International Journal of Smart Home
Vol. 9, No. 2 (2015), pp. 243-252
http://dx.doi.org/10.14257/ijsh.2015.9.2.22

Simulation Experiment on Acoustic Emission of Pipeline Leakage

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Abstract

With the heater pipeline leakage experiment conducted on the experiment table, inner pipeline leakage of heater was studied through the leakage failure detection system. The frequency distribution and the amplitude of acoustic emission signals of leakage versus internal pressure were analyzed. Variations of signals versus leakage aperture and dissemination distance were summarized. According to the mapping relationship between the leaking spot and acoustic emission signals, and between the leakage flow and acoustic emission signals, reasons of leakage failure were concluded. The results would be applied to heater leakage failure detection. And an on-the-spot detection in the power plant was conducted to test the heater under pressure in order to verify the results.

Keywords: *acoustic emission; pipeline; leakage; detection; acoustic emission signals*

1. Introduction

Heater is one of the jacked lines, usually applied to heat exchanger such as high-low heat exchanger in the power plant. It can also serve for chemical production, such as high-low reactor. A heater consists of inner pipeline and outer pipeline. The transmission media in the inner pipeline of the heater is water or raw materials while that in the outer pipeline, vapor, hot water, refrigerant or PCB carrier. Due to aging, crack, media erosion, environment erosion, wear and flaws, the transmission media in the inner pipeline of the heater are likely to leak. Acoustic emission of pipeline leakage is influenced by outer pipeline, substance between the inner and the outer pipeline, fluid state and interaction of fluids, the mechanism of which is very complex [1].

The sound wave emitted due to inner pipeline leakage is not a special phenomenon, because the pipe wall only acts as guided wave and doesn't release energy. But the gas leak at the leaking spot would excite the stress wave that could describe the structure of the material. So, it is a generalized acoustic emission phenomenon [2-6].

Waveform and frequency spectrum of acoustic emission signals produced from inner pipeline leakage versus pressure, leakage aperture and transmission distance were studied with the removal of the shell through experiment.

2. The Test System

Online leakage failure detection system and device of acoustic emission consist of two parts

