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Research Article

Research on the Propagation of Acoustic Signal and Attenuation Change Law of Gas Pipeline Double-Point Leakage

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In order to better model the acoustic signal propagation and attenuation of pipeline leaks, a laboratory gas pipeline leak detection platform taking air as the experimental medium is hereby adopted to investigate the law of hole spacing on acoustic signal propagation and attenuation at different pressures for double-point leaks. The results show that in the case of a fixed pressure, the amplitude of the three hole spacing in the propagation along the pipe decreases gradually, while that near the leak point decreases the most, with a maximum difference being up to 90%, after which the difference gap between the amplitude is gradually narrowed; different hole spacing has little effect on the RMS voltage along the downstream of the double-point leak pipe but exercises a greater effect on the RMS voltage propagation between the double-point leak; the attenuation coefficient of the leak signal decreases generally with the distance, which generally becomes smaller with the increasing distance and that along the downstream of the pipeline and near the leakage point decreases the most in the case of the double-point leakage, with a decrease rate reaching close to 50%. Then, the decrease rate becomes smaller gradually and reaches close to 20%, while that of the attenuation coefficient of the two distances between the three sensors is relatively close for the double-point leakage, with the first section close to 50% to 60% and the second section close to 60% to 80%. Under the condition where the pressure is different and the hole spacing remains the same, the acoustic signal increases with the increasing pressure when the attenuation coefficient decreases.

1. Introduction

The efficient exploration and development of natural gas in China has gradually sent natural gas into millions of households. By the end of 2020, about 86,000 km of natural gas pipelines had been built in China, and the total mileage of natural gas pipelines to be renewed or started in 2020 and completed in 2021 is expected to be 3,050 km, with the construction trend still remaining positive. Besides, statistics reveal that the apparent consumption of natural gas in China was 324 billion cubic meters in 2020, with an increase of 5.6% year-on-year. There are many old pipelines in the existing operation in China, some of which are rusted and thinned and overlapped with the city's pipeline network, thus posing severe safety hazards. To this end, the study of acoustic wave propagation law can determine the effective propagation distance of acoustic waves and then reasonably arrange the sensor location, so as to provide technical support for the engineering application of the acoustic wave method [1]. Therefore, a lot of research on the acoustic wave propagation law and attenuation of gas pipeline leaks has been conducted both domestically and overseas. For the study of acoustic wave propagation laws in gas pipelines, Hunaidi and Chu [2] studied the acoustic wave characteristics of leak signals in plastic water pipelines and included the characteristics of the acoustic wave spectrum or the vibration signal as a function of the type of leakage, the flow rate, the pipe pressure, the time period, the determination of the decay rate, and the variation of the propagation velocity. Kim and Lee [3] obtained the cutoff frequency of the acoustic wave of the pipeline system using the experimental method of time-frequency joint analysis and the boundary element method and figured out the propagation characteristics of the acoustic wave in the pipe. Mostafapour and

Davoudi [4] simulated the acoustic signals generated by the pipeline vibrations caused by leaks, recorded the pressure waves propagating through the pipe wall using sensors installed on the pipe wall, studied the propagation law of acoustic waves, and analyzed the effectiveness of the acoustic wave propagation theory for leak monitoring of high-pressure natural gas pipelines through theories and experiments. Li et al. [5] studied a combination of principles of fluid mechanics and Lighthill acoustic analogy theory to derive the three-dimensional transient leak acoustic wave propagation equations, and theoretical simulations of water pipeline leak noise propagation were conducted as well. Brennan et al. [6] carried out an analytical, numerical, and experimental study on the effect of soil properties on the propagation of buried plastic water pipe leakage noise. Cuiwei Liu et al. [7] established and modified oil and gas pipeline leakage propagation models using experimental methods. Hao et al. [8] simulated the effects of various factors on infrasound propagation based on computational fluid dynamics and acoustic theory using the COMSOL software. Guo et al. [9] explored the law of pressure wave propagation and attenuation in the case of pipeline leakage by building a pressure wave pipeline test system, exciting the pressure wave, and analyzing its first wave amplitude characteristics by virtue of mechanical shock. Taking into account the effects of media viscous absorption and heat conduction and the absorption of special fittings (bends, branches, and reducers), Meng et al. [10] developed a model for the propagation of leaky sound waves in pipes. The wavelet analysis method was improved to analyze the time-frequency domain characteristics of the leakage sound wave signal, simulate and analyze the influence of different special fittings on the sound wave propagation, and verify the established propagation model using a high-pressure leakage test device. The acoustic properties of acoustic emission waves in pipes under liquid loads were analyzed by Sun et al. [11], and the propagation and attenuation characteristics of several different modes of acoustic emission waves in steel pipes were measured in liquid pipes.

