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Analysis and Experimental Study on Acoustic Emission Source Characteristics of Corrosion Process in Atmospheric Vertical Tank Bottom

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Abstract

The mechanism of acoustic emission signal from the corrosion in atmosphere vertical storage tank bottom was introduced; and the attenuation law of broken lead's acoustic emission signal within tank water was discussed, including the range of characteristic parameter values of corrosion acoustic emission signals from different mediums and the corrosion regulation, as well as the signal waveform characteristics received by the sensors in the water at different corrosion stages, this provides evidence to corrosion evaluation of the atmosphere vertical tanks.

Key words: Atmospheric vertical tank; Acoustic emission detection; Corrosion; Attenuation

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INTRODUCTION

As a modern nondestructive testing method, the acoustic emission (AE) detection is widely used, mainly because of its characteristics of high sensitivity, wide frequency response range and so on. The method can be used to detect and evaluate the corrosion of the tank bottom plate in the condition of the storage tank is not suspended and not fall down. The maintenance order of the storage tank is listed by the way of classification, which provides safety assurance for the inspection cycle, the best opportunity and the risk assessment of the storage tank. At present, this technology has been applied in the corrosion detection of the vertical tank bottom plate[1-2]. Normally, the bottom plate corrosion of the atmospheric pressure vertical tank includes uniform corrosion and local spot corrosion,uniform corrosion can cause the uniform reduction of bottom plate thickness, spot corrosion can lead to localized thinning or even perforation[3]. Spalling or friction of the corrosion product, the cracking of hydrogen bubbles produced by corrosion and the fracture of surface passivation film and so on, these situations can produce acoustic emission source[4]. Different from the defect propagation signal, in the process of corrosion average amplitude of acoustic emission signal is lower. Meanwhile, the propagation path of corrosion acoustic wave is not unique, which can be spread along the metal of tank bottom or along the medium in the tank (the shortest path). However, for large atmospheric pressure vertical storage tanks, if the central area of the tank bottom plate has the corrosion defect acoustic wave, no matter which path the acoustic wave propagate along, the attenuation amplitude is very large. Therefore, how to reflect the corrosion status of the tank bottom plate more comprehensively is a key point for the application of acoustic emission testing technology. At present, there are mainly two methods for the experimental study on the acoustic emission source characteristics of the bottom plate of the atmospheric pressure vertical tank. The first is adopting the method of hanging pieces, the metal test pieces are suspended in the corrosive liquid, partial or total corrosion acoustic emission detection is carried out, the characteristics of the acoustic emission source signals are extracted; the other is adopting the method of directly simulating the coupling sensor of the tank wall of the tank with the medium, and carry out the on-line corrosion detection. On this basis, the authors propose a new test method, which is puttingthe corrosion source into a small stainless steel storage tank with water. At the same time, a sensor is placed in the water of tank, and anarray of sensors is distributed around the tank wall near the bottom of the tank to receive the corrosion AE signal.

1. EXPERIMENTAL INVESTIGATION

1.1 Research Purposes

The attenuation law of pressing lead AE signal in the water of storage tank was researched by a methodcombined putting sensors in the water medium of tank with putting a array sensors around the tank wall near the bottom; compared the range of characteristics parameters and the corrosion law in different propagation medium; extracted the corrosion signal waveform characteristics received in different corrosion stages from sensors in the water medium.

1.2 Test System

Utilizing the SAMOS system manufactured byAmerica Physical Acoustics Corporation (PAC), the core of the system is the parallel processing of the PCI-8 sound transmitting function card with PCI bus, the type of the sensor is DP3I, working frequency range is 20~220 kHz, 40 dB gain, coupling agent is vacuum grease. The sample size is: 200 mm × 4 mm × 100 mm, the material is Q235 steel pipe, the upper part of the sample is connected with the PP-R pipe to make it contact with air, the flange welded on the bottom, which insert a piece of material for the Q235 blind plate to fixed. A certain amount of sulfuric acid solution (PH=2) is put into the steel tube, corrosion detection needs to continue for 15 hours. A small atmospheric pressure vertical storage tank was select to simulation. The device schematic diagram of corrosion source was shown in Figure 1.

