Condition Monitoring of Aboveground Storage Tank Using Acoustics Emission Testing – Field Testing

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Abstract

This paper presents a condition monitoring technique of a storage tank using Acoustics Emission Testing (AET) based on time domain. The acoustics emission (AE) signals were acquired from the storage tank in field testing to monitor the corrosion activity and potential leak activity of the aboveground storage tank. The storage tanks had diameter of 33 meter with product level equal to 70%. The feature of AE related with characteristics of corrosion signal such as amplitude, hits, duration time, rise time and count. These parameters can be used to identify and to separate a group of signals for condition grading based on risk matrix combination for tank inspection assessment. The AET techniques can be used to detect the active corrosion and potential leak to apply for a large storage tank monitoring. This study may be used to compare the result with other NDT techniques such as magnetic flux leakage (MFL) to verify and to map the event location of AE signal.

Keywords: condition monitoring, acoustics emission testing, corrosion, leak, storage tank

1. INTRODUCTION

The acoustics emission testing (AET) is the method for nondestructive testing (NDT). AET was applied in many fields for material structure degradation [1]. In real condition, the bottom plate of aboveground storage tanks remain a most difficult part of the storage tank and pressure vessel to inspect for corrosion damage. Typically, the opening tank for internal inspection was used to inspect the tank bottom using convention nondestructive testing and the products were removed for tank empty. The costs of internal inspection including cleaning, purging and loss of production availability create a significant financial burden for the tank owner or operator.

Now, the advanced NDT methods with the capability of assessing the condition of the tank floor without opening the tank that is acoustic emission testing (AET) in order to monitor the tank floor. The AE method requires installation of the sensors on the outside wall of the tank and monitors the tank floor passively for corrosion damage and its extreme case of leakage at substantially lower cost. The AET can be holed product at 50%-90% level of storage tank it provides both an enhanced level of tank reliability and significant cost saving over time–based periodically [2]. This paper provides an overview of the AE inspection methods as applied to aboveground storage tank (AST), a brief description of its use in a condition based maintenance program including a case study of the practical use of AE monitoring for tank bottom inspection [3].

2. ACOUSTIC EMISSION TESTING (AET)

Acoustic emissions are stress waves produced by sudden release of the energy in stressed material. Classic acoustic emission sources include defect related deformation processes such as crack growth and plastic deformation [2] that release of elastic energy some of which is converted to stress wave propagation in which move on the surface of structural element. Leaking gases and liquids also cause acoustic emission. In the case of aboveground storage tanks (AST), the sources of interest are the fracturing of corrosion product as an indication of corrosion emission from tank bottom [3].

The sensors, typically piezoelectric, mounted on the external surface of the outside wall of the tank near its base or tank bottom to detect these stress waves and output an electrical waveform that contains information about the source of corrosion [4]. Acoustic emission signals original in the material itself from active or propagation defects whereas most other methods such as radiography and ultrasonic testing detect geometrical discontinuities, active or not emission from defects is excited by applying a load. The most AE tests are carried out under controlled simulation using systematically increasing mechanical or thermal loading. In the case of tank bottom, the fluids load in the tank is used to excite the emission and monitoring is carried out over a prescribed time interval [5]. The remote monitoring capability allows the whole volume of the structure to be inspected globally and non-intrusively as the emissions travel from the active defect through the liquids in the tank to remote sensors on the outside of the tank. It is not necessary to scan the structure point by point or scanning the structure looking for local defects [1]. This leads to major savings in testing time and the global AE inspection is used to identify areas with structural damage or deterioration and other NDT methods are then used to identify and fully characterize them, if necessary, in terms of shape, orientation and size.

AET is a powerful method for NDT and material evaluation. Other NDT techniques such as radiography and ultrasonic detect geometric discontinuities into the structure. AE can detect microscopic movement, not geometric discontinuities. The definition of AE is the class of phenomena of transient stress/displacement waves are generated by the rapid release of the energy from localized sources within a material and produce the transient wave [1]. Other terms that have been in AE literature include (1) stress wave emission, (2) microseismic activity and (3) emission or acoustic emission with other qualifying modifiers. AE techniques have been used in many applications such as in material degradation [6], leak and flow [7]. The growing defect makes its own signal and the signal travels to the detecting sensors. The main benefits of AE compared to other NDT methods that AE is a real-time methods and non-intrusive methods. The discontinuities of defects can be detected by AE at an early stage when they are occurring or growing. The AE requires a sensor to access only. In order to detect AE event, a transducer is required to convert the very small surface displacement to a voltage as small as 10^{-14} m. [8] detected by the use of the most sensitive. The couplant is needed for good transmission and achieved by ultrasonic couplants together to maintain contact surface.

