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Location Detection of Pipeline Corrosion Damage by Acoustic Emission Technology

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Abstract **Review Article**

In this paper, the acoustic emission instrument is used to collect the signal emitted by the steel pipe when it is damaged in electrochemical corrosion. Through the analysis and processing of the collected waveform signal data, the change law of the energy and effective voltage value of the steel pipe corrosion damage is obtained. It is found that the closer the sensor is to the serious corrosion area of the steel pipe, the more the number of impact, energy and effective voltage values is collected. The real-time dynamic detection of the steel pipe corrosion damage development process is realized. The results show that the acoustic emission technology can be used to detect the corrosion damage of steel pipe accurately.

Keywords: Acoustic emission instrument, Steel pipe corrosion, Damage location detection.

INTRODUCTION

Acoustic emission refers to the phenomenon of transient elastic waves caused by the rapid release of energy due to local damage [1, 2]. At present, the development of acoustic emission technology has been relatively mature and is mostly used in the damage detection of various components [3-5]. In recent years, many scholars have used acoustic emission technology to detect the leakage position of steel pipes [6]. Transmitting sensors were placed at the pipe nodes at both ends to collect the acoustic emission signal of the water leakage, and then the degree of leakage of the water pipe was determined [7]. Some scholars also proposed the application of multi-channel waveform acoustic emission detection system [8]. Yin et al. [9] adopted a new triangular time difference algorithm to realize the sound source localization of the two-dimensional panel. Han et al. [10] made use of the research on time difference positioning.The probe arrangement method of the sensor during actual measurement is given. Liu et al. [11] took the carbon fiber composite material board as the research object, studied the relative angle relationship between the acoustic emission source and the sensor array, and realized the acoustic emission source positioning in the carbon fiber composite board on this basis. Li et al. [12] used acoustic emission technology to detect the effectiveness of steel pipe pitting corrosion. Xu et al. [13] used acoustic emission technology to review the characteristics and generation mechanism of acoustic emission signals in the process of metal electrochemical rot, stress rot and candle rot under high temperature and high pressure water environment.

Based on the above discussion, in order to more accurately detect the damage location of the steel pipe, this paper uses the acoustic emission acquisition instrument to collect the signal emitted by the steel pipe in the case of electrochemical corrosion, and analyzes and processes the acoustic emission signal to convert the intuitive impact number, energy and effective value voltage The test data is used to obtain the position of the acoustic emission source, thereby realizing the location detection of the damage position of the steel pipe.

Detection principle

Principle of acoustic emission testing technology

When the acoustic emission system is used for structural damage detection, the damaged part of the component is used as the acoustic emission source and generates a corresponding waveform signal, which will produce vibration displacement on the surface of the material. The acoustic emission sensor installed on the surface of the component can collect this displacement and then the mechanical vibration is converted into an electrical signal, and the electrical signal is amplified by connecting the preamplifier for collection. Finally, the acoustic emission acquisition software is used to analyze and process the acquired waveforms to understand the damage of the components.

Three-dimensional positioning of acoustic emission sources

A three-dimensional coordinate is established and the time difference between T_0, T_1, T_3 and T_2 is measured with T_2 reference point. Assuming that the wave velocity of the acoustic emission signal in the three-dimensional space is a fixed value, the distance difference between the sound source and each sensor can be obtained according to the spatial geometric relationship equations, and then the relative spatial coordinates of the sound source can be calculated to achieve the purpose of damage location. The four sensors are located in the same spatial plane as shown in Fig.1. S is the position of the sound source. Suppose the coordinate of T_2 is (0,0,0), T_0 is (X_0, Y_0 ,Z_0), T_1 is (X_1, Y_1 ,Z_1) ,T_3 is (X_3, Y_3 ,Z_3), and S is (x, y, z), the distance difference can be listed as follows:

$$|ST_0|-|ST_2|=d_{02}$$
$$|ST_1|-|ST_2|=d_{12}$$
$$|ST_3|-|ST_2|=d_{32}$$

So there is

$$\sqrt{(x-x_0)^2+(y-y_0)^2+(z-z_0)^2}-\sqrt{x^2+y^2+z^2}=d_{02}$$
$$\sqrt{(x-x_1)^2+(y-y_1)^2+(z-z_1)^2}-\sqrt{x^2+y^2+z^2}=d_{12}$$
$$\sqrt{(x-x_3^{\,2})+(y-y_3^{\,2})+(z-z_3^{\,2})}-\sqrt{x^2+y^2+z^2}=d_{32}$$

