Application of Gas Leak Position Visualization Device to Iron- and Steel-making Equipment

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Abstract:

Conventionally, gas leakage from piping has been investigated by using gas detectors, equipment using directional microphones, etc. However, it has been difficult to specify an accurate leakage position due to the characteristics of these equipment. The equipment introduced in this paper is developed jointly with JFE Advantech, in order to visualize and identify leak points easily. We will introduce examples of using this leak detector on iron- and steel-making equipment.

1. Introduction

Conventionally, investigations of gas leaks due to construction defects or deterioration of gas transportation piping had been conducted with gas detectors, equipment using directional microphones, etc., but due to the characteristics of those devices, detection as such was sometimes impossible when the species of gas was different from that detected by the detector, and it was difficult to specify the position of leaks accurately, even when using a directional microphone detector.

Therefore, to solve the above-mentioned problems, JFE Steel and JFE Advantech jointly developed an ultrasonic detection device that can easily identify the position of leaks. This paper describes the performance verification of the developed device and presents examples of its application to actual iron- and steel-making equipment.

2. Conventional Leak Detection Technologies

2.1 Direct Gas Detection Methods

Several conventional methods for detecting gas leaks exist. One is detectors using a sensor, which detect the gas itself by using a semiconductor type or electrochemical type sensor. Because the gas is detected by passing the gas itself through the sensor, safety-related problems can occur in case of poisonous gases. As an additional problem, because a different sensor is used for each gas species, detection is difficult if the species of leaking gas cannot be specified in advance.

Next, there are methods in which smoke or a fluorescent agent is mixed with the leaking gas in order to visualize the leak, and the position of the leak is identified by the discharge of smoke or fluorescent agent from the point of the leak. However, this method also has weaknesses. In case smoke is mixed and the equipment is located outdoors, etc., visual confirmation of the leak from the leak point may be impossible due to wind in the surrounding area. On the other hand, if a fluorescent agent is used, it may be difficult to locate the leak because that fluorescent agent cannot be used due to the type of leaking gas.

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2.2 Detection Using Ultrasonic Device

Ultrasound is one leak detection method that solves above-mentioned problems. An ultrasonic wave is generated when a gas under pressure from piping into a low pressure atmosphere, and the leak can be detected by capturing this ultrasonic wave. Moreover, the possible area of the leak can be narrowed down by using a parabolic sound collector to enhance signal receiving directivity. At JFE Steel, equipment trouble has been reduced by utilizing leak detectors based on this principle to identify the location of leaks. However, because the equipment in a steel works extends over a wide area, much time is required to locate the source of a leak, as it is necessary to move the sensors in all directions and gradually narrow down the possible area based on the condition of detection of ultrasonic waves. Moreover, noise close to the frequency of the ultrasonic wave generated from the leak will also be detected at the same time. Therefore, when identifying the location of a leak, it is necessary to use a detection method in which the possible area of the leak is gradually narrowed by changing the measurement location little by little, while also considering the influence of noise.

3. Leak Detector: Air Leak Viewer MK-750

Photo 1 shows the newly-developed leak detector. For remote detection of gas leaks and easy identification of the location of leaks, this device uses the beam forming method, in which ultrasound detection elements are arranged in a plane and the direction of a leak is identified from the difference in the time of detection of the ultrasonic wave by each element. The development of the basic technology of this device was done at JFE Steel West Japan Works (Kurashiki), and the final device was commercialized by JFE Advantech as the Air Leak Viewer (MK-750)[1]. The MK-750 was commercialized after confirming its effectiveness in various studies at Kurashiki, including repeated experiments in which the location of leaks in actual piping was detected, and tests demonstrating the possibility of detecting leaks from nitrogen gas piping from a distance of 16 m[2,3]. In addition, the basic performance of the MK-750 related to identification of the location of leaks, and the relationship between the possible detection distance and leak condition were investigated at JFE Steel East Japan Works (Chiba). Supposing a gas leak from actual piping, a minute hole was made in simulated piping to allow the gas to leak from the piping so as to achieve a uniform pressure in the piping. In this experiment, the degree to which weak leaks can actually be detected was investigated by changing the pressure in the piping and the distance from the experimental equipment to the detector. As the experimental method, first, a simulated leak condition was created by making a hole with a diameter of 1.7 mm, which is the estimated diameter of a pinhole, in 15 A piping, and passing nitrogen gas in the piping. Next, the internal pressure in the piping and the measurement position from the leak location to the MK-750 were varied to investigate the relationship between the detectable pressure and the detection distance. **Photo 2** shows the experimental equipment. The 15 A piping is located in the central part of the figure, and the leak point where the hole was made is in the central part in the vertical direction. **Figure 1** shows the condition of leak detection when the MK-750 was actually used. The experi-