For the study of acoustic wave attenuation laws in gas pipelines, Barabanov and Glikmna [12] obtained the experimental measurement results of the attenuation coefficient of the acoustic wave propagation in oil and refined oil pipelines and proposed an approximate dependence of the attenuation coefficient on the flow dimensionless parameters. In order to accurately identify the location of the leaks, a leak location localization algorithm based on negative pressure wave attenuation was proposed by Li et al. [13]. Liu et al. [14] established an acoustic wave amplitude attenuation model in viscous homogeneous flow media, with gas flow, turbulence effect, and viscous heat effect considered, and verified the accuracy of the model by experiments. Wen et al. [15] simulated water supply pipes for pipe leak detection experiments and experimentally demonstrated that the attenuation characteristics of leak acoustic waves can be used to locate leaks in metallic water pipes. Zhang [16] studied the relationship between the attenuation coefficient and metal grain scattering and heat flow loss for the attenuation of acoustic emission waves generated by leaks propagating along the pipe wall and established an accurate model of acoustic emission energy attenuation. Liu et al. [17] investigated the wave propagation attenuation characteristics of liquid-filled steel pipes and PVC plastic pipes in elastic media. Liu and Yuan [18] analyzed the attenuation of signals at different frequencies in the pipe, plotted the amplitude-frequency characteristic curve of signal transmission in the pipe, and concluded that the signal in the pipe presents a fluctuating attenuation with the increase of the frequency.

Many studies on pipeline leakage prefer a single hole, but once leakage occurs, the situation is complicated. Although considerable research on multipoint gas pipeline leakage has currently been conducted, the main focus is placed on signal processing methods and simulation. Based on this, the laboratory leakage detection platform is hereby used to study the small hole leakage caused by corrosion in the gas transmission pipeline and explore the propagation and attenuation changes of the two-point leakage acoustic signal under different pressures, so as to forge a theoretical foundation for the new gas transmission pipeline leakage detection and positioning technology. The research results of this paper, in the actual detection, can help better understand some situations of gas pipeline leakage and can also provide theoretical guidance and a basis for the characteristics of water supply pipeline leakage acoustic signal and the identification of leakage conditions.

2. Theory of Sound Wave Propagation and Attenuation

The attenuation of acoustic waves refers to the phenomenon that the energy of acoustic waves gradually decreases with the increase in propagation distance during the propagation of the medium [19]. Under the leaking state, gas is ejected from the leakage port to the outside of the pipe, and the interaction between the gas and the pipe wall produces an acoustic emission source to radiate energy outward and form a pressure wave propagating along the pipe. Sound waves propagate in the medium, and the attenuation equation [20] can be expressed as follows:

$$P = P_0 e^{-\sigma \alpha x}, \tag{1}$$

where x denotes the acoustic wave propagation distance, m; P_0 is the sound wave amplitude at the leak point, P_a; P is the corresponding propagation distance x at the sound wave amplitude, P_a; σ is the correction factor, used to correct the difference in the pipeline medium, 0.5~1.5 for gas pipelines; and α is the viscous heat absorption coefficient, used to characterize the attenuation of acoustic intensity caused by viscous absorption and heat conduction. According to the literature contents of Chi et al. [20], the correction coefficient is only a range without a clear value. Therefore, in order to avoid the influence of the difference in the value of the correction coefficient on the results, the correction coefficient σ and the viscothermal absorption coefficient α are combined, that is, the product of the two coefficients is hereby taken as the acoustic attenuation coefficient.

Equation (1) indicates that the sound wave propagates downstream, and that the two downstream sensors correspond to the propagation equations as shown in equations (2) and (3).

$$P_1 = P_0 e^{-\sigma\alpha x_1}, \tag{2}$$

$$P_2 = P_0 e^{-\sigma\alpha x_2}, \tag{3}$$

where P_0 refers to the acoustic signal amplitude at the leak point, mV; (formula (1) in the sound pressure for the pressure value, the amplitude of the experimental equipment obtained for the time domain amplitude of the acoustic signal, so the time domain amplitude of the acoustic signal instead of the pressure value is hereby adopted for the calculation); x_1 and x_2 are the two sensors downstream to the leak point distance, m; P_1 and P_2 are the values measured by the sensor acoustic signal amplitude, and mV; and $\sigma\alpha$ is the attenuation coefficient. The attenuation coefficient can be obtained from the sensor amplitude ratio, i.e., equation (2) divided by equation (3):

$$\frac{P_1}{P_2} = e^{-\sigma\alpha\left(x_1 - x_2\right)}. \tag{4}$$

We transform the formula to obtain

$$\sigma\alpha = -\frac{\ln\left(P_1/P_2\right)}{x_1 - x_2}. \tag{5}$$

As can be seen from equation (5), the value of the attenuation parameter can be calculated as long as the amplitude of the acoustic emission sensor at the measurement point and the distance between sensors are given.

3. Pipeline Leakage Test Experiment

3.1. Experimental Setup. The gas pipeline leakage experimental platform on the first floor of the laboratory is used for the acoustic test of the two-point leakage of the annular pipeline. Considering the safety problem, air, instead of natural gas, is used as the experimental medium [21]. The structure of the experimental system is shown in Figure 1, which consists of a gas source control module, a data acquisition module, and an annular overhead pipe module.