ISSN: 1975-4094 IJSH

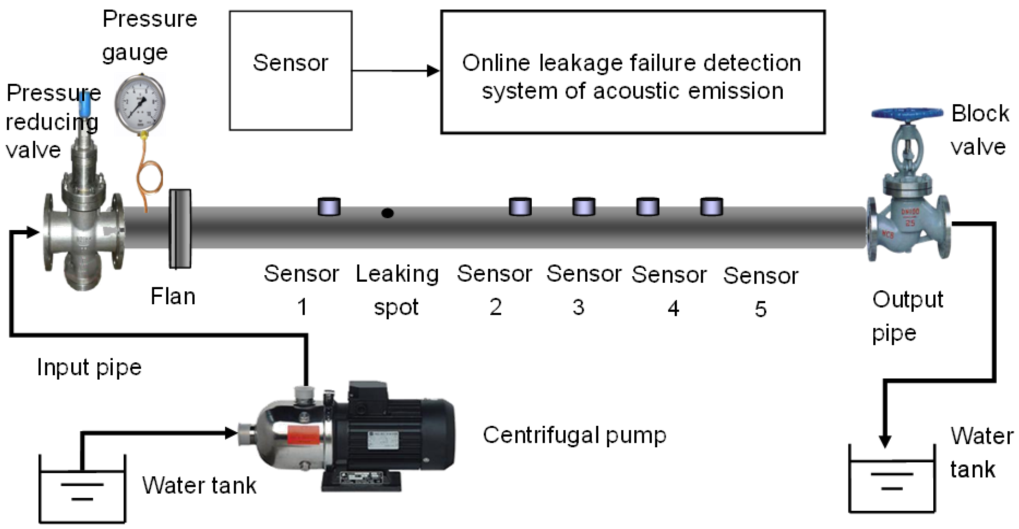

Figure1. Simulation system of pipeline leakage

(1) Online Leakage Failure Detection System of Acoustic Emission

As was introduced in Chapter 4, hardware included sensor, pre-amplifier, signal acquisition card, device and data processing and analysis system. The signal acquisition card was the AEDSP2 32 /16 made in U.S. The sensor was the single-ended broadband R15, produced by PAC, with the band ranging from 50kHz ~ 1MH. The pass-band fluctuation was smaller than 30d and its sensitivity was 120 dB. To make the sensor the pipeline fit, coupling agent was smeared on the surface of the sensor and a magnetic installation seat was used to ensure the tightness.

(2) Simulation system of pipeline leakage

The seamless pipeline was 12m in length, 5mm in wall thickness and of ϕ 90mm outside diameter. Pressure reducing valve and pressure gauge were installed at the input pipe. Block valve was installed at the output pipe. Centrifugal pump was responsible for supplying water and producing pressure. Details are shown in Table 1.

3. Experiment

(1) Noise signals during normal operation of the pipeline and acoustic emission signals under leakage were collected. Waveform and frequency spectrum of noise signals and acoustic emission signals were carefully studied to determine whether the leakage occurred [7-10].

(2) At the same leaking spot, leakage signals were collected under different internal pressures. Waveform and frequency spectrum versus pressure were studied. At 1mm, the inner pressure was increased from 0.2MPa to 0.5MPa. Acoustic emission signals of leakage were collected for adding every 0.05 MPa.

(3) Under the same pressure, the leakage aperture was changed. The leaking spot was increased from 1mm to 5mm. Acoustic emission signals of leakage were collected for adding every 1 mm.

(4) Under the same pressure and the leakage aperture, the distance between the leaking spot and the sensor was changed. Leakage signals were collected to study the variation of signals versus transmission distance. The distance was increased

from 1m to 5m and each time 1m was added. The internal pressure was adjusted at a proper time. Dispersion of acoustic emission signals of leakage was studied on the basis of data collected

