ISSN: 2414-1895 DOI: 10.6919/ICJE.202107_7(7).0011

# The Law of Acoustic Emission Signal when PE Pipe is Damaged by a Third Party

Tao Li, Qi Li, Junlin Shi

School of Sichuan University of Science & Engineering, Yibin 644000, China.

## Abstract

**Aiming at the characteristics of existing urban water supply pipelines that are vulnerable to third-party damage and causing pipeline ruptures, the acoustic emission monitoring technology for pipeline impact failure was tested and studied. Set up a PE water supply pipeline impact failure system, use a water pump to pass water into the pipeline system to simulate the pipeline in-service state, use a simple beam impact test to simulate the impact test on the pipe body, and change the impact pendulum from 43°, 53°, and 63° angles Static release, collect the acoustic emission signals at 200mm, 300mm, 400mm, 500mm from the impact point, and analyze the signal characteristic parameters and spectrum law. The results show that the amplitude, energy count, and ringing count tend to decrease with the increase of the monitoring distance, and increase with the increase of the impact angle. The main frequency of the impact process is distributed in a certain range.**

## Keywords

**PE Water Pipe; Impact Failure; Acoustic Emission; Monitoring.**

## 1. Introduction

With the continuous development of economic construction and the further popularization of urbanization, the society's demand for water resources is increasing. As the main method of water transportation, the development of PE water pipelines is also changing with each passing day [1]. However, due to the current large-scale construction of cities and towns, external force damage behaviors that cause direct or indirect damage to pipeline-related equipment and tools are mainly manifested as impact failure, that is, third-party damage[2][3]. According to domestic and foreign research reports, third-party damage to urban pipelines accounts for more than 50% of total pipeline accidents[4].

Regarding the damage of the PE pipeline by a third party, relevant scholars have conducted a lot of research. Zhou Liguo[5-6] used ABAQUS finite element analysis software to conduct numerical simulations from both direct and undirected excavation loads to study the dynamic response and mechanical characteristics of the pipeline. The results show that the pipeline is directly damaged by a third party, The pipeline stress is concentrated, the deformation is obvious, and the impact is small when there is overburden protection. Li Jun [7] carried out mechanical analysis under the action of excavation for the excavation and destruction of urban pipelines. The mechanical response model of PE pipe under excavation load is established, and the failure process under typical working conditions is analyzed. The results show that the main failure position of the pipe under the action of mechanical teeth is the two ends of the contact position between the mechanical teeth and the pipe. The failure criterion based on strain can be used. Make better use of the plastic properties of PE pipes, and the position of mechanical teeth has less effect on the mechanical response of the pipe; the increase in pipe diameter and wall thickness can reduce the stress in the pipe and at the same time reduce the cross-sectional ellipse of the pipe.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202107_7(7).0011

The damage of the PE drainage pipeline by a third party has a great impact on the production and life of urban residents. In view of the characteristics of buried PE pipelines that are not suitable for excavation, effective non-destructive monitoring of them is of very positive significance. At present, there are many documents on third-party damage monitoring of pipelines, but there are few studies on the application of acoustic emission to third-party damage monitoring of PE water pipelines. Acoustic emission technology has the advantages of strong real-time performance, high sensitivity, strong integrity, etc. The practicability of this technology has been extensively verified in the nondestructive inspection of pipeline accidents. This paper studies the third-party damage of the PE pipeline, collects its acoustic emission signals, analyzes its signal characteristic parameters, and summarizes its changing law, so as to achieve the purpose of real-time and effective monitoring of the third-party damage of the pipeline.

## 2. Experimental part

### 2.1 Raw materials

PE water pipe (SDR11).

### 2.2 Instruments and equipment

Impact testing machine: Model XJJ-50, Jinjian Testing Instrument Co., Ltd., Chengde City, Hebei Province;

Full-information acoustic emission instrument: DS5-16C, supporting software DS5AE2020, Beijing Soft Island Technology Company.

