Acoustic Emission Data Analysis of Tank Settlement

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Abstract. The uneven settlement around the tank and the corrosion of the bottom are main factors affecting the safe operation of the tank, so it is necessary to monitor the settlement and corrosion of the tank in real time to prevent and eliminate the hidden danger in time. In this paper, the large crude oil storage tank is taken as the research object to carry out uneven settlement monitoring and acoustic emission dynamic detection. By analyzing the measured settlement data and acoustic emission characteristic parameters, the author explores the influence of tank settlement on acoustic emission signal of tank floor corrosion, so as to provide reference for the extension of service life of storage tank and anti-corrosion work of storage tank.

Keywords. Tank bottom; uneven settlement; fiber grating; acoustic emission testing.

1. Introduction

The importance of large storage tanks for the petroleum industry is self-evident, but repeated safety incidents have aroused people’s strong attention to the safety of storage tanks, and put forward higher and higher requirements for the safety and reliability of storage tank facilities. The settlement and corrosion of the tank bottom will affect the normal operation of the tank. How to effectively manage the tank and do a good job in the safety protection of the tank has always been a big problem faced by the petrochemical industry. The uneven settlement around the tank \cite{1} is the most serious damage to the tank, which will cause the radial deformation of the shell and the stress increase of the fillet weld between the tank wall and the bottom plate and the edge plate of the tank bottom. The change of the stress will lead to the change of the corrosion rate of the tank bottom plate. The acoustic emission technology is usually used to detect the dynamic defects of the tank bottom plate. According to the relevant provisions of “Vertical Cylindrical Steel Welded Oil Tank Operation, Maintenance and Repair Regulations” \cite{2}, when there is no ring wall, the height difference between any two points in every 3m arc length around the tank shall not be greater than 12mm. However, in the process of field test, it is found that the elevation difference between adjacent measuring points of large storage tank is often greater than 12mm. If these hidden dangers cannot be found in time by inspectors, the normal operation of storage tank may be affected.

In this paper, a 30000 m\textsuperscript{3} large floating roof crude oil storage tank is taken as the research object, the influence of tank settlement on the acoustic emission signal of tank bottom corrosion is analyzed, and the uneven settlement monitoring \cite{3} and acoustic emission detection are carried out respectively. This paper mainly compares and processes the monitoring data of uneven settlement and acoustic emission of storage tank, controls the liquid level of storage tank from 12.8m to 9m in turn, reduces 0.5m each time, detects and records the data of each observation point each time, and explores the correlation and law of acoustic emission signal of settlement and corrosion with the change of liquid level of storage.
tank, so as to provide reference for the settlement observation, acoustic emission detection and data processing of large storage tank.

2. Qualitative and Quantitative Analysis of Tank Bottom Corrosion Detection
At present, the relatively mature open tank detection technology is generally used as the quantitative evaluation method of safety management for large storage tanks in China, which can detect the defects and safety failure of storage tanks in an all-round way, and the inspection results are intuitive and accurate.

According to the inspection results of open tank inspection in the past, it can be seen that the most critical part affecting the normal operation of the tank is the corrosion of the tank floor. However, there are three main problems in this method. First, many tanks cannot be shut down on schedule for routine open tank inspection, resulting in varying degrees of safety risks. Second, the economy of open tank inspection should be considered. The inspection and maintenance cost of large storage tank is very expensive (1.4 million RMB for 100000 m³ tank mechanical cleaning), and the inspection time is very long. Third, the lack of scientific basis to determine the maintenance object. Judging the corrosion status of storage tank only based on the operation time and experience of storage tank, it may not be able to find the vertical storage tank that really needs to be repaired in time and effectively, thus affecting the safety production. However, the acoustic emission on-line qualitative detection technology of tank bottom can make up for the above shortcomings, and can preliminarily evaluate the overall corrosion of the tank without opening the tank, so this detection work is carried out.

3. Introduction of Testing Device

3.1. Introduction and Arrangement of the Monitoring Device for Uneven Settlement of Storage Tank
The uneven settlement monitoring of storage tank mainly relies on fiber bragg grating sensing technology [4], and the detection equipment is shown in figures 1 and 2. Fiber bragg grating displacement sensor needs to be completely sealed, which is composed of fiber bragg grating strain gauge, high-performance spring, connecting rod, protective shell, universal joint and other components. The wavelength of fiber bragg grating will change when the connecting rod is pulled out from the sensor body, and the accurate displacement can be obtained by reading the wavelength (the accuracy can reach 1 mm).

![Figure 1. Fiber bragg grating sensor.](image1)

![Figure 2. Fiber bragg grating demodulator.](image2)

In this test, 22 settlement observation points are evenly arranged along the circumferential direction on the top surface of the foundation (150 mm away from the tank wall) on the outside of the tank bottom plate. Before the test, the joint needs to be cleaned, and then the fiber bragg grating sensor and demodulator are connected for settlement monitoring.
3.2. Introduction and Layout of Acoustic Emission Testing Technology

Acoustic emission testing technology [5] can realize the real-time dynamic monitoring and testing of tank floor, which is a very widely used nondestructive testing technology in the field of testing pressure vessels. Installation of acoustic emission sensors on the tank wall and testing during a quiet period allows the user to determine if there is leakage or corrosion in the container. The acoustic emission detection technology includes sensors, preamplifiers, acoustic emission detection lines, acoustic coupling agents, acoustic emission acquisition system, analysis software AEwin and other parts.

Any fault or noise in the above acoustic emission components will have an adverse impact on the test results. Therefore, when the sensors are arranged on the tank wall, sandpaper shall be used to remove the rust and paint on the surface of the tank wall, so as to expose the metal on the tank wall and ensure its smooth surface. Then, acoustic couplant shall be evenly applied to reduce the friction between the sensor and the metal surface, so as to ensure the reliability of the data, as shown in figure 3. In this acoustic emission detection, 22 detection channels are evenly arranged around the storage tank along the circumferential direction, corresponding to 22 settlement observation points respectively. The acoustic emission acquisition system is shown in figure 4.