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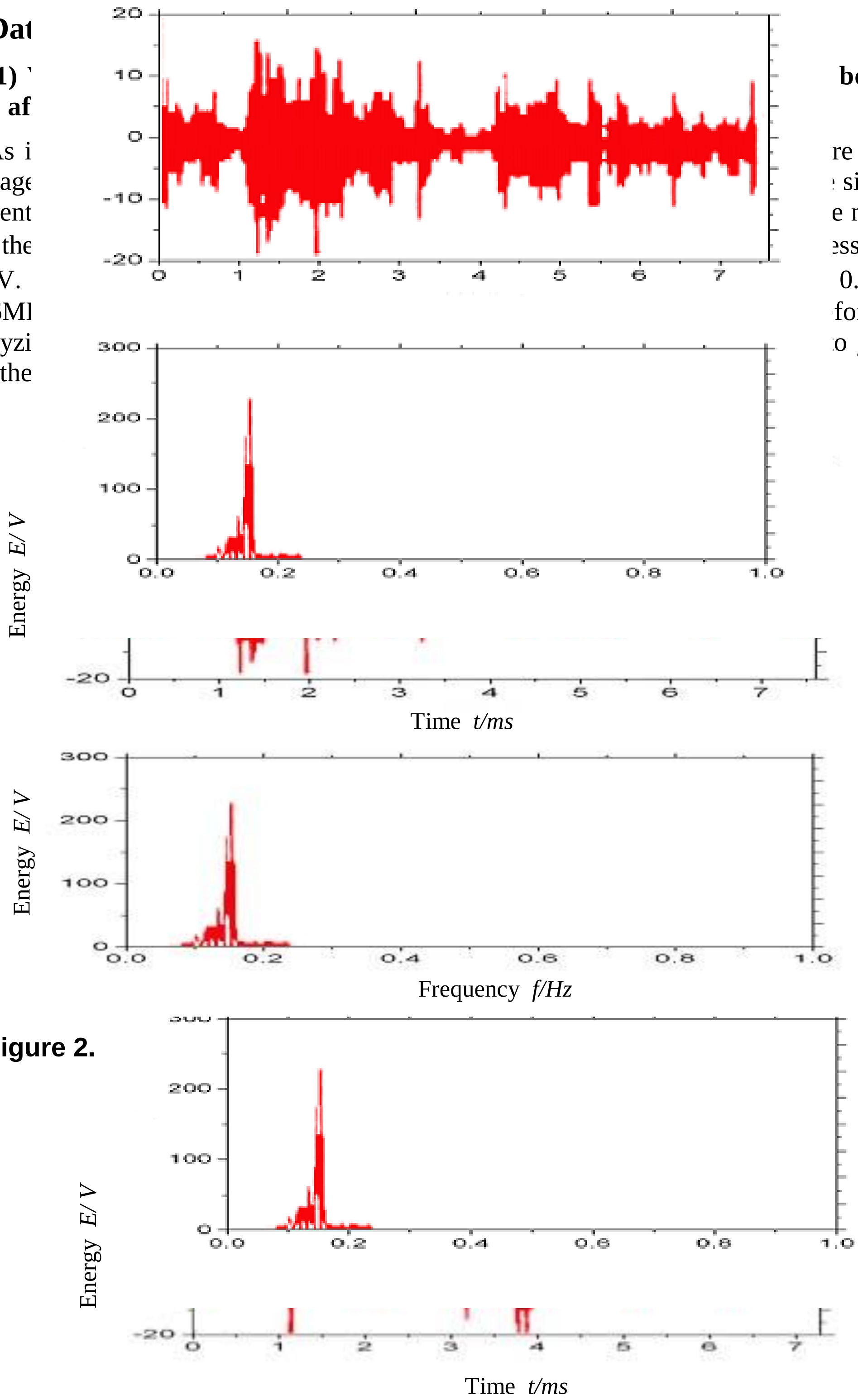


Figure 2.

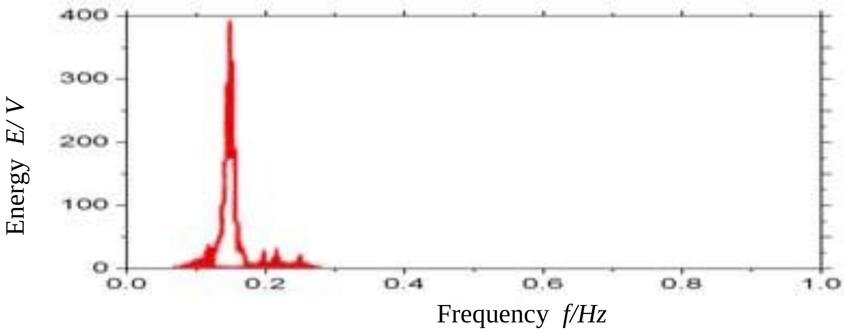


Figure 3. Acoustic Emission Signals and the Spectrum Under Leakage

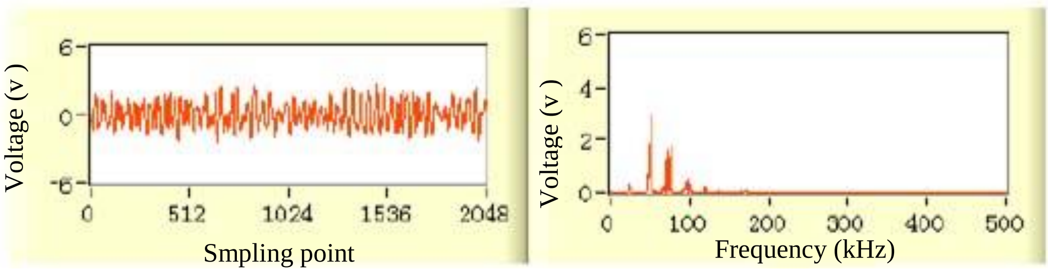
(2) Variation of Waveform and Frequency Spectrum of Leakage Signals versus Internal Pressure at the Same Leaking Spot

Figure 4 shows waveform and frequency spectrum of leakage signals at 1mm of leaking spot when the internal pressures are 0.25MPa and 0.45MPa.