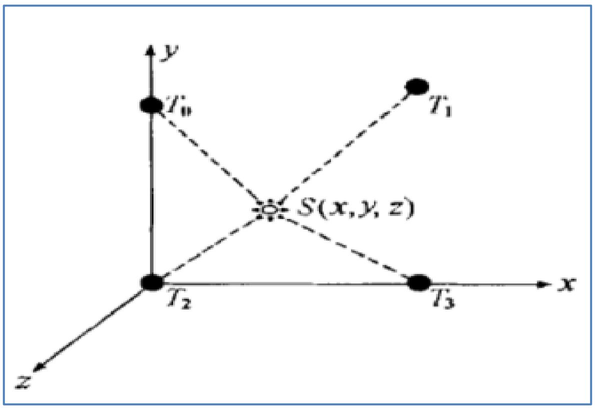

Fig-1: The position of the sound source and sensors

Test equipment

The test materials and equipment mainly include: Q235 steel pipe with a radius of 700m, a wall thickness of 5mm, and a height of 260mm. PS-305D electrochemical corrosion DC stable power supply, output current range 0-3A, the accuracy is 0.01A. The model is DS5-8A acoustic emission collector. It provides a preamplifier of 10KHz-1.2MHz. The test setup is shown in Fig.2.

Fig-2: Test device

Measurement of acoustic emission signal wave velocity of corroded pipeline

The measurement of wave speed mainly adopts the lead-breaking method, and the measurement scheme is shown in Fig.3. No. 1 and No. 5 sensors at 145mm and 235mm from the bottom of the steel pipe are placed respectively. Using a pencil lead (0.5mm HB) at 50mm between the No. 1 and No.5 sensors, three lead-breaking tests are performed on the surface of the steel pipe. Through the correlation analysis of the signal collected by the acoustic emission sensor, and at the same time, according to the signal received by the No. 1 sensor and the average wave speed, the calculated longitudinal wave speed is 5000m/s. Eight sensors are arranged in this experiment, and arrangement distance parameters are shown in Table 1.

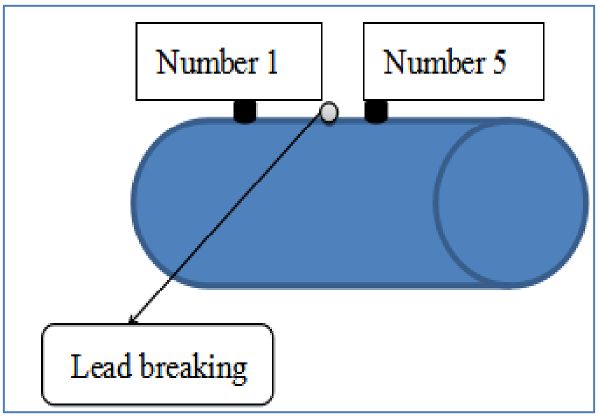

Fig-3: Sensor and lead-off position

Table-1: Position parameters of acoustic emission sensor and steel pipe

sensor	Height(mm)	Angle (°)	Radius (mm)
number 1	145	0	70
number 2	145	90	70
number 3	145	180	70
number 4	145	270	70
number 5	235	0	70
number 6	235	90	70
number 7	235	180	70
number 8	235	270	70

Electrochemical corrosion test plan

Taking the Q235 steel pipeline as the test object, from the bottom of the steel pipe to the position of 145mm as the corrosion area is measured. The steel pipe with the sensor is put in the Nacl solution, and the copper sheet connected to the electrochemical corrosion power supply is placed near the No.4 sensor. Then turning on the electrochemical corrosion DC power supply, the corrosion test starts. At the same time, an acoustic emission acquisition instrument is used to collect electrical signals generated by steel pipe corrosion. The electrochemical corrosion test lasts for 5 days, and the acoustic emission test also lasts for 5 days.