50 mm away from the bottom of the tank, coupled with 6 sensors around the tank wall at the same distance, numbering 1# ~ 6#; coupling a sensor at the bottom of the tank, the number is 7#; coupling a sensor in the outer wall of the steel tube, the distance between sensor and the bottom of the tank is 50 mm, numbering 8#. At the same height as the 8# sensor from the bottom plate, put the 9# sensor into the water, the connection of sensor and signal lines should be sealed. In this device, the arrangement of the sensor is shown in Figure 2.

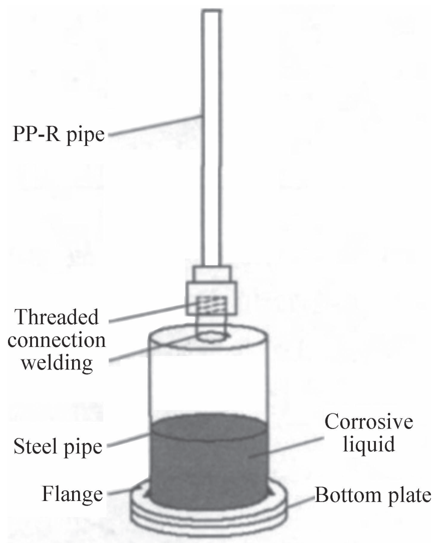


Figure 1
Schematic Diagram of Corrosion Source

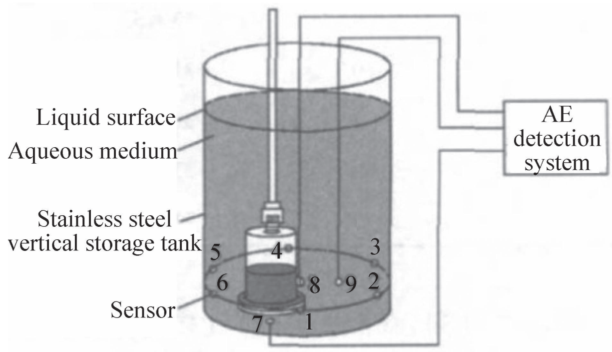


Figure 2
Sensor Placement

2. ANALYSIS OF TEST RESULT

2.1 Attenuation characteristic of pressing lead signal of water in tank

At the beginning of the corrosion test, the 9# sensor was put into water in the tank at position which is 50 mm away from the tank bottom. When the sensor is stable, each increase of 100 mm, find a point pressing leadat the bottom of the tank, pressing lead 3 times at each point, a total of 10 measuring points. Amplitude variation results are shown in Table 1.

Figure 3 is the variationcurve of signal amplitude with distance. The curve shows that the acoustic wave spreading in the water can reflected, so it has the echo characteristic. That is, the echo phenomenon (high amplitude signal in a short time) will appear after a certain distance, but the curve as a whole showed a downward trend. The signal amplitude is attenuated from 81 dB to 53 dB, and the attenuation loss is close to 28 dB, and the average attenuation of each 100 mm is 2.8 dB. Therefore, the method of acoustic emission detection that put sensors in the water of tank can be measured.

Table 1
The Amplitude Variation of Pressing Lead AE Signal Versus Distance

		Signal amplitude *A*/dB									
Distance *D*/mm		50	150	250	350	450	550	650	750	850	950
Times of pressing lead *n*	1	82	78	76	80	74	70	66	62	59	53
	2	81	81	77	78	72	67	68	64	58	55
	3	81	76	73	71	68	64	59	55	56	50
Average		81.3	78.3	76.0	76.3	71.3	67.0	64.3	60.3	57.6	52.7