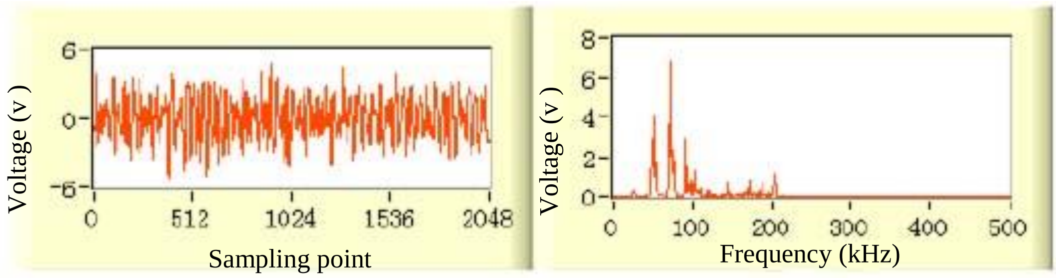
1) When the pressure is 0.25MPa, the amplitude of leakage signals is about 3V. When the pressure is 0.45MPa, the amplitude increases to 5V. The conclusion reached is that under the same leakage aperture, the amplitude of leakage signals continues to increase versus internal pressure.

2) The frequency of leakage signals mainly concentrates between 0~300 kHz. As the internal pressure increases, more leakage signals are of high frequency.

These two conclusions are in line with the theory introduced in Chapter 2. When the leakage aperture remains unchanged, the higher the pressure is, the higher the noises are and the bigger the amplitude of leakage signals is. And according to theories, when the internal pressure increases, the leakage speed would also raise and leakage signals would be of higher frequency, which results in that more signals are of high frequency than under a low pressure [14-15].



