INVESTIGATION ON AE SIGNAL/NOISE PROCESSING IN CORROSION DAMAGE EVALUATION OF TANK BOTTOM

ZHENGWANG LI 1, SHIGENORI YUYAMA1, MINORU YAMADA2, KAZUYOSHI SEKINE3, SHIGEO KITSUKAWA4, HIROAKI MARUYAMA5 and SHIGEO KONNO6
1) Nippon Physical Acoustics Ltd., 8F Okamoto LK Bldg., 2-17-10, Higashi, Shibuya-ku, Tokyo 150-0011, Japan; 2) National Research Institute of Fire and Disaster, Mitaka, Tokyo 181-8633, Japan; 3) Yokohama National University, Yokohama, 240-8501, Japan; 4) High Pressure Institute of Japan; Chiyoda, Tokyo 101-0025, Japan; 5) Japan Oil, Gas and Metals National Corp.; Bunkyo, Tokyo 112-0002, Japan; 6) Petroleum Assoc. of Japan, Chiyoda, Tokyo 100-0004, Japan

Abstract

Acoustic emission (AE) testing based on database consisting of test procedures and evaluation criteria has been widely used in Europe for the evaluation of floor conditions (corrosion damage) in above-ground tanks. Since the test procedures were introduced to the Japanese industry in 1999, fundamental studies in laboratory and field applications have been made by several organizations. In performing AE field testing, various environmental noise caused by rain and wind are unavoidable. This paper discusses a method of AE signal/noise processing in corrosion damage evaluation of tank bottom, based on the field tests conducted on more than 70 tanks in Japan.

Keywords: Tank bottom testing, Corrosion damage, Noise

1. Introduction

In recent years, much attention has been paid to the possibility of applying AE test to evaluate corrosion damage of tank bottom, as an alternative in-service monitoring method [1]. In Europe, AE testing has been made for more than 1000 tanks per year as a cost-effective maintenance planning tool, based on the database [2] built by AE inspection of several thousands oil storage tanks. This technique was introduced to the Japanese industry in 1999. Since then AE field tests have been carried out on more than 70 tanks with different diameters by three research groups. Intensive works have been made of AE test procedures, data evaluation methods, and so forth [3].

This paper discusses about a method of AE signal/noise processing in corrosion damage evaluation of tank bottom, based on the tests conducted in Japan. It summarizes test results from the research project of High Pressure Institute of Japan (HPI), sponsored by the National Oil Corporation of Japan.

2. Case Studies - Noise in Tank

When applying AE testing to tank bottom evaluation, it is essential to discriminate valuable AE signals from other noise. However, since AE signals from corrosion are usually very weak, the AE testing system is set to very high sensitivity, resulting in data including possible noise. Moreover, since oil storage tanks are in the outdoors, various environmental noise due to rain, wind and, in addition, EMI are unavoidable.
Here, case studies, based on examples of AE data showing typical environmental noise, are demonstrated and a method of AE signal/noise processing is discussed.

2.1 Noise due to Wind

It has been demonstrated that the influence of wind generally appears at a wind speed of greater than 4 m/sec. Under the maximum wind speed of 10 m/sec, a source location result of wind noise is shown in Fig. 1. Event location exhibits a radial pattern, spreading from the center of the tank. Although it is possible to install a wind gauge and to record the output as an external parameter of AE measurement in order to monitor wind speed, the data might be different between tank circumference and the place where the gauge is installed. The wind speed is quite different around the tank, depending on the location where it is monitored. Because of this, it is often very difficult to filter wind noise by post-test analysis. However, the noise resulting from a sudden speed change can be filtered by post-test analysis, based on wind data monitored in real time. Figure 2 shows an example of such wind noise. The periods when wind speed exceeded 6 m/sec are indicated by the boxes, which show a good correlation with very high AE activities.

![Fig. 1 AE source location based on TANKPAC procedure for AE data collected under strong wind (Crude oil tank, 82 m in diameter).](image)

2.2 Noise due to Rain

As shown in Fig. 3, noise due to rain usually produces AE signals with large amplitudes over 80 dB. Source locations resulted from rain noise are spread evenly all over the whole region of
Fig. 2 History of AE hit rates (upper) and wind speed (lower), observed in a crude oil tank (83.3 m in diameter). High AE activities correspond to strong wind indicated by the boxes.

the tank bottom and clusters can be seen in some areas. Moreover, the noise does not stop until rainwater on the tank roof flows out completely. Especially, in a case of a large tank with a diameter of 80 m, the influence may remain for more than 24 hours. An example of rain noise, measured 24 hours after the rain had stopped, is given in Fig. 4. Source location indicates linearly spread cluster, which can be attributed to flow of rainwater in a drainpipe.

Fig. 3 Source location (left) of AE data collected in a product tank (12 m in diameter) under rain. Amplitude and hit rate history are also demonstrated.

