Experimental Design of Acoustic Emission Detection for Micro Leakage in Marine Compressed Gas System

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Abstract. In order to detect the micro leakage of marine compressed gas pipeline system, an experimental platform for detecting the micro leakage of compressed gas is designed by using acoustic emission technology. The results show that the experimental platform can effectively simulate the two typical marine compressed gas pipeline leakage problems: pipe wall damage and valve internal leakage. At the same time, these leakage problems can be effectively detected by using acoustic emission signal acquisition and processing system.

Keywords: trace leakage, nondestructive testing, acoustic emission technique.

1. Introduction
For large underwater vehicle, compressed gas system is an important guarantee of its vitality. Once the compressed gas leaks, the floating of underwater vehicle and the use of some equipment will be affected, which will threaten the safety of underwater vehicle. The underwater ship pipeline has the characteristics of numerous valves, large background noise and complex working environment. At the same time, part of the pipeline is also affected by high temperature, radiation, installation location and other factors, which lead to the leakage of these compressed gas pipelines is sometimes difficult to detect in time, so the detection of micro leakage of marine compressed gas pipeline is of great significance.

Acoustic emission testing technology is a dynamic nondestructive testing method using modern sensors. The technology is flexible and does not need to send out signals actively. The system's own signal can be detected and identified by using this technology, and the active defect status of pipelines and valves can be detected and evaluated. It is suitable for on-line monitoring and early and near failure prediction, especially in the case of difficult or inaccessible detection.

In the research of pressure pipeline leakage detection, Wu Shaoke et al [1] designed an experimental platform for leak location of marine water pipelines, and used wavelet transform and pressure gradient method to identify and locate pipeline leaks. Lin Weiguo et al [2] proposed a non-intrusive acoustic wave monitoring method for valve internal leakage with a dual sensor structure, aiming at the internal leakage of pipeline valves. In the research of acoustic emission pipeline leak detection, Wu Mengmeng et al [3] analyzed the working mechanism of valve leakage acoustic emission detection, and used wavelet analysis to obtain the characteristics of valve internal leakage. Zou Bing et al [4] established a pre-defect gate valve internal leakage simulation test platform, by using acoustic emission detection technology combining with fluent software to simulate the flow
field under the leakage state and discuss the distribution of acoustic emission characteristic parameters in the process of gas valve internal leakage. Li Zhenlin et al [5] conducted detection experiments on valve gas internal leakage. The experiment showed that when the valve leaks, the root mean square of acoustic emission characteristic signal parameter can effectively reflect the gas volume leakage rate, and the detection error of the valve leakage rate by the acoustic emission detection technology is within 10%.

On the basis of previous studies, compressed gas pipeline leakage test is designed by fully considering the composition and function of the marine compressed gas system. The rupture of the compressed gas pipe wall and the internal leakage of the valve is detected by using acoustic emission technology, which provides a basis for the subsequent in-depth development of the acoustic emission online monitoring and positioning of the compressed gas pipeline leakage.

2. Basic Theory

2.1. Marine compressed gas system

Marine compressed gas system is mainly composed of air compressor, air drying and filtering device, gas cylinder, compressed gas distribution valve and pipeline accessories, which is mainly used to manufacture, store, distribute and use compressed gas for underwater ships. Figure 1 is a simplified schematic diagram of the marine compressed gas system. After drying and filtering, the compressed gas is controlled by a valve and transported to a gas cylinder through a pipeline and then stored. Compressed gas system is a whole ship system, which is mainly used to float underwater vehicle and supply gas to the system which needs compressed gas. The compressed gas in the cylinder is delivered to the designated user through the pressure pipeline, when the user needs to use it.

![Fig.1 Simplified schematic diagram of marine compressed gas system](image)
2.2. Acoustic emission technology
Acoustic emission (AE) detection mainly relies on acoustic emission sensor to detect the system to be tested. The collected signal is amplified and filtered to estimate the characteristic parameters, and then the leakage fault can be judged by the change of parameter characteristics. Its main characteristic parameters include effective value voltage (AERMS) and average signal level (ASL). The steps and methods of acoustic emission detection [3] are shown in Fig. 2.