(a) The Internal Pressure is 0.25Mpa

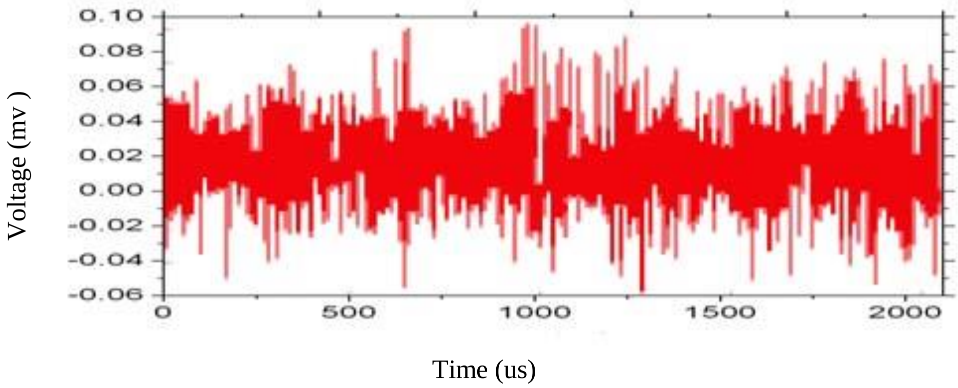


(b) The Internal Pressure is 0.45Mpa

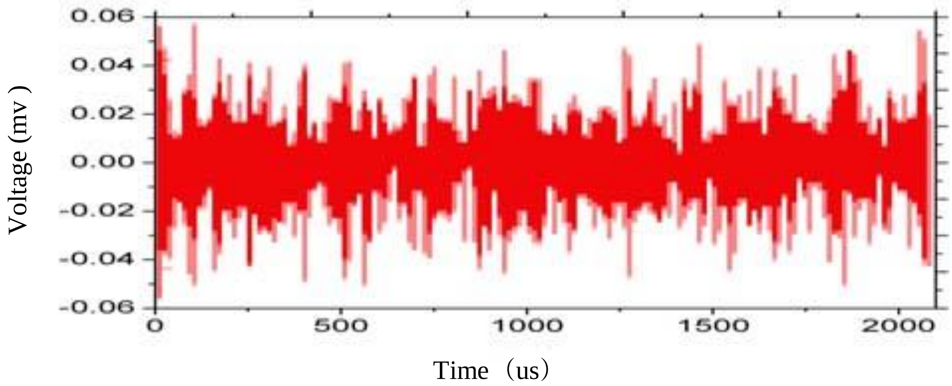
Figure 4. Waveform and Frequency Spectrum of Leakage Signals under Different Pressures

(3) Variation of waveform and frequency spectrum of leakage signals versus leakage aperture

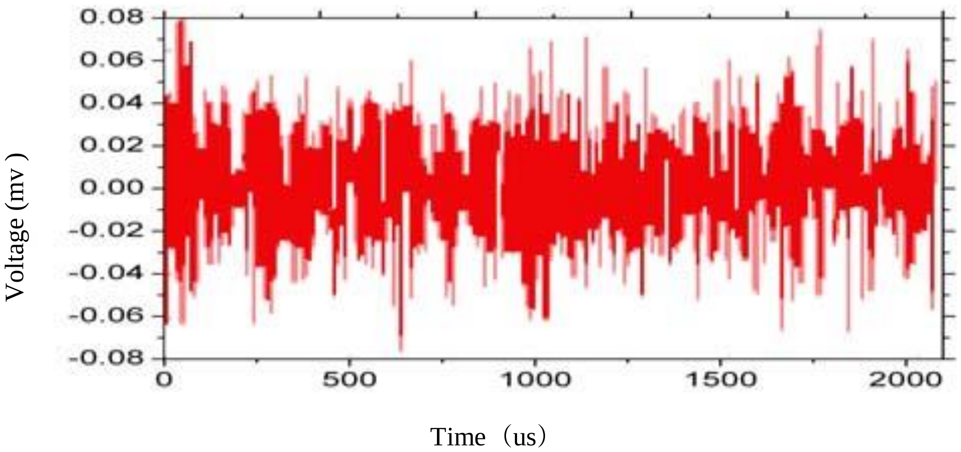
(a)~ (e) In Figure 5 are acoustic emission signals at 1, 2, 3, 4 and 5mm of leakage aperture when the internal pressure is 0.25MPa. From the waveform, it can be seen that the leakage signals are constant.