The gas source control module consists of air compressor, filter, cooler, gas storage tank, pipeline, and electric ball valve. The maximum supply pressure of the air compressor is 3.0 MPa, and the design pressure of the gas storage tank is 3.0 MPa. The data acquisition module is mainly composed of the main control room, INV3062 type distributed data acquisition instrument, and acceleration sensors. Six sensors are used for the experiment, which are arranged upstream and downstream and near the four leakage holes as shown in Figure 2. The diameter of the leak hole is 0.8 mm, and the locations of the four leak points are indicated by A, B, C, and D, respectively. The upstream and downstream sensors are labeled as No. 1 and No. 6, while the rest are No. 2, No. 3, No. 4, and No. 5 in turn, with the upstream No. 1 sensor as the standard, and the distance between each of the remaining sensors and No. 1 sensor is shown in Table 1.

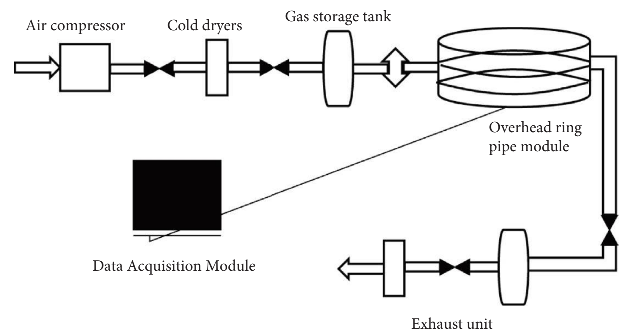

Figure 1: Diagram of the experimental system structure.

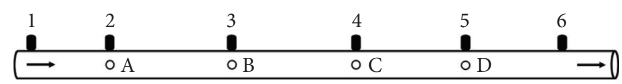

Figure 2: Diagram of the sensor arrangement structure.

Table 1: Distance of each sensor from sensor No. 1.

Sensor serial number	Distance to sensor No. 1 (m)
2	2.02
3	21.13
4	40.24
5	59.35
6	67

The overhead annular pipe is a long annular pipe, consisting of a DN125 steel pipe with a diameter of 140 mm, a leakage device, and a solenoid valve. The physical diagram of the pipeline and the location of the leakage hole is shown in Figure 3.

3.2. Experimental Steps. The experimental procedure for double-point leakage in gas pipelines is specified as follows [22]:

(1) Turn on the main control computer and the power of the pipeline and check whether the solenoid valve in the pipeline is closed.

(2) Test the gas tightness of the device, then connect the sensor to the data acquisition system, and open the safety bleed valve at the end of the pipe.

(3) Open the air compressor to fill the storage tank until it reaches a slightly higher pressure than the experimental pressure and then close the air compressor and adjust the pressure reducing valve to achieve the required pressure for the experiment.

(4) Open the pipeline solenoid valve from the main control room, adjust the pressure reducing valve from low to high every 0.2 MPa after the gas in the pipe is running stably, and then collect the data. In order to simulate the real pipeline leakage working condition, open the valve at the two leakage points as fast as possible and record the change pattern of each parameter in real time.

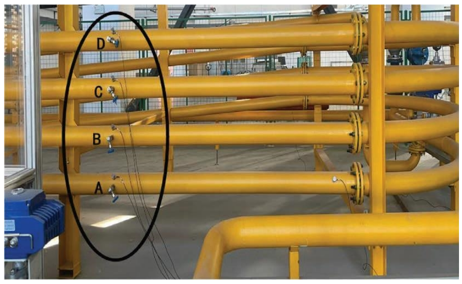

Figure 3: Physical view of the annular pipe and leak hole location.

(5) Close the valve at the two points of leakage and start the next set of experiments when the gas in the tube is running stably. Repeat the above process until all experimental conditions are met.

To reduce the experimental error, each group of experiments is repeated five times with a sampling rate of 100 kHz and 10 seconds per acquisition. Factors affecting the gas leakage characteristics of the pipeline are the leakage pressure and the leakage hole spacing, respectively. In this experiment, the leak pressure is 0.2, 0.4, 0.8, and 1.0 MPa, and the leak hole spacing is 19.11, 38.22, and 57.33 m, respectively.

4. Analysis of Experimental Results

4.1. Experimental Background Noise. Background noise refers to all disturbances that are not related to the desired leak acoustic wave in the process of measuring the leak acoustic signals, such as the interference from equipment operation and human behavior activities in the laboratory [19]. When the gas in the tube is flowing steadily and the leak hole is not opened, the collected acoustic signal is regarded as background noise. The time-domain diagrams [23] of the background noise acoustic wave and the leakage acoustic wave are shown in Figures 4 and 5, and the signal measured by sensor No. 2 at 0.4 MPa is selected here.

Sound is a continuous wave that propagates through a certain medium, also an analog signal that changes continuously with time, which is known as sound wave in physics. Figure 6 reveals that the acoustic signal is continuous with the continuous change of time, the time-domain waveform is stable, and the subsequent experimental data are effective. The time domain maximum value of the background noise is 0.0154 m/s^2, while that of the leakage signal is 0.8707 m/s^2, with a difference of nearly two orders of magnitude between the two values.