### 2.3 Impact experiment scheme under acoustic emission

In order to study the impact failure of PE water pipes, this experiment builds a PE water pipe system, uses a water pump to transport water into the pipe, and lifts the impact pendulum to the angles of 43°, 53°, and 63° to release statically, and collect distances from the impact point. Acoustic emission signals at 200mm, 300mm, 400mm, and 500mm, the experimental platform design is shown in Figure 1:

Figure 1. Impact failure test platform

### 2.4 Elimination of experimental environment interference

In order to reduce the interference of irrelevant factors to the experiment process as much as possible, the qualified PE water pipes are selected to be welded and assembled into a pipeline system according to the standard. Before the experiment, the acoustic emission collection system is grounded and the environmental noise is measured. The final environmental noise acoustic emission signal amplitude is 3mV. In accordance with the requirements of the acoustic emission acquisition system, the water pump should be kept away from the test site as much as possible during the experiment, the noise of the water pump should be shielded, and the experimental environment temperature should be kept at room temperature.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202107_7(7).0011

## 3. Results and analysis

When the PE water pipe fails due to impact, the speed of the pendulum of the impact testing machine will drop to 0 in an instant, and all the kinetic energy of the pendulum will be transmitted to the pipe body. The pipe body will vibrate violently, and the internal molecular chain of the material at the impact point will be Oscillation occurs, due to the speed difference between the mass points of the molecular chain, the acoustic emission signal is generated and collected by the acoustic emission sensor arranged on the tube. The acoustic emission signal collected in this experiment is a burst signal.

The parametric analysis method is one of the most commonly used methods to analyze acoustic emission signals since 1950. This method uses several simplified characteristic parameters with time as the horizontal axis to characterize acoustic emission signals, including amplitude, ring count, and energy count. In this experiment, the amplitude, energy count, and ringing count are selected as the research objects, and their definitions and uses are shown in Table 1 [8] [9] [10].

Table 1. Characteristics, definitions and uses of acoustic emission characteristic parameters

| Parameter | Definition | Features and uses |
|---|---|---|
| Amplitude | The maximum amplitude value in the waveform of an acoustic emission signal. | What is reflected is the size of the event, which has nothing to do with the size of the threshold, and its size determines the detectability of the event. |
| Energy count | The area under the envelope of the signal detection wave can be divided into total count and count rate. | Reflect the relative energy and relative intensity of the event. |
| Ring count | The number of oscillations of the signal crossing the threshold can be represented by the total count and the count rate. | Reflect the intensity and frequency of the acoustic emission signal. |

### 3.1 Variation of characteristic parameters of PE pipe acoustic emission signal under third-party damage

#### 3.1.1 Variation law of amplitude characteristic parameters

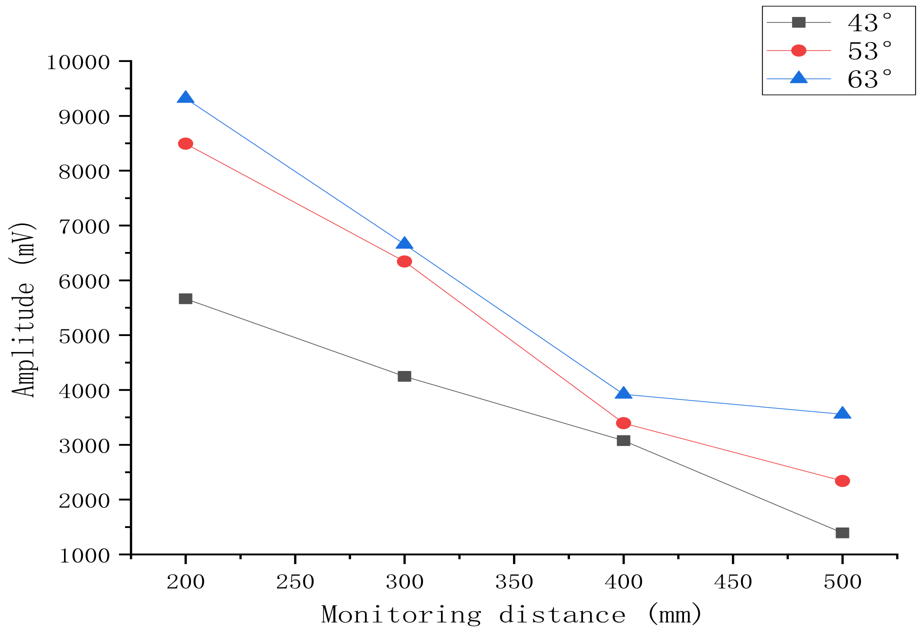



Figure 2. Distribution diagram of amplitude characteristic parameters at various impact angles