3. Experimental Design and Analysis
On the basis of being familiar with the marine compressed gas system and mastering the basic theory of acoustic emission leak detection, a marine compressed gas pipeline leakage detection experimental platform is designed. In the design process, first of all, the similarity between the system model and the marine system must be considered, mainly using dimensional analysis and similarity principle [6]. In the design of compressed gas pipeline, there are mainly three aspects: gas source setting, pipeline layout and user selection [7]. Generally speaking, physical system similarity mainly includes three basic conditions: geometric similarity, kinematic similarity and dynamic similarity. For compressed gas pipeline design, it mainly includes three aspects: gas source setting, pipeline layout and user selection. The schematic diagram of compressed gas pipeline leakage test bench is shown in Figure 3.
In figure 3, the system is divided into three parts: compressed gas preparation module, pipeline system operation and fault simulation module and leakage detection module. In the compressed gas preparation module, the external air is sucked into the working chamber of the air compressor through the suction valve. After compression, the compressed gas is manufactured and stored in the cylinder. The safety valve is installed on the cylinder to ensure the safety of gas storage in the cylinder. The pressure gauge 1 is installed on the gas supply pipeline of the gas cylinder to measure the total discharge pressure of the gas cylinder. In the pipeline system work and fault simulation module, the compressed gas in the cylinder is transported to the designated gas equipment through the fault area by the pipeline. The adjustable pressure reducing valve is used to control the gas pressure input into the pipeline system during the working process. The gas pressure after depressurization control is measured by pressure gauge 2 as the inlet pressure of simulated fault area. The fault setting is mainly through the installation of pipeline with leakage point or valve with leakage characteristics, which are used to simulate the leakage of pipeline and internal leakage of valve respectively. In the leakage detection module, two acoustic emission sensors are fixed in the fault area to be tested. The sensor is used to collect the elastic wave signal. After filtering and amplifying, the signal is transmitted to the acoustic emission detection device for processing and analysis, and then the compressed gas pipeline leakage is identified.

The compressed gas system on board is divided into high pressure gas system, medium pressure gas system and low pressure gas system. Different compressed gas systems provide different gas pressures, ranging from 0 to tens of MPa. Therefore, the selection of air compressor should be considered from the following two aspects: on the one hand, from the safety point of view, the maximum pressure should not be too high, so as to avoid the danger of leakage gas pressure to personnel or articles; on the other hand, from the perspective of applicability, in order to detect the micro leakage of the pressure pipeline, if the pressure of the compressed gas in the pipeline is small, the leakage detection can be carried out, then the situation with higher pressure is easier to achieve. Figure 3 shows the air compressor used in this experiment. The speed is 980r / min, the working pressure is 0.8MPa, and the displacement is 0.6m3/min.
The leakage test and measurement scheme of compressed gas pipeline are shown in Figure 4. Figure 4(a) shows the experimental arrangement for leakage of compressed gas pipeline. The lowest part on the left side is the adjustable pressure reducing valve of the intake pipeline, then the intake flowmeter, intake pressure gauge, pipeline to be tested, exhaust pressure gauge and exhaust flowmeter are arranged along the intake direction. Figure 4(b) shows the arrangement of valve internal leakage test and measurement scheme. The black machine is the acoustic emission acquisition processor. In the pipeline system behind the processor, the pressure pipeline fault parts are replaced by straight pipes and the stop valve is installed to simulate the valve internal leakage.

In the experiment, acoustic emission sensors are attached to the pipeline and valve, as shown in Figure 5. Figure 5(a) shows the acoustic emission sensor, and figure 5(b) shows the sensor arrangement for valve leakage detection. Sensor 1 is arranged at the inlet end for input signal monitoring, and sensor 2 is arranged at the valve for leakage monitoring. The layout of pipeline leakage monitoring is similar to that in Figure 5(b), but the location of sensors is slightly different. The two sensors are respectively arranged on both sides of the leakage point according to a certain distance.