4.2. Propagation Law of the Double-Point Leakage Acoustic Signal in Pipelines. Time domain amplitude generally refers to the maximum magnitude of the signal in the time domain, which is commonly used for the type identification of wave sources, intensity, and attenuation measurements [24]. By extracting the maximum amplitude of the time domain waveform graph, the variation law of its relation to the propagation distance under different leakage conditions can be obtained. For continuous acoustic signals, a more in-

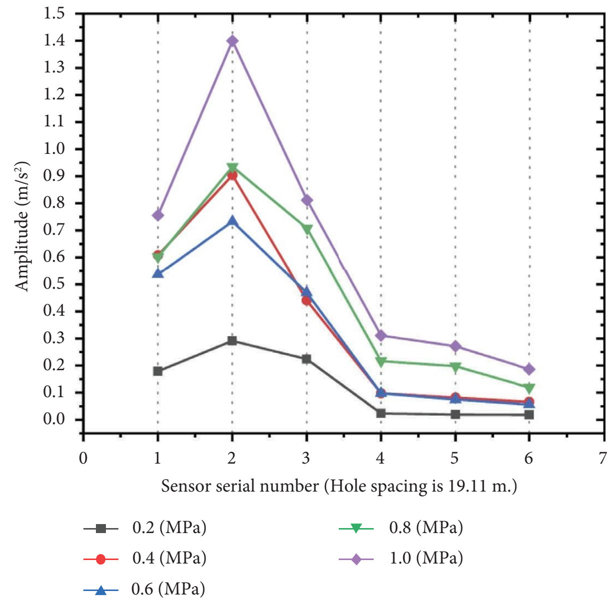

Figure 4: Variation of the amplitude of A and B leakage with the distance under different pressures.

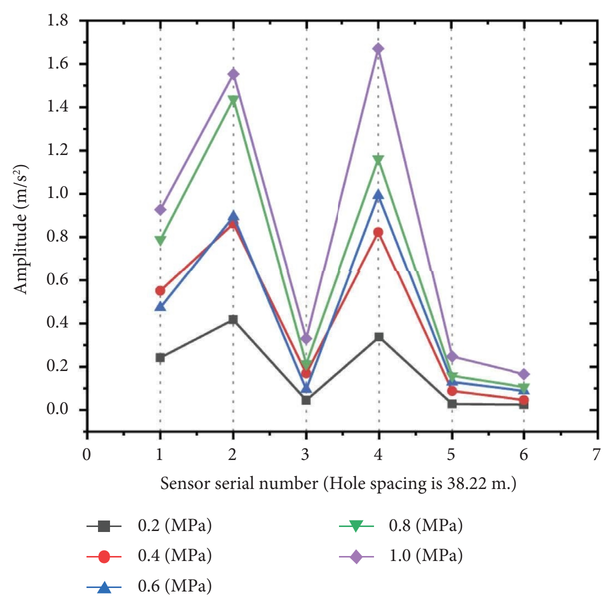

Figure 5: Variation of the amplitude of A and C leakage with the distance under different pressures.

depth study of the propagation law of the acoustic signals of double-point leaks in pipelines based on the rms voltage (RMS) can be performed from the energy perspective.

4.2.1. Pipeline Double-Point Leakage Sound Wave Amplitude Propagation Law. After several measurements, the maximum amplitude of the acoustic signal measured by six sensors (the maximum amplitude here is the average of the corresponding values of each sensor measured five times at each pressure) with different hole spacing and double-point leaking at the same time but at different pressures, the

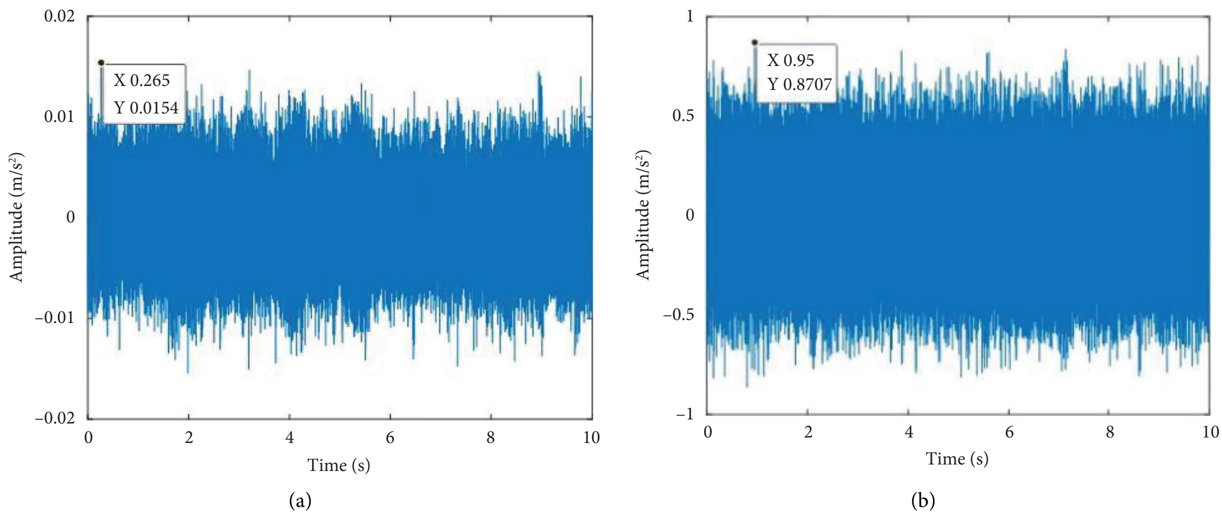

FIGURE 6: Time domain diagram of acoustic signals with no leakage and leakage at 0.4 MPa. (a) Acoustic signal without leakage. (b) Acoustic signal with leakage.