Photo 1 Air leak viewer (MK-750)

Photo 2 Outline of experimental equipment

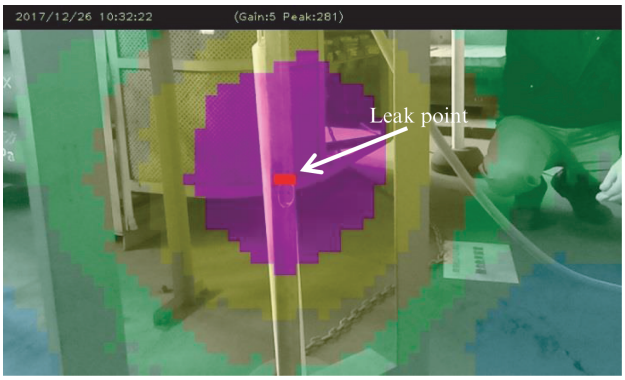

Fig. 1 Detection of leaks from pinholes

mental conditions at this time were a piping pressure of 70 kPa and a distance of 5 m from the leak position to the detector. The red spot in the center is the location with the highest sound pressure. Because that point coincides with the leak point in the piping, it can be said that correct identification of the leak point was possible. Verification was carried out by varying the pressure in the piping and the distance to the leak point. The resulting relationship between the piping pressure and the detection limit distance is shown in **Fig. 2**. The piping pressure was varied in the range from 0.5 kPa to 40 kPa, and the distance from the leak point to the detector was varied from 0.5 m to 6 m. The line in Fig. 2 expresses the limit of the distance from the leak point to the detector at each piping pressure. Here, the area to the lower right from this limit line is the detectable range, and the area to the upper left is the range where detection was not possible. From this, it can be understood that the detection range becomes shorter as the pressure decreases, and conversely, the detection range becomes longer as the pressure increases. It should be noted that the maximum distance of 6 m in this experiment was used due to the limitations of the experimental setup; however, as mentioned previously, remote detection from distance of 10 m or more is possible with the MK-750.

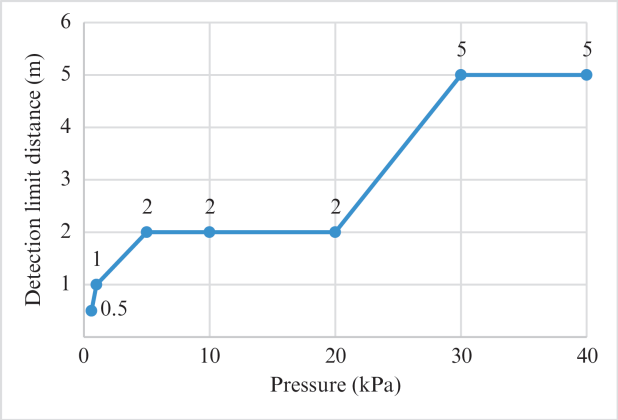

Fig. 2 Relation between piping pressure and detection limit distance

Next, supposing leaks that can actually occur, leaks from piping joints were detected. **Figure 3** shows the condition of leak detection. The experimental conditions were a piping pressure of 34 kPa and a distance of 1 m from the leak point to the MK-750. The joint was loosened, allowing a gas leak, in order to create a simulated leak condition, and the joint part was coated with soapy water to visualize the leak. As the result of this experiment, the fine bubbles that escaped from the joint could be detected with the MK-750.