3 ACOUSTIC EMISSION WAVEFORM

The parameters of AE are used to analyze such as Hit, Event, Count, Energy, RMS, Duration Time and Rise Time. These parameters are used to separate and classify in the corrosion process. The typically signal has two types. First, the burst signal, the transient wave pattern, is predicted an active corrosion process as shown in figure 1. Second, the continuous signal has a long duration time such as background noise signal.

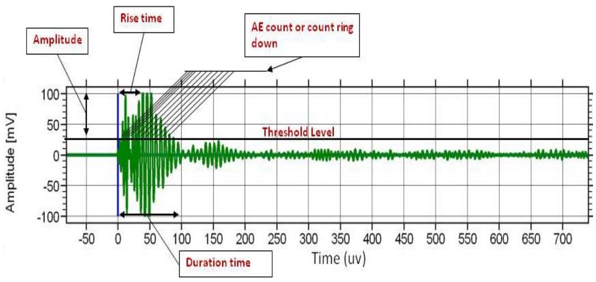

Fig.1 The characteristic of AE parameters [9]

AE event count is the number of times that the burst signal crosses a preset threshold and AE event rate is the time rate at which AE event counts occur. **AE count** or ring down count is the number of times the burst signal amplitude exceeds the preset threshold and count rate is AE count per unit time.

Rise time is the time interval between the first threshold crossing and the maximum amplitude of the burst signal. **Decay time** is the time interval between the maximum amplitude and the last time that the burst signal exceeds the preset threshold. **Signal duration** is the time interval between the first and the last threshold crossing of the burst signal. **AE energy** is the measurement of the relative energy of an AE signal, which is calculated from the area under the envelope of the square of the signal. **RMS AE** is the energy rate or the root mean square of voltage, which is generally an indicator of average AE energy over each averaging time. The number of counts (N) can be calculated by R. K. Miller, 1987.

$$N = \frac{\omega}{2\pi B} \ln \frac{V_o}{V_i} \qquad (1)$$

Where ω is frequency response, B is decay constant, V_0 is initial signal amplitude, V_i is threshold voltage of counter. AE rms can be defined as

$$V_{RMS} = \sqrt{\frac{1}{T}\int_0^{\tau} V^2(t)\,dt} \qquad (2)$$

Where $V(t)$ is signal voltage function, T is period of time. **AE Hit** is the detection and measurement of an AE signal on a channel [1].

4 DATA EVALUATION

The result in previous paper [9], The AE signal interpretation of the tank bottom is a system which can separate a good tank from a bad condition and so direct maintenance to where it's most needed. Basic input from a maintenance management point of view is the overall condition of the tank bottom plate expressed as an overall tank grading. The grading was developed first by analyzing the acoustic emission data accumulated during a two-hour monitoring period to identify and locate overall corrosion and potential leak activity. Special filter separate corrosion and leak data from the total data set and the location of these data are displayed on a plan view of the tank bottom. After the analysis and interpretation, the acoustic activity in category as:

Category I: The overall corrosion grading (OCG) was graded A to E in table 1.

Category II: The potential leak grading (PLG) was graded 1 to 5 in table 2.

The potential leak grades 1 through 5 are based on the number of active acoustic emission events emitted from any one cluster of acoustic emission activity. The data is characteristic of severe localized corrosion damage, grade A including no or minor damage and grade E including a highly active location. Not actual leakage, but a future “potential leak” location.

The combination categories of the overall corrosion grade (OCG) and the potential leak grade (PLG) that gives the tank owner the composite grade and thus, the reference on the time recommended before the next inspection, based on the Tank Bottom Risk Matrix in table 2. [10]. When the maintenance was planned by recommendations are expressed in Table 3, in terms of the AE retest interval, varying from 0.5 to 4 years with increasing AET grading. In term of follow-up recommendations it is mentioned that the AE information should always be combined with the other (historical) information available.