Test phenomenon and data analysis

Test phenomenon

Before the start of the test, the surface of the steel pipe was smooth without obvious defects. Putting the steel pipe into the Nacl solution, electrochemical corrosion started. The solution in the container did not change significantly on the first day of corrosion. Through continued corrosion, the solution began to turn reddish brown on the second and third days, indicating that the steel pipe had begun to be damaged by corrosion. On the fourth day, the color of the solution deepened and a small amount of impurities appeared on the surface of the solution.

Through observation, it was found that corrosives began to adhere to the outer wall of the steel pipe, indicating that the surface impurities of the solution were rust produced by the decomposition of ferrous hydroxide, a corrosion product of the steel pipe. Explain that the steel pipe is damaged by corrosion become serious. On the fifth day, the solution became very viscous. Some corrosion cracks were found in the steel pipe. Then, when the steel pipe was taken out after the corrosion was stopped, a large area of corrosion cracks was observed in the steel pipe. It shows that corrosion damage is particularly serious. The changes before and after the corrosion damage of the steel pipe are shown in Fig.4.

a Before steel pipe corrosion | b The steel pipe began to corrode the next day | c Corrosion on the fourth day | d After the fifth day

Fig-4: Damage before and after corrosion of steel pipe

Accumulated energy

Energy refers to the integral value of acoustic emission amplitude versus duration in an impact sound, which can reflect the relative energy and intensity of the event. According to Fig.5, it can get the energy range 0-450000 (mv*ms) collected by sensors No.1 to No.4, and the energy range collected by sensors No.5 to 8 is 0-210000 (mv*ms). From the energy range value, it can be preliminarily inferred that No.1 to No.4 sensors are close to the corrosion area. In addition, copper sheets are mainly placed near the No.4 sensor area in electrochemical corrosion. The corrosion rate is the largest and the energy released is the most.

Effective value voltage

The effective value voltage (RMS) is the integral value of the acoustic emission amplitude over the duration of an impact, which can well reflect the damage degree of the material. According to Fig.6, it can be seen that the cumulative effective value voltage range of No.1 to No.4 sensors is 0-21000 (mv), and the cumulative effective value voltage value range of No.5 to No. 8 sensors is 0-17000 (mv), which is also explained according to the voltage value range. The damage degree of the steel pipes near No.1 to No.4 areas is greater than that of No.5 to No.8 areas. In particular, the effective value voltage collected by channel 4 is significantly larger, which further shows that the corrosion degree of No. 4 area is the most serious, which is consistent with the result of the serious corrosion of the steel pipe caused by the placement of copper in the No.4 area. At the same time, according to the histogram, it can be observed that the energy and effective voltage (RMS) trends corresponding to the 8 channel numbers are basically the same. From the maximum energy and RMS voltage quotas of channel 4, it can be judged that the corrosion damage of area 4 is relatively serious.