2.3 Noise from Bird Movement on Tank Roof

As seen in Fig. 5, many signals were detected, showing high AE hit rates, for a period from 2600 seconds to 2700 seconds. Since several crows were seen to move on the tank roof during this period, the sudden increase of AE signals was attributed to the movement of the birds. Although most of such noise can be filtered by post-test analysis, it is important to pay attention to the situation around the tank to identify such noise in real time.
Fig. 4 Noise due to water flow in a drainpipe, observed 24 hours after rain stopped (Crude oil tank, 82 m in diameter).

Fig. 5 Noise due to movement of birds on the tank roof (Crude oil tank, 61 m in diameter).
Fig. 6 Source location of AE data including signals due to water drops from the tank roof (water tank, 17 m in diameter).

Fig. 7 Source location of filtered AE data excluding signals due to water drops from the tank roof (water tank, 17 m in diameter).
2.4 Condensation Dripping in the Tank

Signals resulted from condensation dripping in the tank can be removed by using two rows of sensor array. Figure 6 indicates a source location result including condensation-dripping noise. 842 AE sources are detected and some clusters are observed. After signals attributable to condensation-dripping noise were filtered, only 80 AE sources remained and clusters disappeared, as seen in Fig. 7.

2.5 Pipe Vibration Noise due to Pump Operation

To perform AE testing properly, tanks must be set in quiet situation. Therefore, it is necessary to stop operation of pumps connected to the tank through pipes. Figure 8 shows amplitude and hit rate history indicating noise from strong pipe vibration. It should be noted that even if the threshold was set to 58 dB, many signals around 60 dB were detected, produced by pipe vibration. On the other hand, Fig. 9 gives results obtained under a threshold of 48 dB when pipe vibration was weaker than that of Fig. 8. It should be noted that all noise may not have been filtered due to continuous signals from the vibration. Therefore, in order to avoid such noise, it is necessary to stop pump operation near the tank during the test period.

2.6 Periodic Noise

In the case of a tank with dome roof, the inner pressure of the tank changes, depending on outside temperature. Nitrogen gas is charged or discharged in order to maintain a constant pressure. As shown in Fig. 10, the injection of nitrogen gas generates periodic extraneous noise. Note that nitrogen gas was charged at an interval of about 60 seconds and high noise continued for about 18 seconds. Such periodic noise can be identified by installing a guard sensor to detect signals beyond 90 dB in amplitude (Fig. 10) near the injection pipe of nitrogen gas. These noise can be filtered by post-test analysis. However, it is recommended that AE test should be carried out at a time when the atmospheric temperature is stable, so that the interval of gas injection becomes as long as possible.
Fig. 9 Amplitude (upper) and hit rate (lower) history for the data after having filtered noise due to vibration of pipes by setting threshold at a high level (Corn roof tank, 11.6 m in diameter)

Fig. 10 Amplitude (upper) and hit rate (lower) histories, showing periodic noises due to pressure control by nitrogen gas injection (Dome roof tank, 13.5m in diameter).

2.7 Unidentified Noise (I)

When performing AE test, high AE activities are sometimes observed in a certain channel. One-hour monitoring was conducted three times in a crude-oil tank for two days. As shown in Fig. 11a to Fig. 11c, one of the three channels exhibits very high AE activities as compared to others. Although the source of these signals is not clear, it is very likely that they should be attributed to unidentified noise.

Although one hour monitoring is usually enough to perform tank bottom evaluation, it is necessary to extend testing time in order to obtain meaningful data when high AE activities are observed due to unidentified noise.
Fig. 11a Amplitude (upper) and hit rate (middle-upper) history of AE signals detected at other channels than CH-1 and the same for CH-1 during the first test (Crude oil tank, 82 m in diameter).

Fig. 11b Amplitude and hit rate history observed during the second test. High AE activities due to noise are observed at only CH-18 (Crude oil tank, 82 m in diameter).

Fig. 11c Amplitude and hit rate histories observed during the third test. High AE activities due to noises are observed at only CH 20 (Crude oil tank, 82 m in diameter).

2.8 Unidentified noise (II)

Shown in Fig. 12 is discontinuous noise generated in more than two channels for certain periods. Although, many signals were detected for six periods (about 620 s to 680 s, 700 s to 1000 s, 1160 s to 1620 s, 3860 s to 4030 s, 4180 s to 4230 s and 4380 s to 4503 s), the AE source that produced them could not be identified. Meanwhile, these signals were different from those resulted from condensation dripping. Furthermore, as shown in Fig. 13, source location showed no AE clusters in this case.
Fig. 12 Amplitude (upper) and hit rate (lower) history observed in a water tank (17 m in diameter). Strong noise detected during a certain period (1,160 - 1,620 s) by multiple sensors.

Fig. 13 Source location of AE data detected during 1160-1620 s in the water tank (17 m in diameter). No cluster observed in the figure.
The AE signals due to corrosion do not show such AE behavior. Therefore the above high AE activities were considered to be unidentified noise and meaningful AE signals observed in other periods were used for the evaluation.

3. Conclusion

Since AE signals due to corrosion are usually very weak, AE system is set to very high sensitivity, which very often results in detection of useless noise. Therefore, discrimination of meaningful signals from noise is essentially important in performing field test. Great care must be taken during AE tests by experienced inspectors to avoid unnecessary noise in real time.

References

