-FEG, Holland) were employed to identify the chemical composition of the corrosion scale. EDS was employed at 10 kV accelerating voltage. Detection of water samples was carried out by ICP-MS (7500CX, Japan). The electrochemical measurement of potentiodynamic polarization curve was conducted using an electrochemical workstation (PGSTAT 302N, Switzerland). Before this, the specimen was cleaned in acetone to eliminate the surface contamination.

2.4. Weight loss experiment

The rectangular test specimen made of the ×52 pipeline steel was 50 mm × 10 mm × 3 mm with a 6 mm hole. The composition (wt%) of ×52 carbon steel is as follows: C (0.071), Mn (1.23), Si (0.25), S (0.003), P (0.017) and balance Fe. At first, the specimens were mechanically abraded with a series of emery papers (from 240 to 800 grades). The second step was degreased with acetone and cleaned with absolute alcohol [6]. The immersed solution was taken from Ma Huining oil pipeline. The samples were weighted before and after the tests using an analytical balance with a precision of 0.1 mg. The tests were weighed for 3 times to obtain the final data. The corrosion rate was calculated by the following equations [6,7]:

$$\nu = \Delta M/(S \times t) \tag{1}$$

$$B = \frac{\Delta M}{\rho At} = \frac{1}{\rho} \times \nu \times \frac{365 \times 24 \times 10}{100^2} = 8.76 \times \frac{\nu}{\rho} \tag{2}$$

Table 1
The analysis of water samples from Quzi station.

Item	Unit	Storage tank	Field sampling	Trend
pH	Dimensionless	7.00	7.24	↑
Sr	mg/L	286	220	↓
Conductivity	ųS/cm	1.52×10^3	1.69×10^3	↑
Hardness (Ca & Mg)	mmol/L	15.8	15.0	↓
Mineralization	mg/L	2.79×10^4	3.06×10^4	↑
Salt content	mg/L	2.58×10^4	2.64×10^4	↑
Sulfate	mg/L	Not detected	39.5	↑
Chloride	mg/L	2.30×10^4	2.58×10^4	↑
Fluoride	mg/L	0.53	0.34	↓
Sulfide	mg/L	0.155	0.017	↓
K	mg/L	96.4	97.3	↑
Na	%	0.96	1.07	↑
Ca	mg/L	305	304	↓
Mg	mg/L	227	231	↑
Fe	mg/L	0.84	1.37	↑
Fe^{2+}	mg/L	0.805	0.255	↓
Fe^{3+}	mg/L	0.035	1.11	↑
Ba	mg/L	22.7	<0.05	↓