maximum amplitude values under different working conditions are processed into dotted line plots using origin software, as shown in Figures 4–7.

Figures 4–7 indicate that in the case of different pressures, the sound wave amplitude increases with the increase in pressure. The amplitude under 1 MPa is always at the top, indicating that it is always the largest, while the remaining four pressure conditions of the sound wave amplitude are basically in line with the decreasing order. In the case of a certain pressure and hole spacing, the amplitude of the acoustic signal in the pipeline gradually decreases with the increase in distance, which finally tends to be stable, and the acoustic signal near the leakage point is greater than that at the nonleakage point. Under the three working conditions, the attenuation amplitude of the leakage signal at the nearest point (No. 2) and the signal amplitude at the leakage point (No. 3) are the largest. This phenomenon is most obvious when pressure is 1.0 MPa, and the amplitude difference between adjacent biggest can reach 6.7 times, visible on the pipeline leakage acoustic signal transmission attenuation speed, which is attributed to the huge leak point momentum change. The extrusion vibration of air inside and outside the tube wall is strong, but this phenomenon is not obvious at a distance.

It can be observed from Figure 4 that when A and B leak at the same time, the hole spacing is 19.11 m, and the same point in the pipe sensor measures acoustic wave amplitude as the pressure increases, basically for the upward trend. However, these two curves appear different at 0.4 and 0.6 MPa pressure. Li et al. [21] suggest that the number of cycles of particle vibration per second in the acoustic wave field is called frequency, and each vibration has a specific response frequency. At the leakage point A, which corresponds to sensor No. 2, the acoustic signal amplitude of 0.4 MPa is greater than that of 0.6 MPa. The reason is inferred from the fact that when the pressure rises from 0.2 MPa to 0.4 MPa, the pressure reducing valve controls the unstable gas flow and enhances a certain frequency in the

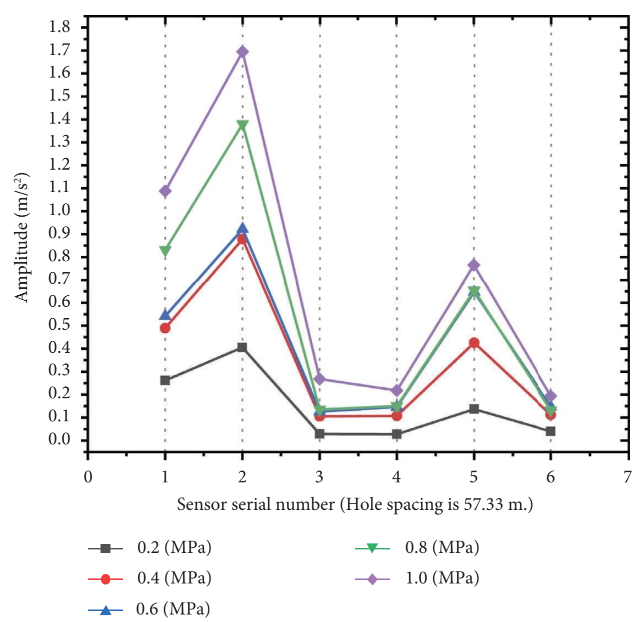

FIGURE 7: Variation of the amplitude of A and D leakage with the distance under different pressures.

signal. Under sensor No. 2, this frequency plays a dominant role in the signal, thereby resulting in the experimental phenomenon of an excessive increase in the amplitude of this point. In the subsequent propagation of acoustic signals along the pipeline, the attenuation trend tends to be 0.6 MPa, but there are still signs of regression below 0.6 MPa.

Figure 5 reveals that when A and C leak at the same time leakage, the hole spacing is 38.22 m, and the two points in the middle of the sensor 3 correspond to the amplitude compared with the sensors 2 and 4. There is a cliff-type attenuation, and 0.4 MPa under the amplitude is greater than 0.6 MPa under the amplitude, which may be attributed to the fact that the acoustic signal leaks at point C along the pipe propagation back to the 3 sensor, thereby causing a superposition of signal amplitude and two differences of 0.0738 m/s^2. In sensors 2 and 4, the sensors correspond to the sizes of the two measured values at the leak point, and there is no rule, which is mainly caused by the difference in the amount of leakage at the leak point.