Figure 2 is the distribution diagram of amplitude characteristic parameters at various impact angles. From the diagram, the following rules can be obtained:

ISSN: 2414-1895
DOI: 10.6919/ICJE.202107_7(7).0011

(1) In an impact accident, the acoustic emission signal amplitude level is relatively high. The amplitude distribution range of 43°-63° is 1391.54-5664.07mV, 2342.27-8491.22mV, 3556.92-9316.41mV, and the amplitude appears as the monitoring distance increases. The decreasing trend is due to the high attenuation of PE pipes. During the propagation of the acoustic emission signal, there is a certain amount of loss in its strength and acoustic emission energy, and as the propagation distance increases, the higher the attenuation degree. As a result, the amplitude of the acoustic emission signal obtained at a long monitoring distance is relatively small.

(2) The amplitude shows an increasing trend with the increase of the impact angle. This is because in an impact accident, the greater the impact pendulum angle, the greater the potential energy of impact. At the moment of impact, the energy is completely applied to the PE In the pipeline, the greater the deformation near the impact point, the greater the velocity difference between the particles in the pipeline, and the greater the amplitude of the acoustic emission signal obtained.

### 3.1.2 Variation law of ringing count characteristic parameters

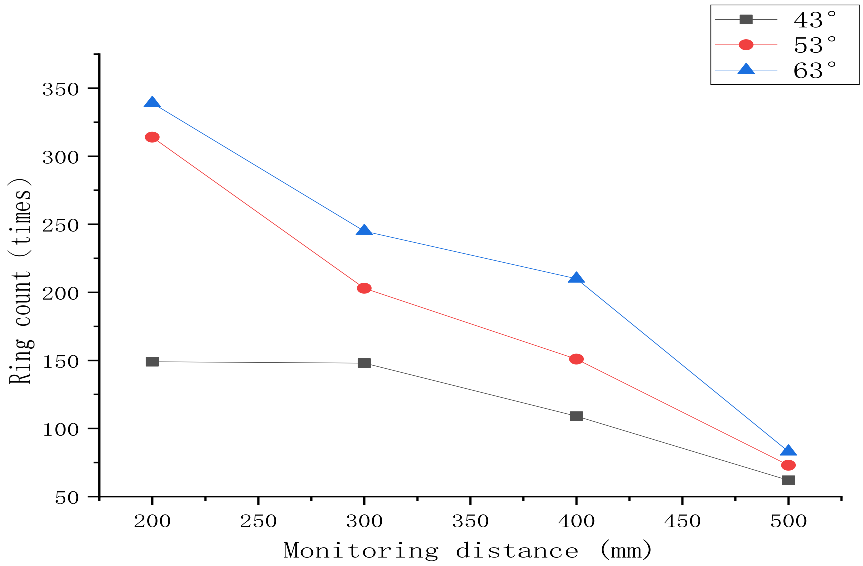



Figure 3. Distribution of characteristic parameters of ringing count under various impact angles

Figure 3 is the distribution diagram of the ringing count characteristic parameters at various impact angles. From the diagram, the following rules can be obtained:

(1) At an impact angle of 43°-63°, the distribution range of acoustic emission signal ringing counts is 62-149, 73-314, and 83-339, respectively. The ringing count decreases as the monitoring distance increases. Small trend, this is due to the loss of acoustic emission signal strength during propagation, which leads to a decrease in the number of times the signal is higher than the threshold value. Therefore, as the monitoring distance increases, the number of ringing counts decreases.

(2) The ringing count value shows an increasing trend with the increase of the impact angle. This is because when the impact angle increases, the intensity of the acoustic emission event generated by the PE pipe increases, and the acoustic emission signal crosses the threshold. The more the number of vibrations, the ringing count tends to increase.