4. Test Data

4.1. Settlement Observation Results

“Vertical Cylindrical Steel Welded Oil Tank Operation, Maintenance and Repair Regulations” (SY/T5921-2017) points out that the height difference between any two points in every 3m arc length without ring wall should not be greater than 12mm. Therefore, by calculating the elevation difference between adjacent measuring points of the tank, the data of measuring points with an elevation of more than 12mm and the data of corresponding acoustic emission detection channel are selected for matching and comparison. It can further verify the influence of settlement on acoustic emission signal of tank floor. Four measuring points (measuring points 4, 6, 7 and 21) whose absolute value of elevation difference between adjacent measuring points is greater than 12mm are selected. The observation results of tank foundation settlement of these four measuring points at different liquid levels are shown in table 1.
Table 1. Settlement of storage tank (mm).

| Level/m | Point 4 | Point 6 | Point 7 | Point 21 |
|---------|---------|---------|---------|----------|
| 12.8    | 28.4    | 22      | 35.8    | 24.9     |
| 12.3    | 28.5    | 22.4    | 35.6    | 25.2     |
| 11.7    | 27.8    | 21.8    | 34.9    | 24.4     |
| 11      | 26.4    | 20.6    | 33.5    | 24.1     |
| 10.5    | 27.6    | 20.7    | 33.9    | 24.6     |
| 10      | 26.8    | 20.2    | 33.4    | 23.6     |
| 9.5     | 27      | 21      | 33.2    | 23.7     |
| 9       | 26.7    | 20.9    | 33.3    | 23.5     |

4.2. Acoustic Emission Test Results

The number of acoustic emission (AE) impacts [6] reflects the total amount and degree of AE activities, and refers to the total count of relevant signals that exceed the threshold value and make a certain channel obtain data. Therefore, the total AE impact number of all channels is selected as the characteristic parameter of acoustic emission signal in this test, and the change curve of total AE impact number of tank floor at different liquid levels is shown in figure 5.

![Figure 5. Total AE impact number of all channels.](image)

As can be seen from figure 5, with the continuous increase of liquid level, the total number of AE impacts also increases, which indicates that the acoustic emission activities of all channels are more frequent, and the corrosion condition of tank bottom plate will become worse. Therefore, it is suggested that the tank should be kept in low liquid level operation, and stop production for maintenance if necessary.

5. Analysis of Settlement and Acoustic Emission Test Results

In order to further verify the influence of tank settlement on acoustic emission signal of tank floor corrosion, the data of 4, 6, 7 and 21 settlement observation points and corresponding 4 acoustic emission detection channels were selected for comparative analysis. Ringing count [7] refers to the number of oscillations over the set threshold signal (40dB), which reflects the intensity and frequency of acoustic emission signal. Therefore, the ringing count of each channel is selected as the characteristic parameter to compare with the settlement. The results are shown in the figures below.
It can be seen from figures 6-9 that with the continuous rise of the liquid level of the tank, the settlement of each observation point under the corresponding liquid level also increases, the stress of the tank floor gradually increases, and the relevant characteristic parameters of acoustic emission of each channel will also change. Through data comparison and calculation, it is found that the settlement monitored by measuring point 4 accelerates the corrosion rate of the floor near this part by 1.26 times, the corrosion rate of the floor near measuring point 6 by 1.12 times, and the settlement of measuring point 7 is the largest, which accelerates the corrosion rate of the floor near this part by 1.34 times. The change trend of the corresponding channel ringing count is also the most obvious. The corrosion rate of the bottom plate near the measuring point 21 is increased by 1.16 times.

It can be seen that the greater the settlement of the tank, the greater the ringing count, and the faster the corrosion rate of the tank bottom plate [8]. Therefore, the uneven settlement of the tank should be fully considered in the safety protection of the tank.

6. Conclusions
Through the comparative analysis of tank settlement monitoring results and Corrosion Acoustic emission detection signals, the following conclusions are obtained.

(1) According to 5.8.1.1 of the standards (SY/T5921-2017), the foundation settlement of new tanks should be detected once a year within three years after they are put into operation; However, in the actual operation process of the tank, it is found that the tank settlement is rarely monitored, and the risk of settlement is not known. The blind operation leads to the lack of reference of settlement data in the process of acoustic emission detection of the tank, which leads to the inaccurate evaluation of acoustic emission [9].
(2) According to 5.8.1.1 of the standards (SY/T5921-2017), the settlement detection shall be carried out in combination with the overhaul of the tank after the tank has been put into operation for 3 years. In the actual production process, 80% of the tanks do not have the time or funds to carry out tank overhaul, which leads to the neglect of tank settlement observation, thus laying a hidden danger for the safe operation of the tank. It is suggested that regular observation time should be set after the tank has been used for three years, such as once every two years, which is not only conducive to the prevention and preparation of tank safety problems caused by settlement, it also provides reference for acoustic emission testing.

(3) In the actual acoustic emission detection process, the acoustic emission signal caused by settlement should be considered together, so as to improve the detection accuracy.

With the continuous change of the liquid level of the tank, the settlement of the tank floor increases, the corresponding floor stress also increases, the intensity and amplitude of acoustic emission detection signal increase, and the corrosion rate of the tank floor accelerates. In the process of tank evaluation, the contribution of stress to corrosion rate should be fully considered. At the same time, the tank management unit should increase the frequency of uneven settlement and on-line detection of tank bottom with large settlement to ensure the safe operation of the tank.

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