Table 1 Condition Corrosion Grading

Overall Corrosion Grading	Tank Bottom Condition
A	Very minor/ No damage
B	Minor Damage
C	Intermediate Damage
D	Active Damage
E	Highly Active Damage

Table 2 Tank Bottom Risk Matrix

	OCG				
PLG	A	B	C	D	E
1	I	I	II	II	II
2	I	I	II	II	III
3	II	II	III	III	III
4	II	III	III	IV	IV
5	III	III	IV	V	V

Table 3 Assessment Recommendation

Category Grade	Next Inspection (Years)
I	4
II	2
III	1
IV	0.5
V	Require Internal Inspection

Furthermore direct classification of condition in terms of AE data, the latter data provide valuable input into more detailed risk-informed, inspection based maintenance management decision making on whether to repair the damage or defection, repair the tank bottom plate or re-monitor at a later date.

This strategy of short-term AET of Aboveground Storage Tank (AST), allows both early detection of significance and intensity of the damage, and aids the development of cost-effective priority based maintenance procedure depending on actual damage and its significance for structural integrity of the storage tanks. AET was complemented by in-service history and experience and integration of this information with Fracture Mechanics and assessment providing a sound basis for responsible care of the tanks [10].

5. EXPERIMENT

The example for the standard sensor arrangement equally distributed along the circumference of storage tank and high of one meter above the tank foundation as shown in figure 4 in side view. The used sensor is the VS30-SIC-46dB of Vallen-System, which has flat response especially with in the used bandwidth centering at 30 kHz using filter during 25-45 kHz [5]. The sensitivity of each measuring channel is checked with the Hsu-Nielsen source before the test [8]. The AE system is an AMSY-5 of Vallen-System, Which is capable of acquiring AE data simultaneously for each channel. It has an internal pulsing unit, which sends on request an electric pulse to a sensor.

The AE system measures the time period for travelling from the emitting to the receiving sensor and that gives together with the distance between emitter and receiver the speed of sound. The software for data acquisition, visualization and frequency analysis are also provided by Vallen-Sytem with VisualAE™ 2D and 3D plots may be produced to show the tank floor activity in order to identify that may be both leakage and corrosion.

Fig. 2 Diesel Oil Storage Tank

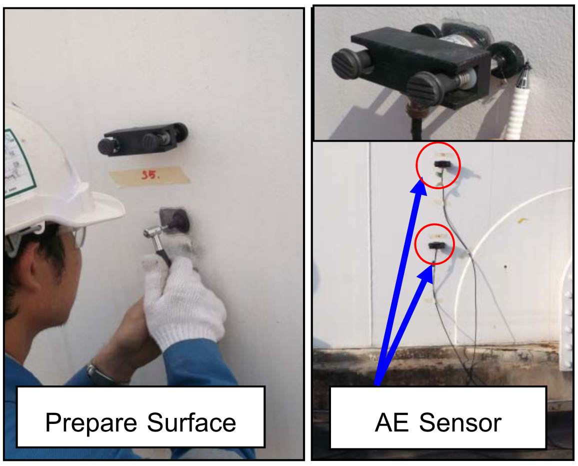

Fig. 3 preparing surface and clamping sensor

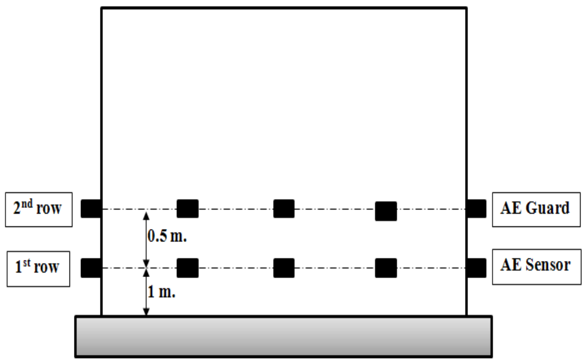

Fig 4 position of sensor around tank

Tank Description:

Tank ID:	Diesel Oil Tank
Year of built:	1999
Dimensions:	33 m diameter
Product:	Diesel Oil
Product Level:	> 70%
Product Temp:	$30\,C^{\circ}$
Capacity:	10,771 m^3
Base:	Concrete
Roof:	Fixed
Insulation:	No

Before mounting sensor, the painting surface on tank wall are removed by polishing as shown in figure 3. Then, the sensors are mounted by magnetic clamp on tank wall as shown in figure 4. This work, the senor was used to mount on the wall of 12 sensors with 6 guard sensors shown in figure 4. These sensors must be attached at tank wall.