### 3.1.3 Change law of characteristic parameters of energy counting

Figure 4 is the distribution diagram of energy counting characteristic parameters at various impact angles. From the diagram, the following rules can be obtained:

(1) At an impact angle of 43-63°, the energy count distribution ranges are 3301.13-9636.13mV*ms, 4857.92mV*ms-16206.33mV*ms,4941.67mV*ms-21778.41mV*ms, and the value increases with the monitoring distance This is because the pipeline is attenuated and the energy of the acoustic emission signal is lost in the propagation path, which leads to a decrease in the energy count of the acoustic emission signal at a longer monitoring distance.

ISSN: 2414-1895
DOI: 10.6919/ICJE.202107_7(7).0011

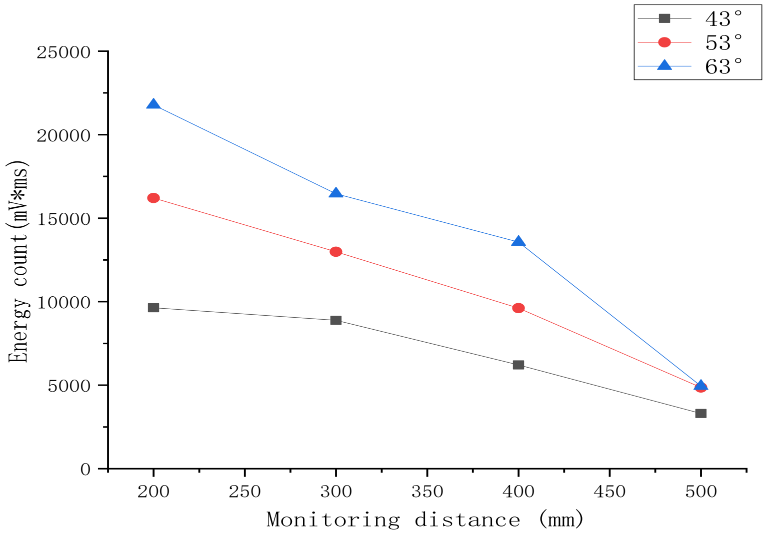
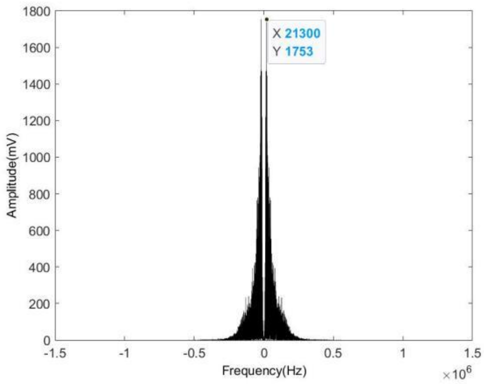



Figure 4. Distribution of characteristic parameters of energy counting at various impact angles

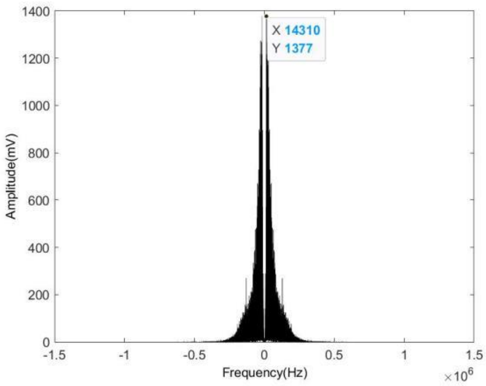
(2) As the impact angle increases, the energy count value increases. This is because under a larger angle impact, the impact pendulum has greater potential energy, and the greater the energy transferred to the PE pipe at the moment of impact, resulting in the monitored The energy count is larger.

