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Field Application Study for Leak Detection Using Acoustic Emission Technology

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1. Introduction

Leak detection method for pressure vessel such as valve, pipe and flange, etc. using acoustic emission technology has been developing through laboratory study and field testing experiences. Fundamentally, two types of detection method are used. The first one consists of a microphone that picks up airborne ultrasound, typically in the 35 to 45 ㎑ frequency range (Dawes, 1967; Dau, 1976). The second method, which is the main concern of the present discussion, detects structure-borne signals by attaching a sensor on the structure. Such a practice utilizes the technique of acoustic emission and is capable of leak location, continuous on-line surveillance and monitoring hard-to-access location. This paper, problems frequently raised are discussed when this AE method is considered as measuring leak detection for pressure vessel. And also discussed the first of these factors from a fundamental viewpoint, and gives examples of the practical capabilities of the AE leak detection method.

2. Selection of Sensor Frequency

In practice, the leak noise arised from near plant is wide-band, ranging from below 1 ㎑ up to around 1 ㎒ (Jax, 1980; Dau, 1976). Due to the higher attenuation with increasing frequency and the mechanical noise at low frequencies most systems operate in the range of 100 to 400 ㎑. Sometimes, when the background noise is not a problem, vibration transducers(accelerometers) are added to monitor the low frequency signals (below 50 ㎑). Published data cover three orders of magnitude in frequency and there is as yet no precise rationale for determining the optimum monitoring frequency.

3. Minimum Detectable Leak Rate

Minimum detectable leak rate varies greatly with the fluid, the pressure difference across the valve, the valve size and the detecting instrument. Through laboratory testing, we detected a gas leak rate of 90 ㎖/sec through a 1.33 ㎜ (0.05 in.) diameter vertical hole type specimen, but the signals were one order of magnitude stronger for a 0.21 ㎜ (0.08 in.) diameter vertical hole type specimen with the same leak rate. Dickey et al. (1978) reported a measurable leakage of 2 ㎖/sec for a 281.4 kgf/cm^2 (27.6 MPa) high pressure air valve. Detection of a gas leak as small as 0.3 ㎖/sec through a flow control valve operating at 147.7 kgf/cm^2 (14.5 MPa) was reported by smith et al. (1979). In the case of field monitoring, the ASTM recommended practice for AE leak detection quotes about 1 ㎖/sec for liquid or 10 ㎖/sec for gas. The U.S. Nuclear Regulatory requirements for light water reactors state that the leak detection system should have the capability of detecting leaks less than 63 ㎖/sec.

4. Distance from Leak to Sensor

This is an important factor since the acoustic signal diminishes in amplitude as it travels away from the source, according to familiar laws of acoustic. Thus, in designing a monitoring system or inspection procedure there is a trade-off between the sensor spacing and the minimum detectable leak rate. Techniques for locating leaks are based on searching for the point of highest signal amplitude with a mobile sensor, or on comparing the measured signal amplitudes at several fixed sensors.

5. Relationship between AE Level and Leak Rate

A good approximation in the form $V \propto M^S$ where V is the RMS(root mean square) or average signal level, M is the leak rate, and *S* is a constant, has been reported in many cases. The value of the exponent *S* depends on individual experiments and we are conformed that *S* values are between 0.6 and 2.0 from our laboratory testing.

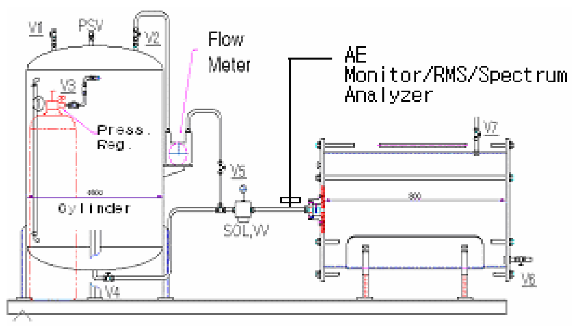

Figure 1. Experimental set-up for leak detection

As an example of leak detection, a 400 ㎖ gas cylinder with less than 120 kgf/cm^2 cylinder pressure was used to test the leak through its valve orifice. Figure 1 shows the schematic set up. The leak rate was controlled by adjusting the value V5. A displacement-sensitive sensor with wide frequency bandwidth up to 1 ㎒ range was first used to examine the frequency contents of the detected signals, after that three resonance type sensors were used to evaluate their sensitivities. The resonance frequencies of the sensors are 25~530 ㎑(S1) and 100~400 ㎑(S2) in case of PZT AE sensors and 35 ㎑(S3) in case of accelerometer. The output signals from the sensor were fed into a Portable AE Monitor. The monitor amplification was set for 60 ㏈ and the internal filter was 25 to 530 ㎑. The AE monitor output was then fed into an HP 3400A RMS voltmeter and a spectrum analyzer for signal analysis. Two flowmeters, one with a full scale of 1 ㎖ /min, water used alternatively to indicate the large or small leak rate.