In order to verify the effectiveness of the experimental device, the pipe wall leakage and valve leakage were tested.

3.1. Experimental analysis of pressure pipeline wall leakage
The whole pipeline system is made of DN25 galvanized steel pipe. The diameter of the pipeline is 0.25m, and the length of the pipeline in the area to be measured is 1m. There is a 0.01m leakage hole drilled in the middle of the pipeline in the measurement area. The position of measuring point 1 is
0.3m from the inlet end to the leakage hole, and the position of measuring point 2 is 0.3m from the
exhaust end to the leakage hole. Figure 6 shows the measured power spectrum under the condition of
pipeline wall leakage at the inlet pressure of 0.06MPa.

![Power spectrum of leakage signal of compressed gas pipeline](image1)

**Fig. 6** Power spectrum of leakage signal of compressed gas pipeline

Through further analysis of the data, the variation trend of RMS voltage of pipeline leakage signal
is shown in Figure 7. It can be seen from Figure 7 that when the pipeline leaks, the RMS value has a
sudden increase process, and the detection effect is obvious. At the same time, obvious signal changes
can be detected in channel 1 and channel 2. This is because the instantaneous pulsation signal
generated by the leakage point is bidirectional along the pipeline.

![Variation trend of RMS of compressed gas pipeline leakage](image2)

**Fig. 7** Variation trend of RMS of compressed gas pipeline leakage

Figure 8 shows the variation trend of average signal level (ASL) of pipeline leakage signal. It is
further verified that the test bench can better detect the pipeline wall damage and leakage. In addition,
during the period of 45s to 52s, the ASL value fluctuates obviously, which was due to the closing of
the intake valve at the end of the test. When the inlet valve is closed, the residual compressed gas in
the pipe continues to be discharged until it is consistent with the atmospheric pressure, so the change of this value is consistent with the actual situation.

![Fig. 8 Variation trend of average signal level (ASL) of compressed gas pipeline leakage](image)

3.2. Experimental analysis of pressure pipeline valve leakage

In the simulation of pressure pipeline valve leakage experiment, based on the above experimental layout, a stop valve is installed at the end of the pipeline to be tested. By controlling the opening of the stop valve, the leakage simulation is carried out. The inlet pressure of the valve is 0.5MPa, sensor 1 is 0.08m (upstream) on the left side of the valve at the inlet end, and sensor 2 is 0.05m (downstream) on the right side of the valve at the exhaust end. A metal rotameter is installed at the end to measure and record the gas leakage through the valve. Figure 9 shows the power spectrum of valve leakage with a leakage rate of 0.08 m³/min.

![Fig. 9 Power spectrum of internal valve leakage signal in compressed gas pipeline](image)
Fig. 10 Variation trend of RMS of internal valve leakage in compressed gas pipeline

Through further analysis of the data, the variation trend of RMS of the detection signal is shown in figure 10. When the valve leaks, the RMS value suddenly increases and keeps stable. When the valve is closed, the RMS value decreases and returns to the state before leakage. At the same time, obvious signal changes can be detected in channel 1 and channel 2. Therefore, the detection effect is obvious.

Fig. 11 Variation trend of ASL of internal valve leakage in compressed gas pipeline

Figure 11 shows the variation trend of average signal level (ASL) of internal valve leakage in compressed gas pipeline. It is further verified that the experimental platform can detect the leakage of pipeline valves, and the experimental detection effect is ideal.

4. Summary

The trace leakage detection of marine compressed gas pipeline is difficult to be detected in time due to the influence of complex working environment and background noise. Based on acoustic emission non-destructive testing technology, a platform for detecting the micro leakage of marine compressed gas pipeline is designed and built. The preliminary experimental verification was carried out with the experimental device. The results show that the acoustic emission detection platform for marine compressed gas can effectively detect the pipe wall damage and valve internal leakage, which are two typical leakage problems. In the next step, relying on the experimental platform, further theoretical
and Experimental Research on quantitative leakage detection under different variables will be carried out.

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