4. Examples of Application in Steel Works

4.1 Detection of Air Leakage (Negative Pressure) of Outdoor Duct

Many large-scale ducts with lengths of several 100 m or more exist in a steel works, including the ducts of dust collectors, flue gas ducts for heat treatment processes using by-product gases and others. Leaks in these ducts affect production intensity, as leaks in dust collector ducts will reduce dust collection efficiency, while leaks in flue gas ducts represent an energy loss due to the reduced heat exchange effectiveness of heat exchangers. For this reason, large-scale ducts are controlled as important equipment, ducts are inspected regularly, and if a leak is found, repair or other appropriate action is taken. This example concerns the duct of a dry electric dust collector in a sinter plant. Because negative pressure had occurred in the piping, this leak was different from the phenomena described up to this point, in which gas leaked from inside piping to the external environment; that is, in this case, external air was being sucked into the piping. The degree to which leaks can be detected under this condition was verified. **Figure 4** shows an example of detection of the air leakage reaction at a connecting part of an actual duct. As a result, it was found that suction leaks with negative pressure can also be

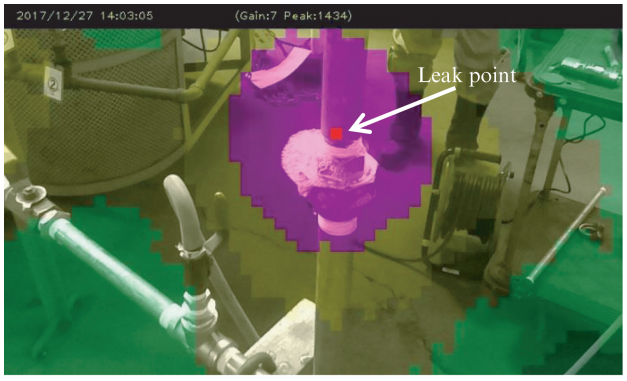

Fig. 3 Detection of leaks from joints

Fig. 4 Detection of leaks in dust collection ducts (sinter plant)

Photo 3 Detection of leaks in dust collection ducts (sinter plant)

detected. When a smoke was burned at the location detected by the MK-750, as shown in **Photo 3**, the smoke was sucked into the duct, confirming that suction of external air under negative pressure can be detected by this instrument.

4.2 Leak Checks of Newly-Constructed Equipment

Next, an example in which a leak check of newly-constructed equipment was conducted and a leak was detected will be introduced. When new piping for gases or fluids is installed, a leak check is carried out by trial operation, etc. Conventionally, the piping was actually filled with a gas, and soapy water was blown on areas around valves and joints to check whether leaks were occurring. When a leak was found in this type of inspection, corrective action was taken by tightening the bolts or adjusting or replacing the packing. In this experiment, detection of the leak point was performed with the MK-750, and it was found that leakage was occurring from a valve connection near an air piping valve, as shown in **Fig. 5**. Thus, it was possible to detect the leak with the detector without blowing soapy water.

Moreover, depending on the place where piping is installed, it may not be possible to blow soapy water because the footing is poor or the piping is located in a high area which is not readily accessible to personnel. In such cases, the presence or absence of leaks can be confirmed from a safe position at a distance from the inspection point by using the MK-750.

Fig. 5 Leak detection status (valve connection)

5. Conclusion

As described up to this point, verification of the MK-750 Air Leak Viewer was performed by applying this device to actual equipment in a steel works, and it was found the leak points can be identified easily, even from a distance, by visualization of the leak point. Because a steel works includes areas where by-product gases and other gases that are harmful to human health are used, the ability to locate leaks from a distance is also a large advantage from the viewpoint of safety.

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