Figure 7 indicates that when A and D leak, the hole spacing is 57.33 m, and the amplitude near the leak point is generally greater than the measured acoustic signal amplitude away from the leak. However, in the leak between the two points of the two sensors 3 and 4, the amplitude of the acoustic signal measured by sensor 4 is greater than the value measured by the sensor 3 at 0.4, 0.6, and 0.8 MPa, which may be attributed to the annular overhead pipe leakage of acoustic signals along the upstream and downstream propagation of the pipeline. Along the downstream pipeline, the acoustic decay rate is slightly faster than that of the acoustic signals upstream, so there is a slight superposition of the previous sensor's acoustic signal, and the measured amplitude of the No. 4 sensor will have a small upward trend, slightly higher than the acoustic signal measured by the No. 3 sensor.

4.2.2. Pipeline Double-Point Leakage Acoustic Wave RMS Voltage Propagation Law. The root mean square (RMS) voltage is applicable to continuous acoustic signals and can demonstrate the energy of acoustic signals, which means that by observing their numerical changes, the acoustic propagation pattern can be obtained. The RMS voltages under different operating conditions are represented in Figures 8–10.

The analysis of the propagation law of the RMS voltage (RMS) at the double-point leakage of the pipe is conducted under different hole spacing conditions. As shown in Figures 8–10, the RMS voltage of the signal propagation along the pipeline based on three types of double-point leaks with hole spacing generally decreases gradually with the increasing distance, and the energy values at points 2, 3, 4, and 5 are basically much larger than those at places where no leaks occur. However, given that the gas flow upstream of the corresponding pipeline at No. 1 is intense and superimposed on the acoustic signal propagated along the upstream of the leak at No. 2, the energy values at points 3, 4, and 5 are smaller than those at No. 1 where no leaks occur. Comparing the three plots, it can be noticed that the increase in hole spacing exercises less effect on the signal propagation along the pipeline and more effect on the signal propagation between the double points. When the hole spacing is 19.11 m, as shown in Figure 8, the RMS voltage measured by sensors 1 and 2 at a pressure of 0.4 MPa appears larger than that measured at a pressure of 0.6 MPa, which is mainly attributed to the fact that the airflow velocity is not a single value during the experiment, and the average value used in the theoretical calculation has individual error points. Similarly, the same situation can be observed for the other two hole spacings for this very reason.

Figures 9 and 10 show that the RMS voltage variation propagated between the double points also increases with the pressure and decays with the increasing distance.

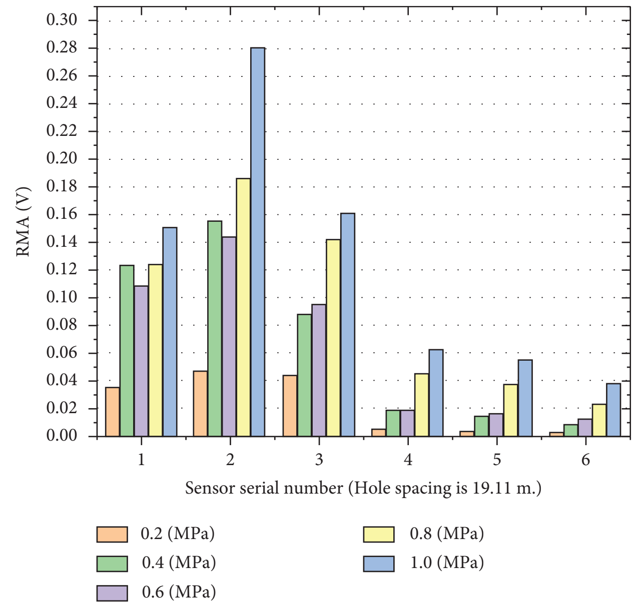

Figure 8: Variation of the leakage acoustic signal RMS value of A and B leakage with the distance under different pressures.

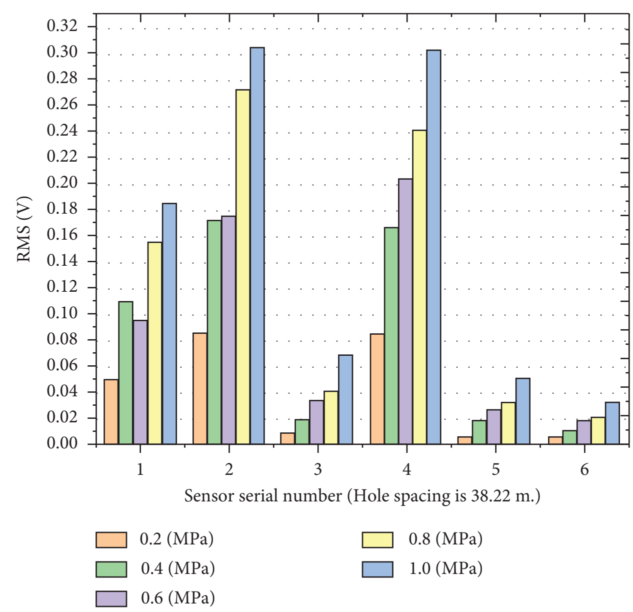

Figure 9: Variation of the leakage acoustic signal RMS value of A and C leakage with the distance under different pressures.