6. RESULT AND DISSCUSION

The data testing included 3,769,172 AE hits, the signal was detected by one sensor, and 1,242 AE events, the signal was detected by threes sensor at the same time, was located in the two-hour period testing.

The total of 1,242 events was calculated corresponding to an overall tank floor condition inspection shown in figure 5. The point represents a source location that was calculated by source location equation of VisualAE software. In addition, the figure illustrates a cluster of data group to represent a cumulative signal activity during period testing. The overall activities of tank condition shown in figure 5(A) 3D histograms and figure 5(B) correlation location with cluster of AE Event location.

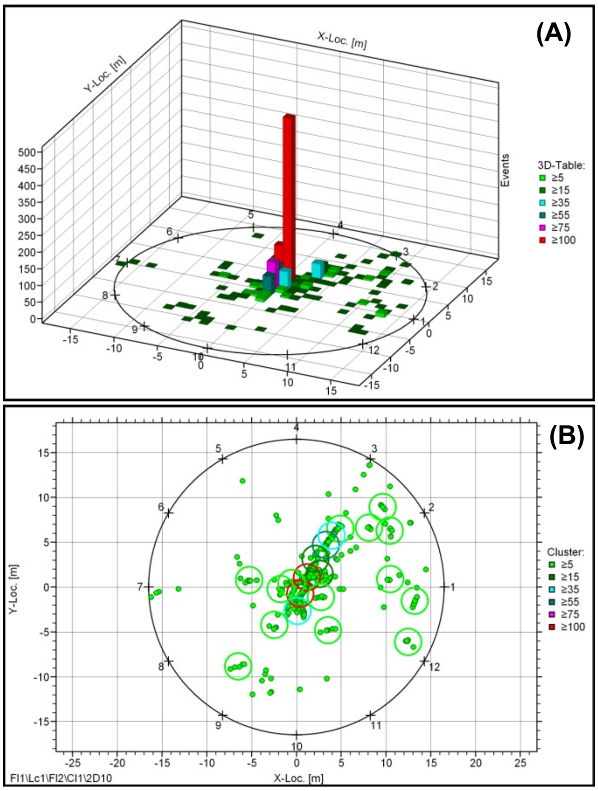

Fig. 5 the Overall Tank Activity (A) 3D Histogram & (B) 2D Correlation Location

The small circle as shown figure 5(B) is the group of cumulative data that appear repeatedly at same location.

After using noise removal with normalization (2 hour test) and filtering data pattern [9], the event of 372 events was calculated and analysed approximately of 30% corresponding to Overall Corrosion Grading (OCG) of "C" to follow table 1 that was shown in figure 6 (A)-(B). The results are illustrated the source location of active corrosion during testing. The result can be used to evaluate the tank floor condition when can be seen the location of AE Event and lead to evaluate the material degradation. The 30% was