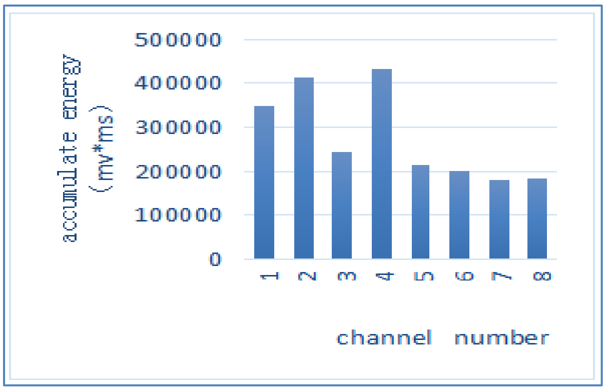

Fig-5: Cumulative energy diagram

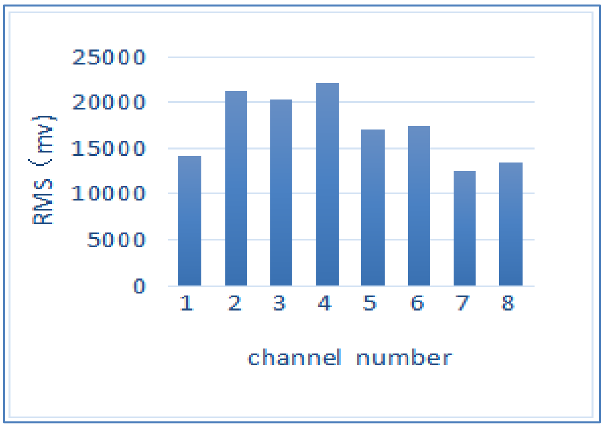

Fig-6: Cumulative effective value voltage

Cumulative number of impacts

The cumulative curve of the number of impacts reflects the change in the corrosion rate of the pipeline during the test. Therefore, two representative channel numbers, No.4 and No.7, were selected near the corrosion area and relatively far from the corrosion area, and the cumulative impact number and time curve were compiled. As shown in Fig.7.

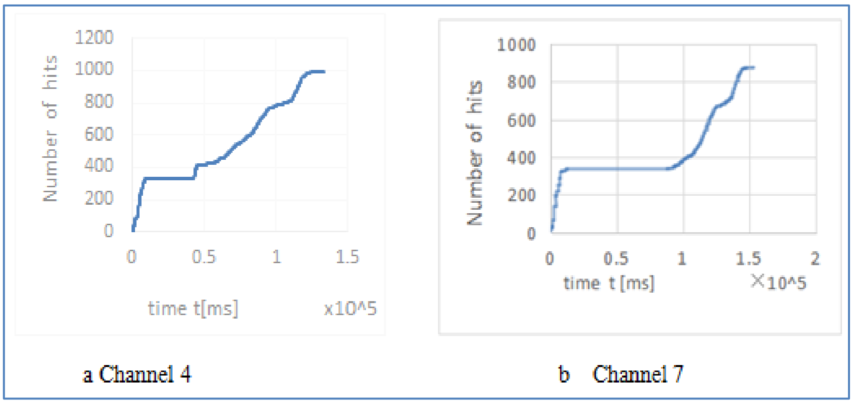

Fig-7: Curve of cumulative number of impacts and time

According to the detection chart in the acoustic emission analysis software, the steel pipe near the No.4 sensor area is more severely damaged, which is consistent with the actual steel pipe damage location, as shown in Fig.8.

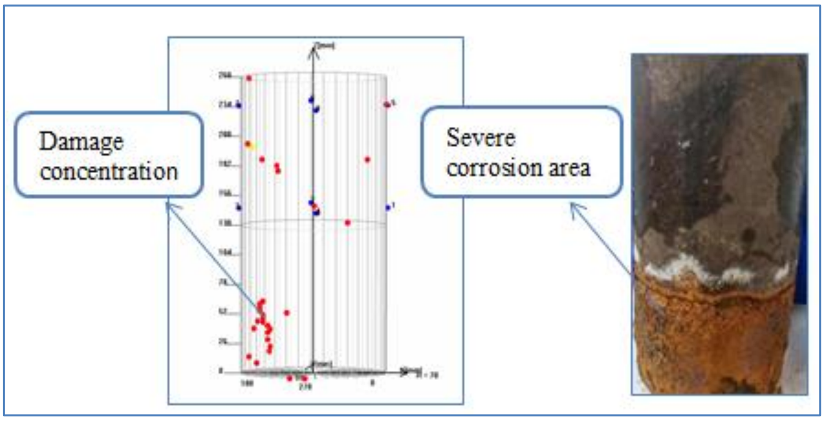

Fig-8: Acoustic emission location results of steel pipe corrosion damage test

CONCLUSION
The test of electrochemical corrosion damage location of steel pipes shows that the location of the acoustic emission source can be effectively located by analyzing and processing the accumulative count of acoustic emission, energy and effective value voltage. This has certain guiding significance for the application of acoustic emission technology in actual engineering to detect the health of components.

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