### 3.2 Research on spectrum law

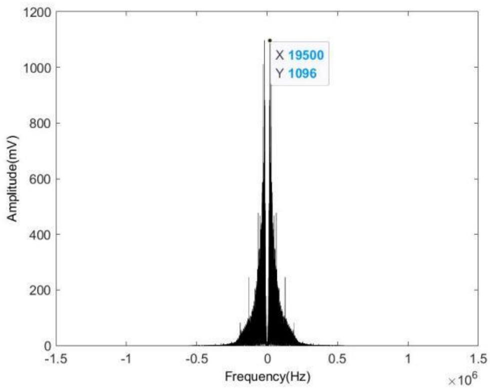
The signal is converted to the frequency domain, and the Fourier transform is used to analyze the spectrum of the acoustic emission signal obtained at each impact angle at each monitoring distance, as shown in Figures 5, 6, and 7.



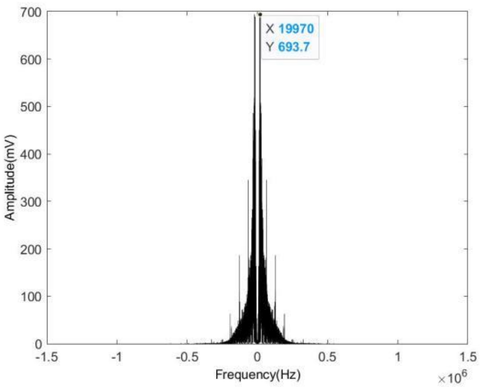

(a) 200mm




(b) 300mm



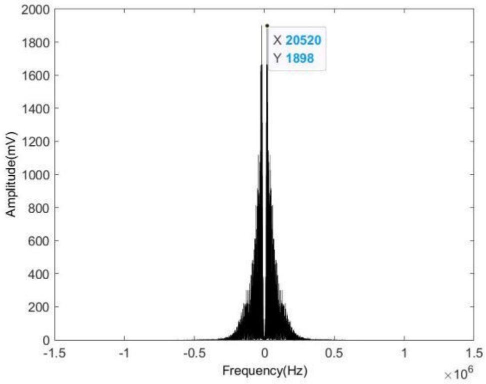

(c) 400mm



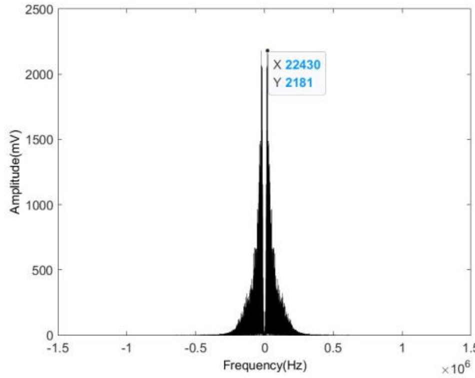

(d) 500mm

Figure 5. The main frequency diagram of the acoustic emission signal at an impact angle of 43°

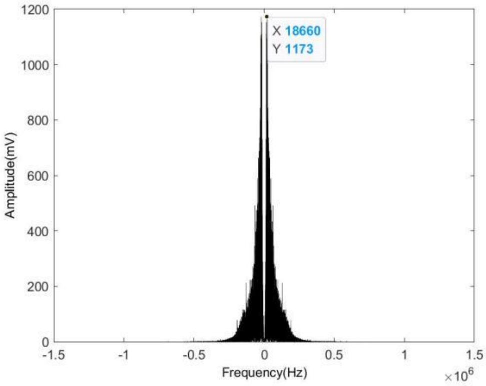
ISSN: 2414-1895
DOI: 10.6919/ICJE.202107_7(7).0011



