Gas Leak & Discharge Viewer MK-770

1. Introduction

A steelworks uses various gases, including compressed air, steam and fuel gases, which are distributed to individual plants and equipment through a large number of complex transport piping systems. Through-holes, cracks and gaps in the piping may occur due to aging and problems related to design and construction, and in some cases, the gases in the piping may leak into the atmosphere. Since unexpected gas leaks cause energy loss and equipment downtime, quick discovery of leaks from piping and repair of the locations where leaks are identified is essential.

JFE Advantech Co., Ltd. sells a gas leak detector called "Gas/Air Leak Viewer MK-750ST" (hereinafter, MK-750ST), a device that visualizes gas leaks by the ultrasonic beamforming method, which is capable of detecting leaks over a wide inspection area and identifying the specific location of leaks. Moreover, JFE Advantech commercialized recently the company's top-end model, the "Gas Leak & Discharge Viewer MK-770" (hereinafter, MK-770). This article introduces the product and a number of new functions.

2. Ultrasonic Beamforming Method [1,2]

2.1 Ultrasonic Leak Detection

One leak detection method is a method using ultrasonic waves. When a gas leak occurs from a through-hole in piping or other equipment, it emits a jetting sound which includes an ultrasonic component due to the turbulence caused by the leakage (**Fig. 1**). Since this ultrasonic component occurs even during leaks too small to be heard by the human ear, leaks can be detected by a noncontact method regardless of the type of gas, by detecting it with an ultrasonic sensor.

As a JFE Advantech product applying this technology, the "Gas/Air Leak Checker MK-730Air" (Fig. 1) collects ultrasonic waves with a parabolic microphone and checks for the presence or absence of leaks. However, since it is necessary to scan the piping, identifying the leak location is time-consuming.

The "ultrasonic beamforming method" solves this problem by using multiple ultrasonic sensors to simultaneously search a wide area and identify the leak location, which is the point where the ultrasound occurs. This method dramatically shortens the time required to identify the leak location.

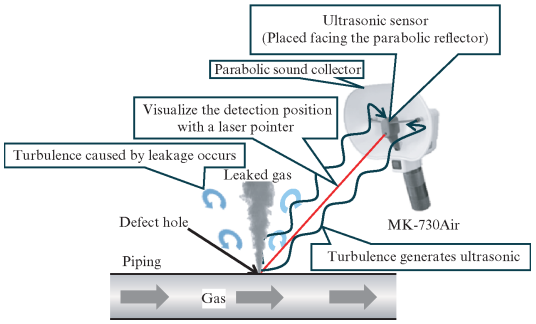

Fig. 1 Conceptual diagram of ultrasonic generation

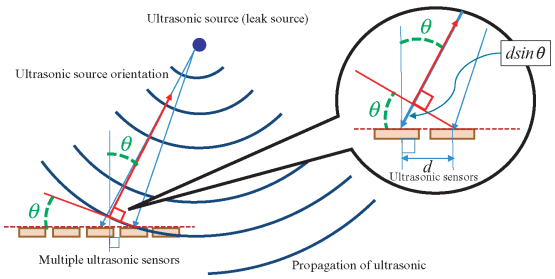

Fig. 2 Ultrasonic source orientation and frequency reach plane angle

2.2 Principle of Ultrasonic Beamforming Method

In the ultrasonic beamforming method, ultrasonic waves are received from a leak source by multiple ultrasonic sensors arranged at arbitrary locations. As shown in **Fig. 2**, the angle θ between the sensor surface and the reaching plane of the ultrasonic wave is the same as the ultrasonic source direction θ as seen from the sensor. The time difference Δt between the arrival of the ultrasonic wave at neighboring sensors separated by a spacing of d is expressed by Eq. (1), where c is the sound velocity.

$$\Delta t = (d \sin \theta)/c \quad \cdots\cdots (1)$$

Since the sound velocity c and the sensor spacing d are constant, the arrival time difference Δt is determined by the ultrasonic source direction θ. When the

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arrival time difference Δt is tuned and the received waveforms of all the ultrasonic sensors are superimposed, the total array of multiple ultrasonic sensors functions as a virtual sensor with high directivity in the θ direction, making it possible to obtain the sound pressure in the θ direction. This method of forming a virtual ultrasonic sensor with high directivity by using multiple ultrasonic sensors is called the ultrasonic beamforming. The sensor arrangement shown in Fig. 2 is a schematic 1-dimensional illustration. However, in the actual MK-770, the sensors are arranged in two dimensions, making it possible to obtain the 2-dimensional distribution of sound pressure (i.e., sound pressure map) of all directions in the search area.