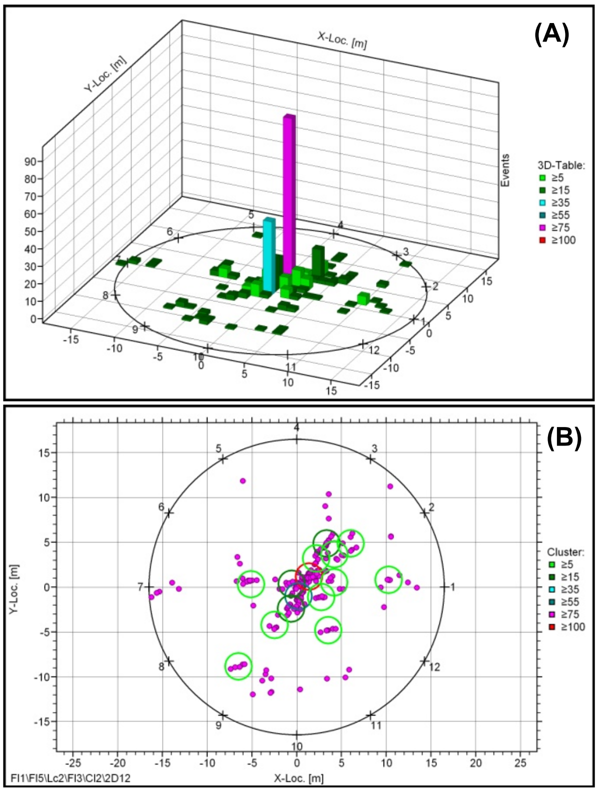

Fig. 6 corrosion activity (A) 3D Histogram & (B) 2D Correlation Location

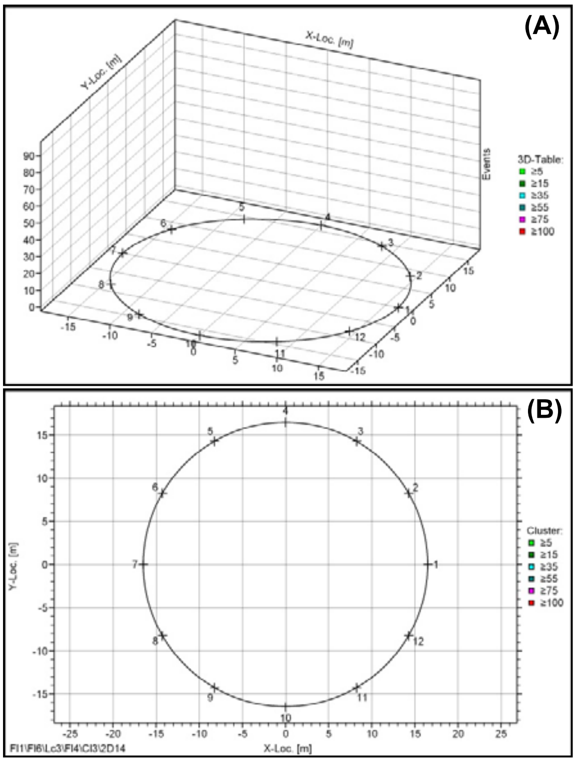

Fig. 7 Potential Leak activity (A) 3D Histogram & (B) 2D Correlation Location

evaluated by the Burst Signal Pattern of the overall activity AE Signals using the parameter of two type signal between burst signal and continuous signal. The active corrosion signal can be generated signal as burst signal. It has the characteristics such as AE during time $\leq 5000 \mu s$, AE Rise time $\leq 500 \mu s$, AE Count ≤ 100 and AE Energy. These parameters acquired of laboratory testing. [9] On the contrary, the continuous signal had the characteristics opposite to the burst signal in all of parameters. Thus, the evaluation data can be set the characteristics into the software VisualAE used for data evaluation.

Moreover, the potential leak events was evaluated and analysed less than of 1 % corresponding to the potential leak activity from the total AE hits and AE Events after analyzed processing shown in figure 7. This tank was rated with The Potential Leak activity grading of “1” because the AE Event couldn’t appear the source in tank bottom. The AE Event of Potential Leak cannot illustrate in figure 7 because data group was filtered by a group of Continuous Signal Pattern of AE Signal. As shown in figure 7. Tank Bottom Risk Matrix was used to classify the level of activity within the two-hour test period when combined the two grading from table 3 for result interpreting. As the result, the evaluation data was concerned for the two types pattern that were the typical signal detected for consideration when the noise was removed.

Thus, Diesel Oil Tank, the tank received Category of “C-1” and The Combination Grade of “II” of *Minor Damage* Condition to repeat inspection within two years.

7. CONCLUSIONS

Acoustics Emission Testing (AET) can be used to monitor the active corrosion and leakage location of storage tank in petrochemical industry plant. The AET techniques have many benefits such as the product can hold in storage tank. The owner isn't losing cost for transfer product or remove product to another place and not only can save cost but also can save time for inspection.

The Storage Tank Inspection has been used successfully on a large number of tanks to access tank floor condition and to identify corrosion damage and leaks. Its role in inspection condition based maintenance management is as screening techniques for front-line input to risk-informed decision making. This correlation is enhanced using in-service tank maintenance history and AE grading as input to the decision making on recommended follow up actions and prioritizing tanks for allocation of maintenance resource.

8. Acknowledgement

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