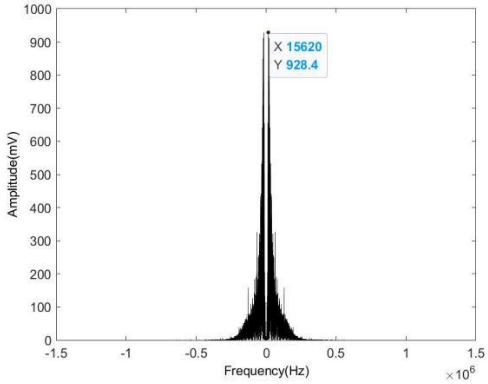

(a) 200mm




(b) 300mm

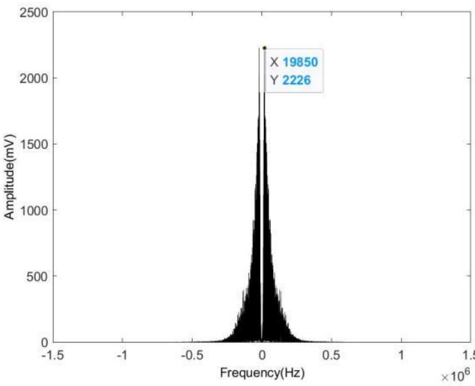



(c) 400mm

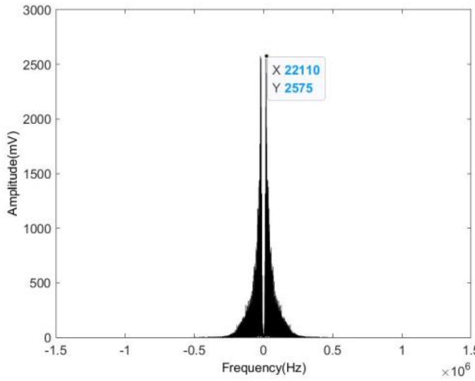



(d) 500mm

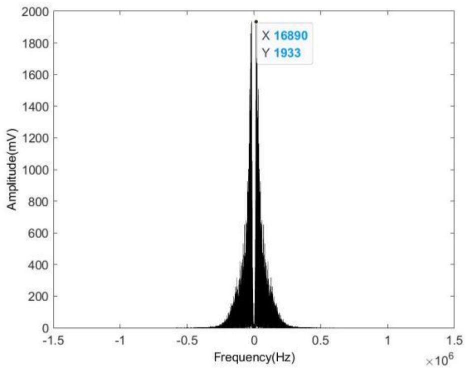
Figure 6. Main frequency diagram of acoustic emission signal at 53° impact angle



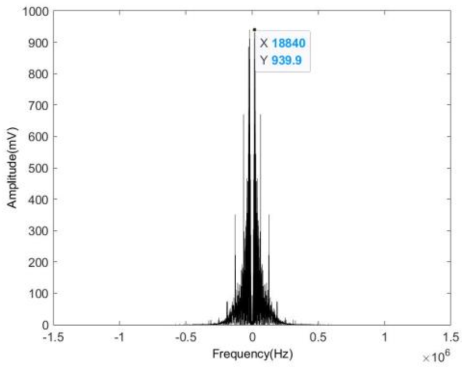

(a) 200mm




(b) 300mm




(c) 400mm




(d) 500mm

Figure 7. Main frequency diagram of acoustic emission signal at 63° impact angle

ISSN: 2414-1895 DOI: 10.6919/ICJE.202107_7(7).0011

According to the above spectrogram, the main frequency distribution analysis at each monitoring distance and impact angle is shown in Figures 8.

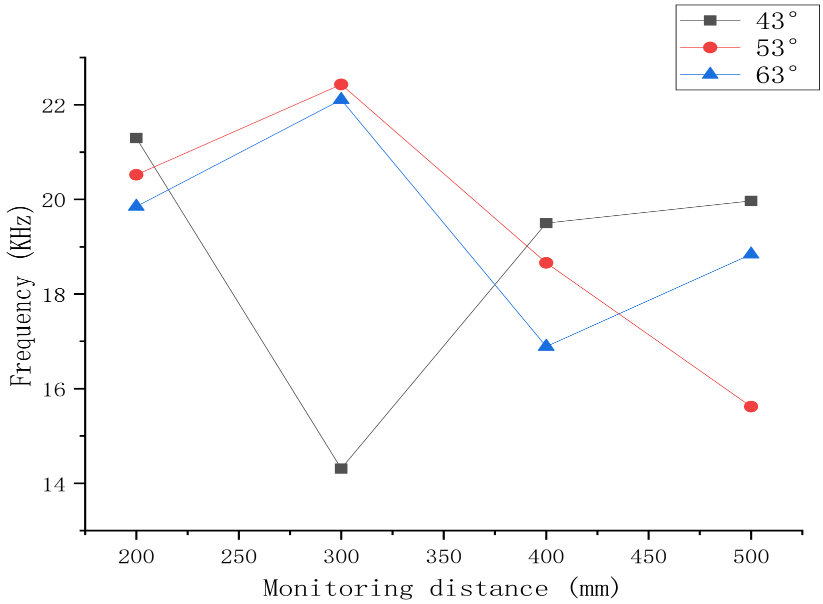


Figure 8. Main frequency distribution diagram under various impact angles

Figure 8 shows the main frequency distribution diagram under various impact angles. From the figure, the following rules can be seen:

At a monitoring distance of 200-500mm, the main frequency distribution ranges are 19.85-21.3KHz, 14.31-22.11KHz, 16.89-19.5KHz, 15.62-19.97KHz, and at an impact angle of 43°-63°, the main frequency release range is 14.31 respectively. -21.3KHz, 15.62-22.43KHz, 16.89-22.11KHz, under each impact angle and monitoring distance, the main frequency of the impact failure process is always distributed in a certain range, this is due to the similar failure mode of the impact failure process, similar failure process and degree , Cause the acoustic emission event and frequency to be consistent, so the main frequency of the collected acoustic emission signal is distributed in a certain range.

## 4. Conclusion

Through the above analysis, the following conclusions can be drawn:

(1) In the process of impact failure, since the impact failure is concentrated at the moment when the pendulum hits the PE pipe, the acoustic emission event takes a shorter time and has the characteristics of higher amplitude.

(2) In the process of impact failure, due to the high attenuation of PE pipes, the characteristic parameters of acoustic emission signal amplitude, ringing count, and energy count show a decreasing trend as the monitoring distance increases; when the impact angle increases, the acoustic emission signal The characteristic parameters of the transmitted signal amplitude, ringing count, and energy count tend to increase with the increase of the impact angle.

(3) Due to the closeness of the impact failure process and time, the dominant frequencies of the impact events occurring at various impact angles at various monitoring distances are similar and distributed within a certain range.

(4) If an acoustic emission signal with high amplitude, short occurrence time, and similar main frequency is detected, it may be considered that the pipeline is being damaged by a third party.

## References

[1] Zhu Jiguang. Application Analysis of PE Water Supply Pipe in Urban Water Supply Project[J]. Construction Materials & Decoration, 2020(16):141+144.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202107_7(7).0011

[2] Yang Dianqiang, Pei Cunfeng, Lin Xianxi, et al.Preventive Management Mode Based on Risk Assessment of Pipeline Subjected to Third Party Damage[J]. Petro & Chemical Equipment 2018, 21(06):82-84.

[3] Liang Yongkuan, Yang FUming, Yin Zheqi, et al. Accident statistics and risk analysis of oil and gas pipelines[J]. Oil & Gas Storage and Transportation 2017, 36(04):472-476.

[4] Wang Chao.Analysis of Natural Gas Pipeline Accidents at Home and Abroad[J]. Chemical Enterprise Management, 2016(14):275.

[5] Zhou Liguo. Research on Damage Risk Assessment Technology of Third-Party Excavation Construction for Urban Gas PE Pipeline[D]. Southwest Petroleum University, 2017.

[6] Zhou Liguo, Yao Anlin, Xu Taolong, et al. Damage analysis of urban gas PE pipeline under excavation load[J]. China Safety Science Journal, 2017,27(03):59-64.

[7] Li Jun, Zhang Hong, Wu Kai, et al. Failure behavior analysis on PE gas pipeline under the effect of third-party excavation[J]. Journal of Safety Science and Technology, 2017,13(04):108-116.

[8] Shen Gongtian, Geng Rongsheng, Liu Shifeng. Parameter Analysis of Acoustic Emission Signals[J]. Nondestructive Testing, 2002(02):72-77.

[9] He Yuming, Peng Likun, Song Fei. Experimental Study Based on Characteristic Parameters and Power Spectrum Analysis for Acoustic Emission Detection of Hydraulic Spool Valve Internal Leakage[J]. Chinese Hydraulics & Pneumatics, 2019(04):113-120.

[10] Luo Mingdi.Study on Acoustic Emission Characteristics of Creep Destruction of Sandstone under Staged Cyclic Loding and Unloading[D]. North China University of Water Resources and Electric Power, 2018.