Figure 9 indicates that in the case of a small hole spacing, the RMS voltage measured between the double point leakage is generally greater than the RMS voltage measured when the hole spacing is larger as shown in Figure 10. The reason inferred for the two sides of the leakage point sound waves in the middle of the double point superposition is not the same, and the former is caused by the closer hole spacing, which leads to faster energy propagation and reduced decay.

Analysis of the propagation law of the RMS voltage at double point leakage of the pipeline is carried out under different pressure conditions. It can be seen from

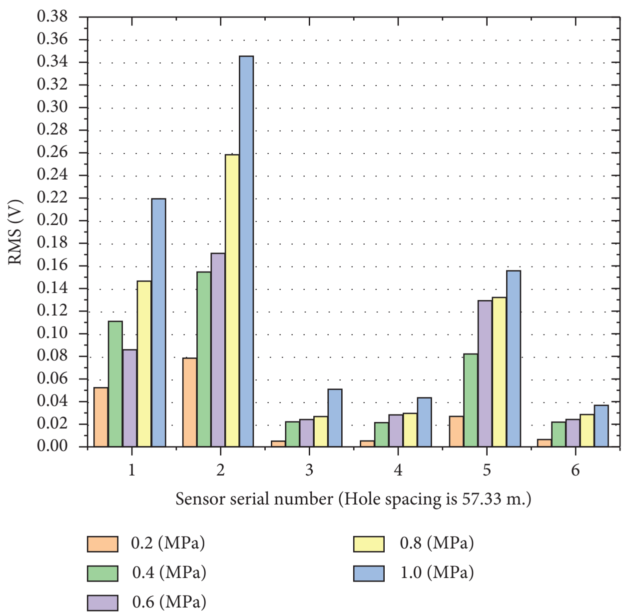

Figure 10: Variation of the leakage acoustic signal RMS value of A and D leakage with the distance under different pressures.

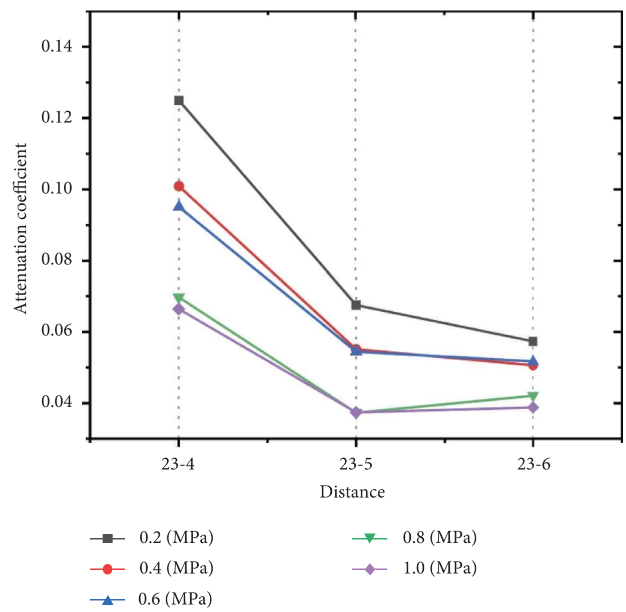

Figure 11: Variation of the attenuation coefficient along the downstream of A and B leakage under different pressures.

Figures 8–10 that the energy along the pipeline increases with the increase of the pressure, with a greater change in the pressure indicating a greater increase in energy value decay. The energy value is relatively low at a pressure of 0.2 MPa along the pipeline at each point, when the signal propagation law changes are not obvious. The reason is inferred that the pressure value is too small under this condition and that the gas collision with the wall of the pipe excited by the sparse shock wave is small; thus, causing the sensor to receive a weak signal that is annihilated in the noise signal and thereby affecting the energy calculation results.

4.3. Pipeline Leakage Acoustic Signal Attenuation Coefficient Change Law. According to the time domain amplitude under different leakage conditions, the attenuation coefficient of the leakage acoustic wave is calculated to analyze the change law of the acoustic wave attenuation coefficient under different leakage conditions [25] as shown in Figure 11. The acoustic attenuation coefficient reflects the degree of energy loss of acoustic waves on the pipe, and acoustic energy can be expressed by the amplitude, thus justifying the reasonability of calculating acoustic attenuation by amplitude [25]. Besides, the acoustic attenuation coefficients under different operating conditions are calculated using the acoustic attenuation calculation method introduced in the previous paper.

4.3.1. AB Point Leakage Acoustic Signal Attenuation Coefficient Change Law. A and B are 19.11 m apart, and the AB section leakage amplitude is taken as a weighted average of the amplitude of No. 2 and No. 3 [26], and the sensors along the downstream of the AB leakage section correspond to No. 4, 5, and 6. The calculated values of the attenuation coefficients are plotted as shown in Figure 11.