3. Features of MK-770

3.1 Overview of MK-770

In 2016, JFE Advantech began sales of the world's first portable gas leakage visualization device, "Gas/Air Leak Viewer MK-750."[3] Subsequently, in February 2021, the "MK-750ST." This device was based on the knowledge gained with the previous MK-750 and the comments of users, and achieves improved display visibility in outdoor environments, a more compact size (about 1/2 that of the MK-750), and enhanced operability. In addition, while retaining the design and basic functions of the MK-750ST, an improved model with additional functions, the "MK-770," was also developed (**Photo 1**).

3.2 Additional Functions of MK-770[4]

3.2.1 Automatic Sound Source Judgment Function

In plants that use many air-driven devices, the background noise at locations reached by ultrasonic waves may interfere with the screen of the MK-750ST. To overcome this issue, JFE Advantech added a function that uses a proprietary algorithm to automatically judge whether a target location is an ultrasonic sound source or not, and display only points judged to be ultrasonic sound sources on the screen.

3.2.2 Video Photography Function

A videorecording function was also added, making it possible to record conditions that are difficult to understand in still images, such as intermittent operation and long intervals in equipment operation. Use of this videorecording function also allow easier sharing of information concerning corona discharge (discussed in 3.2.4), which is an intermittent phenomenon.

3.2.3 Energy Conservation Calculation Function

Another newly-added function provides rough calculations of the annual cost of energy loss due to leakage based on the estimated leakage rate by inputting the unit cost of the energy and the annual operating time and setting the distance to the measurement target. This function provides a clearer grasp of the cost of energy loss due to leakage.

3.2.4 Corona Discharge Detection Function

Air discharge (corona discharge) is a type of partial discharge that occurs accompanying insulation degradation in high-voltage electrical equipment. During corona discharge, it is known that ultrasonic waves with frequencies of several 10s of kHz are generated. Although the frequency of these ultrasonic waves is similar to those that occur during gas leaks, since partial discharge is an intermittent phenomenon with a period corresponding to the AC power voltage, the ultrasonic waves also occur intermittently. For this reason, even though partial discharges can be detected by the MK-750ST, discharges may not be detected in some cases, depending on the timing of sampling.

To reliably detect partial discharge phenomena in all cases, detection performance was improved by changing the sampling time to 24 ms, taking into account the difference (4 ms) in the discharge occurrence time in the period of the AC power source (20 ms is areas such as eastern Japan where the power frequency is 50 Hz). A real-time power analysis function for the detected ultrasound was also added, and displays the ratio of frequency components caused by the discharge phenomenon, making it possible to analyze whether the detected ultrasound is caused by electrical discharge (**Photo 2**).

Photo 1 Exterior of MK-770 and leak detection example

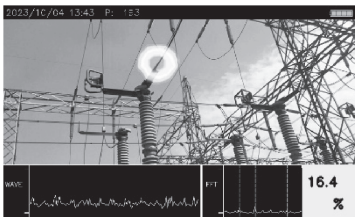

Photo 2 Partial discharge detection example

Use of these improvements in periodic inspections of substation equipment allows the user to verify whether electrical discharges are caused by insulation deterioration or not, contributing to more efficient maintenance activities.

4. Conclusion

This article has presented an overview and the new functions of the "MK-770," which is the newest model in the "Gas/Air Leak Viewer Series" of products that visualize the location of gas leaks.

The Gas/Air Leak Viewer Series received the "Minister of the Environment Award for Climate Change Action" for fiscal year 2024 in the Technological Development and Commercialization Division, and is expected to be used widely in maintenance activities and energy conservation activities.

References

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