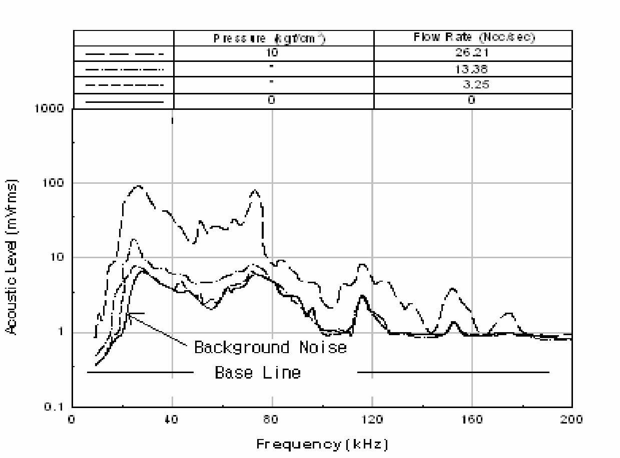

Figure 2. Frequency spectra of leak signals detected by a displacement - sensitive sensor at three different leak rates

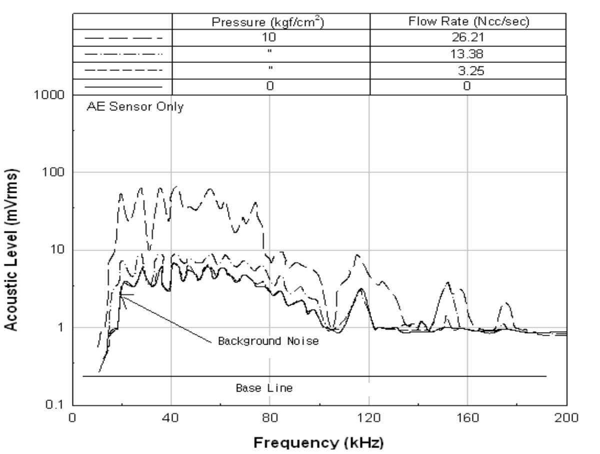

Figure 3. Frequency spectra of acoustic leak signals detected by S1 transducer at three different leak rates

Figure 2 shows the frequency response of the flat displacement sensor. The major frequency content of the detected signals in this case was below 200 ㎑ for leaks smaller than 1 ㎖/min. Larger leak rate increased the amplitude of higher frequencies. The frequency response of the leak signals from the other three transducers indicate that they followed the sensor resonance frequency. Among all sensors tested, S1 sensor with 25~530 ㎑ bandwidth had the best overall sensitivity, especially for the leak rate below 1 ㎖/min. The signal spectrum of sensor with 25~530 ㎑ bandwidth is shown in Figure 3. Using an S1 sensor, Figure 4 shows the variation of AE signals with leak rate at several different pressures. The vertical axis is the ratio of signal noise level in mV, as a RMS value. It is shown that the slope or exponent, S, varies with both the leak rate and the pressure difference, ranging from 1.0 to 3.0. The minimum leak rate detectable with pressure difference higher than 8 kgf/cm^2 was about 1.5 ㎖/sec. This value is quite small compared with other reported data.

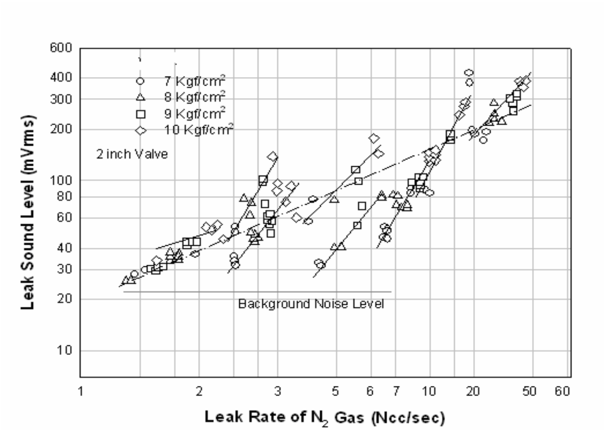

Figure 4. Plot of leak rate vs. acoustic signal amplitude detected by S1 sensor for four different pressure levels

6. Conclusion

Compared with other leak detection techniques, acoustic emission methods give strong advantages in regard to leak location, continuous on-line surveillance, high sensitivity, quick response time, monitoring hard-to-access locations, and potential estimation of leak rate. Many successful applications of AE techniques have demonstrated these advantages. The specification required for can also be met with this method.

Effectively applying acoustic detection methods requires full characterization of the particular leak signals, including the frequency spectrum, attenuation, and minimum leak rate detectable under given test conditions. Using results obtained through this study, an optimum detection system can be set up for either short-term proof tests or long-term surveillance.

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