Figure 11 shows the acoustic wave propagation along the pipe attenuation coefficient decreases with the increasing distance, and the amplitude curve change is not the same. When the pressure is higher, the amplitude curve is higher, but the attenuation coefficient changes on the contrary, and the attenuation coefficient curve is lower with the increase of the pressure. When A and B leak at the same time, and the acoustic signal attenuation amplitude of the leak near the sensor, i.e., the distance from sensor 4 to sensor 5 in Figure 11 is the largest, the acoustic signal attenuation amplitude basically reaches nearly 50%. The acoustic signal attenuation amplitude in the sensor 5 to sensor 6 measured in this section is basically less than 20%.

The values under the pressures of 0.4 and 0.6 MPa are rather close at 23-5, and the decay coefficient of 0.6 MPa is slightly larger than that of 0.4 MPa at 23-6. This phenomenon is more obvious at 0.8 and 1.0 MPa, which is related to the amplitude ratio. Additionally, amplitude superposition can be found here from the above analysis, making the calculated value slightly larger.

4.3.2. The Variation Law of Acoustic Signal Attenuation Coefficient between Double Point Leakage. The sensors between points A and D are 2, 3, 4, and 5, and the values of the attenuation coefficients are plotted as shown in Figure 12.

Figure 12 shows the attenuation coefficient of the acoustic signal between the A and D leak points decreasing gradually with the increasing distance and is similar to the trend shown in Figure 11, with a greater pressure indicating a smaller attenuation coefficient as well, which is inversely proportional to the change in the amplitude. The double point between the No. 3 and No. 4 section of the acoustic signal attenuation amplitude and the double point to No. 4 attenuation amplitude in Figure 11 are similar, but the range

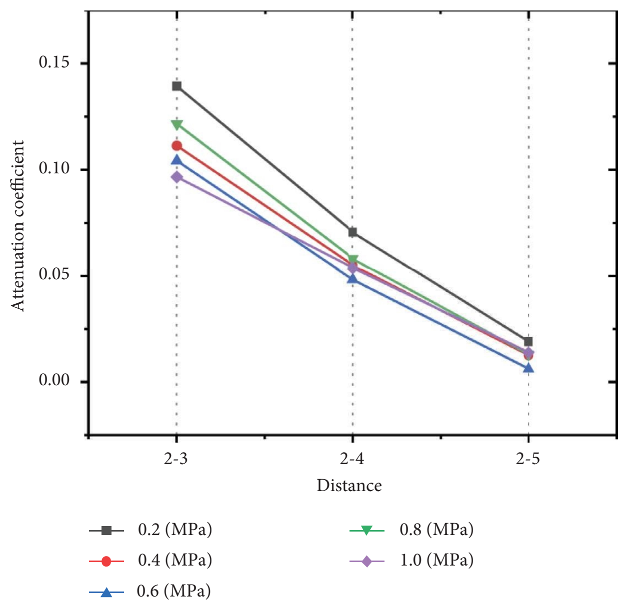

Figure 12: Variation law of the attenuation coefficient between points A and D under different pressures.

from 4 to 5 in Figure 12 is larger than that from 4 to 5 in Figure 11, indicating that the internal attenuation situation is close to the primary function curve. It can be observed that the attenuation of the acoustic signal between the double point and the amplitude of each segment attenuation is close, and the first segment attenuation amplitude is close to 50% to 60%, while the second segment attenuation amplitude is close to 60% to 80%. Compared to Figure 11 along the pipe's downstream acoustic propagation attenuation, each segment's attenuation amplitude becomes gradually flat.

5. Conclusions

The change law of acoustic wave propagation and attenuation of pipeline leakage under different pressures and different hole distance conditions is hereby studied based on a laboratory gas pipeline leak detection platform, and the specific conclusions are shown below:

(1) By comparing the time domain maximum amplitude of the noise signal with that of the leakage signal, the difference between the two is considered two orders of magnitude. Besides, the noise acoustic signal is found to have little effect on the subsequent experiments, and therefore, can be neglected.

(2) The double-point leakage propagation amplitude law is clarified through three different hole spacing double-hole leakage experiments conducted under different pressure conditions. In general, the three propagations basically along the pipe decay gradually, but the decay degree of each section is different. AC point leakage from sensor 4 to sensor 5 section amplitude decays up to 85%. In the case of a fixed pressure, the amplitude change pattern along the pipe also varies, and there will be a slight rebound in some places, which is related to the superposition of acoustic signals.

(3) The double-point leakage propagation RMS voltage change law is also found through three different hole spacing double-hole leakage experiments under different pressure conditions, which indicate that an increase in hole spacing has less effect on the signal propagation downstream along the pipeline, but more effect on the signal propagation between the double points.

(4) The change of the acoustic signal attenuation coefficient and the acoustic signal amplitude change is different from that of the pressure increase, that is, that of the former is gradually smaller, while that of the latter becomes gradually larger.

(5) The change of the attenuation coefficient in the double-point leak along the pipeline near the leak point is the largest, close to 50%, and it becomes basically less than 20% after the change gradually becomes flat, and the change of the double-point leak between the acoustic signal attenuation and that of each segment is large and relatively close, that is, that of the first segment is close to 50% and 60%, while that of the latter segment is close to 60% and 80%.

Data Availability

The data used to support the findings of this study are available on reasonable request to the corresponding author.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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