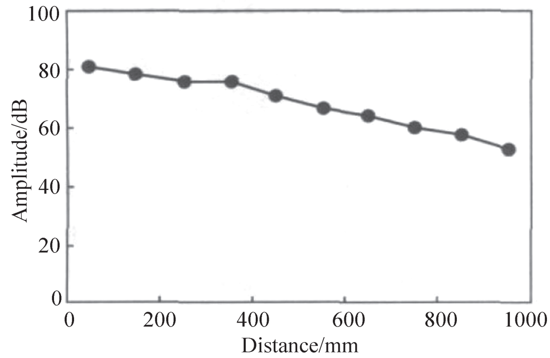


Figure 3
Attenuation Curve of AE Signal

2.2 Corrosion AE Signal Characteristics

2.2.1 Characteristic Parameter Analysis of Corrosion AE Signal

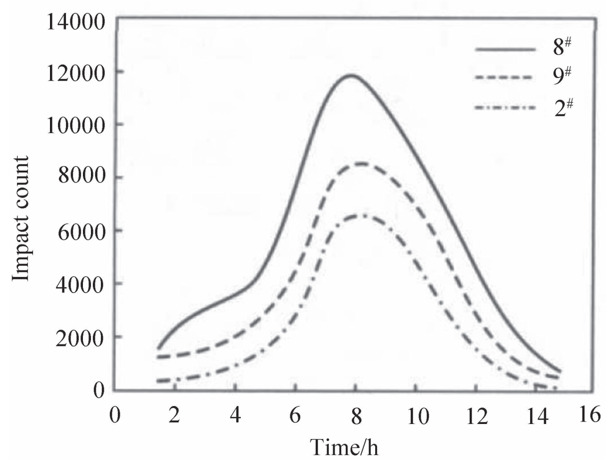
Table 2 lists the values of the various characteristic parameters of the AE signal received by the sensors in different stages of the corrosion.

Table 2
The Characteristic Parameters of AE Signal in Different Stages of Corrosion

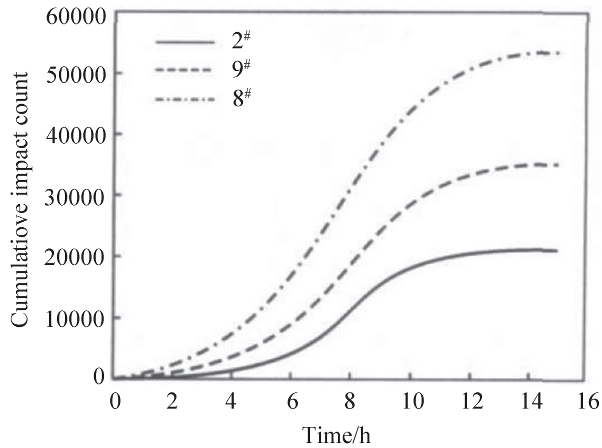
Corrosion stage	Sensor	Amplitude /dB	Impact count	Energy	Duration /μs	Risetime /μs
Corrosion incubation period	2#	30~37	569~1,926	1~9	2~47	1~30
	8#	33~49	1,548~3,443	4~110	13~340	1~326
	9#	31~41	1,123~2,301	1~47	1~692	1~271
Corrosion accelerated period	2#	30~41	1,926~4,031	3~18	3~51	1~37
	8#	33~53	3,443~10,282	4~139	13~369	1~333
	9#	31~46	2,302~4,108	3~57	4~705	1~281
Corrosion stability period	2#	30~40	122~4,031	1~13	2~51	1~32
	8#	33~52	441~10,282	2~119	13~352	1~329
	9#	31~43	187~4,108	3~52	1~695	1~277

From Table 2, we can see that in the whole corrosion process the amplitude of the signal, the number of impact and other parameters of the 9# sensor are significantly lower than the 8# sensor, and the 2# sensor is less than 9#. This is mainly because the signal received by the 9# sensor is transmitted by water. In this process, a part of energy is lost, and the signal amplitude is attenuated. And the signal attenuation amplitude of the 2# sensor which is coupled to the tank wall will be greater. The variation curve of corrosion AE signal impact count and the cumulative impact count is shown in Figure 4.