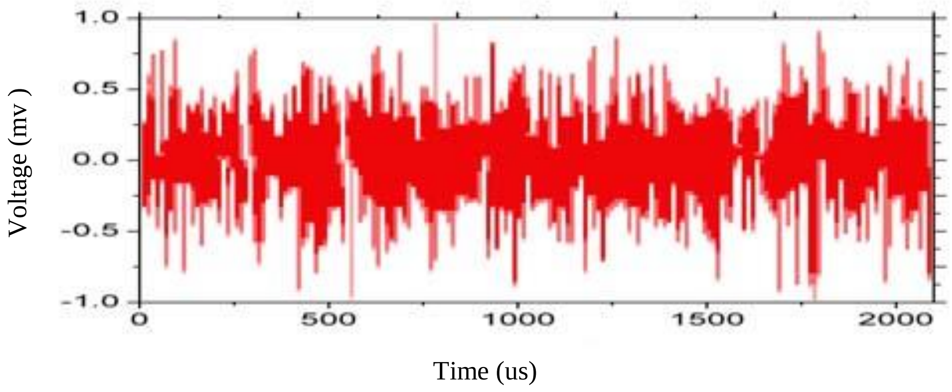
(a)1mm leaking spot



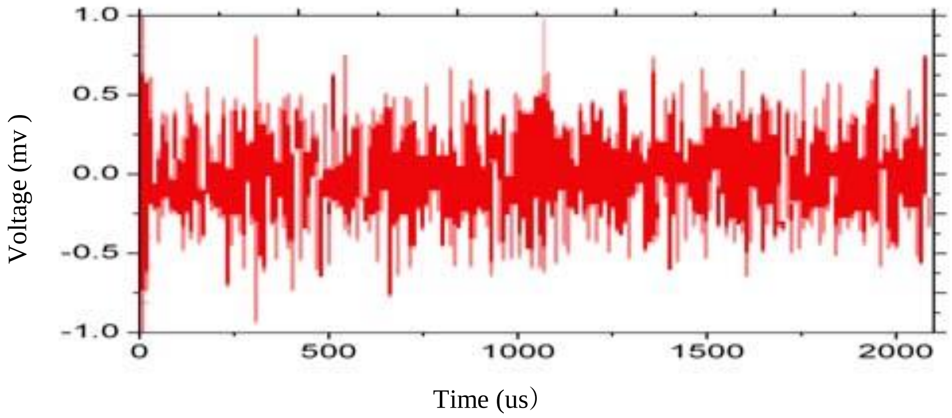
(b) 2mm leaking spot



(c) 3mm leaking spot



(d)4mm leaking spot



(e) 5mm leaking spot

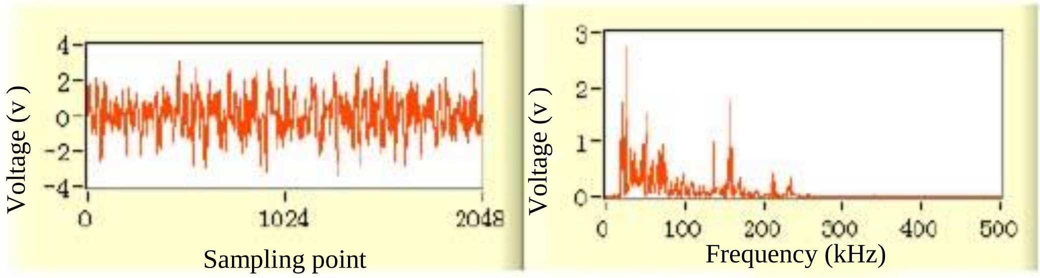
Figure 5. Waveform and Frequency Spectrum of Leakage Signals under Different Leakage Apertures when the Internal Pressure is 0.25Mpa

Figure 6 Waveform and frequency spectrum of leakage signals under different leakage apertures when the internal pressure is 0.3Mpa, From Figure 6, it is known that:

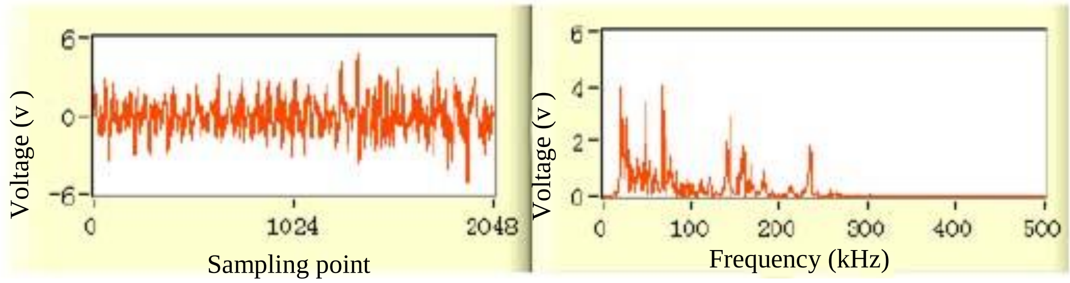
1) Compare waveforms. The amplitude of signals in two figures is different because of different leakage aperture. A big leakage aperture corresponds to big amplitude, which is proved by the fact that the amplitude in (b) is bigger than in (a).