From Figure 4a we can see that the impact count is relatively less in the early period of corrosion. But with the increase of time, the number is increasing, and the impact of the signal reaches the peak value at the time of the corrosion of 11 h, subsequently, the signal begin to decrease and tend to be stable. Figure 4b shows that in the same time,In different media, the cumulative impact count of AE signal has the same trend versus time. But in the unit time, the received signal of cumulative impact count from the 8# sensor is higher than the 9# sensor, and the 9# sensor is higher than the 2#. According to the results of the test, the corrosion process can be divided into 3 stages:



a. Impact count rate



b. Cumulative impact count

Figure 4
Variation Curve of Corrosion AE Signal Characteristics Versus Time

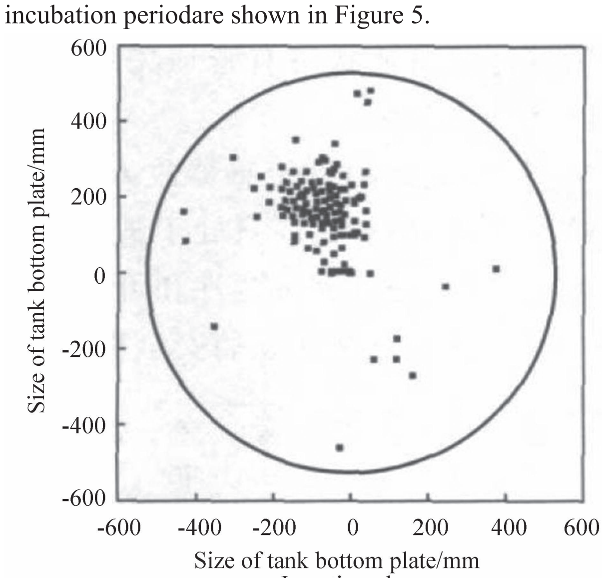
(a) Corrosion incubation period (0~4.5 h). This stage occurs in the initial stage of corrosion, no corrosion products were generated on the specimen surface, and the impact count is relatively less;

(b) Corrosion accelerated period (4.5~9.0 h). As the corrosion continues, the corrosion products aregenerated on the surface of specimen, and the impact count is increased obviously;

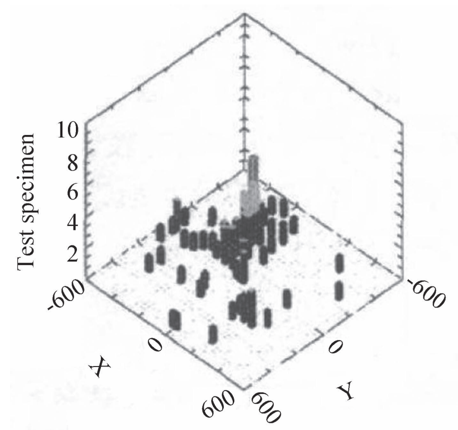
(c) Corrosion stability period (9~15 h). After 12 h of corrosion, because of the surface passivation of the specimen, the impact count began to decrease, but the corrosion continued.

2.2.2 Acoustic Source Localization Analysis Of Storage Tank Bottom

In this experiment, the simulated corrosion source is placed in the bottom of the tank, the distance between corrosion source and the center of tank bottom is 200 mm. The acoustic emission source characteristics of the corrosion process are studied by coupling sensor near the bottom of the tank and putting sensors in the water medium of tank. Theacoustic source localization of tank bottom diagram in corrosion incubation periodare shown in Figure 5.



a. Location plan



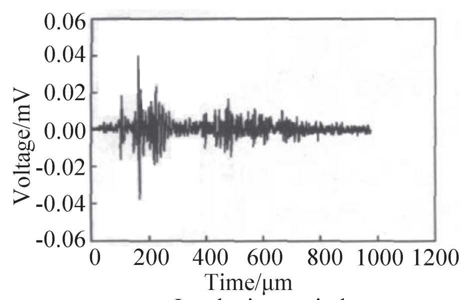
b. Location graphic model

Figure 5
Acoustic Source Localization of Tank Bottom

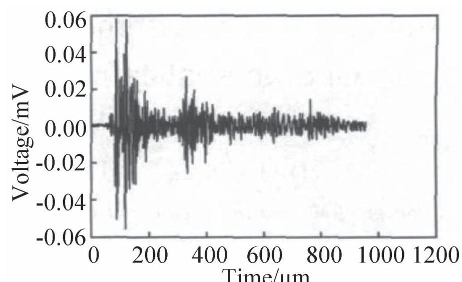
The positioning accuracy of the acoustic source localization technology for tank bottoms still has some limitations. Therefore, in the corrosion acoustic emission detection of the atmospheric pressure vertical tank, acoustic source localization is only a supplementary analysis method, but the results are still of considerable reference value. To a certain extent, the detection results can be predicted through it. From Figure 5, in the detection process of the first 4.5 hours there is a lot of positioning signal of the small stainless steel tanks used in this experiment. And the emergence of the phenomenon of location concentration, can reflect the corrosion condition of bottom corrosion region.

2.2.3 Acoustic Emission Signal Waveform Analysis

As the corrosion process is divided into 3 stages: incubation period, accelerator and stable stage. It is shown in Figure 6 in the 9# sensor in the water in the tank corrosion AE signal waveform characteristics of the received 3 different stages.



a. Incubation period



b. Accelerated period

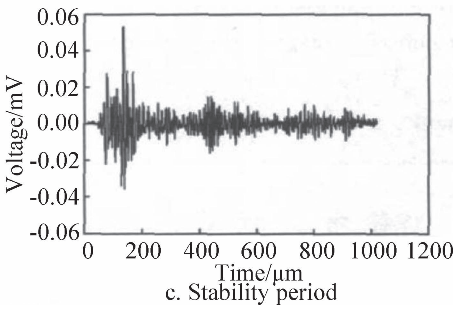


Figure 6
Waveform Characteristics of AE Signal in Different Corrosion Stages

From Figure 6, these 3 different stages of the corrosion AE signal waveform received by the sensor in the water of tank has the characteristic of burst signal, and exists multiple reflections. The signal amplitude of the acceleration phase is strong, the average 55 dB or so, and the energy is large; while the amplitude of incubation period and stability period are lower, the average is about 48 dB, and the energy is relatively less. This is due to the initial stage of corrosion, the surface of the specimen gathered more hydrogen bubbles, the rupture of hydrogen bubbles will produce AE source, but the impact count of AE signal acquisition is less, the signal amplitude is small. When the corrosion is more severe, a large amount of corrosion acoustic waves generated by the failure of the surface film and the corrosion of the spalling of corrosion product, AE signal impact count began to increase, the magnitude of the signal is also large. After 15 hours, as the corrosion product covered the surface of the specimen, the corrosion was stable, the impact of the acoustic emission signal began to decrease, and the signal amplitude was also decreased.

CONCLUSION

(a) The pressing lead AE signal spreading in the water has echo characteristic, the attenuation curve show a rebound phenomenon, but the overall trend is decreasing, and the average attenuation of each 100 mm is 2.8 dB. Therefore, the method of acoustic emission detection that put sensors in the water of storage tank can be measured.

(b) The signal characteristic parameters received by the 3 sensors are different in the range of values, but the variation trend of corrosion is consistent, and the corrosion process is divided into corrosion incubation period, accelerating period and the stability period.

(c) In the whole process of corrosion, the AE signal waveform received by the sensor in the water of tank has the characteristic of burst signal, and exist multiple reflections. The AE signal produced by the corrosion process is closely related to the corrosion state of the metal specimen, the severer the corrosion process is, the more AE signal will generate.

(d) In the paper, the author puts forward the method of on-line detection of acoustic emission in the tank, although it is only in the experimental stage, the test results show that this method is feasible and can provide a basis for the safety assessment of the corrosion state of the bottom plate of the vertical tank.

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