2) Compare frequency spectrums at different leaking spots. Leakage aperture has great influence on the frequency energy of leakage signals but little influence on the frequency distribution. The frequency of signals mainly concentrates between 0~300 kHz.

These conclusions are in line with theories in Chapter 2. When the internal pressure remains unchanged, sound intensity at different leaking spots is distinct. When the sound is loud, the amplitude of leakage signals is big. As the leakage aperture increases, the maximum leakage speed doesn’t change much. Consequently, frequency distribution of leakage signals is hardly affected by leaking spot.



(a)1mmleaking spot



(b) 3mmleaking spot

Figure 6. Waveform and Frequency Spectrum of Leakage Signals under Different Leakage Apertures

(4) Variation of Leakage Signal Amplitude versus Transmission Distance

Figure 7 shows the variation of leakage signal amplitude versus transmission distance when the internal pressure is 0.25MPa, 0.35MP and 0.45MPa at 1mm of leaking spot. It can be concluded that as the transmission distance increases, the amplitude of leakage signals gradually reduces.

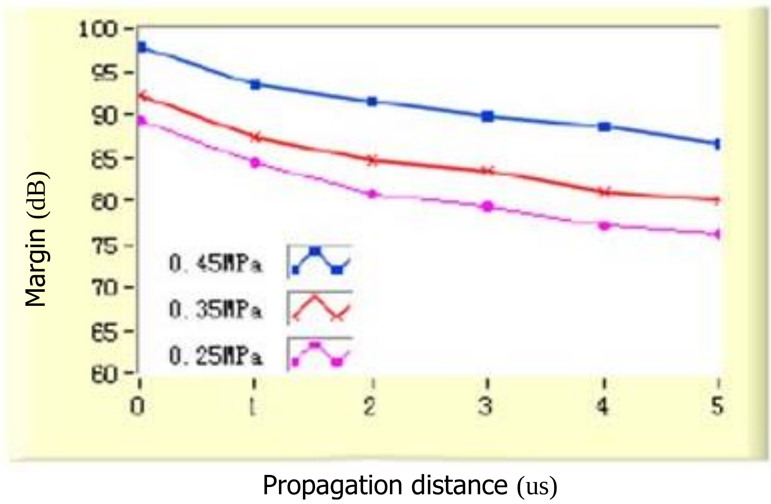


Figure 7. Leakage Signal Amplitude versus Transmission Distance

5. Conclusion

Through the experiment, wave, frequency spectrum, amplitude and energy of acoustic emission signals produced from inner pipeline leakage versus pressure, leakage aperture and transmission distance were studied with the removal of the shell through experiment. This paper reached the following conclusions:

(1) The amplitude and energy of acoustic emission signals of leakage increased versus pressure and leakage aperture, but decreased versus transmission distance;

(2) Energy of acoustic emission signals of leakage mainly concentrated between 0~300 kHz. When the diameter of the leakage aperture was small, some acoustic emission signals were of high frequency. As the leakage aperture increased, signals were mainly of low frequency;

(3) As the internal pressure of the pipeline decreased, the amplitude of acoustic emission signals of leakage continued to decrease. Under different pressures, waves of different frequencies had roughly the same proportion of energy in the total energy;

(4) When the leakage aperture changed, the amplitude and energy of acoustic emission signals of leakage were mainly influenced by the flow rather than by the speed. Consequently, frequency distribution of leakage signals was hardly influenced by the leaking spot;

(5) As the transmission distance increased, the amplitude of leakage signals decreased with signals of high frequency reduced more quickly than signals of low frequency.

Acknowledgements

Foundation item: Nature Science Foundation of Henan Science and Technology Bureau (141008) (141080); Major science and technology research plan project in Henan province (142102110028).

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