Comparison and Analysis of Oil Tank Test Results by PAC and Vallen Acoustic Emission Instrumentations

Shijie Zhang1*, Meng Pan2, Zhi He2, Di Deng2, Jiakai Han2

1Tianjin Research Institute for Water Transportation Engineering, M. O. T., Tianjin 300456, China
2Tianjin Dongfang Tairui Technology CO. LTD, Tianjin 300456, China
e-mail: panmeng, hezhi, dengdi, hanjiakai@tk-aq.com
e-*mail: zhangshijie@tk-aq.com

Abstract In this article, two acoustic emission instruments, PAC and Vallen acoustic emission instruments, are applied to carry on the test of crude oil storage tanks. Four experiments contents have carried out such as active defect test, corrosion test, vibration test, leak test. And compare and analyze the acoustic signal characteristics of the above four detection contents of two acoustic emission instruments. The differences and advantages and disadvantages of the four detected acoustic signals of the two acoustic emission detectors are summarized. The research results provide certain basic test support for the improvement and development of acoustic emission testing equipments and supporting software.

1. Introduction
The large-scale construction of port crude oil storage tanks promotes the rapid development of China's economy, but also brings potential accident risks. Storage medium with high temperature and high pressure, high corrosion resistance and other characteristics, the tank wall and bottom are prone to corrosion, fatigue, or due to the expansion of potential defects in damage, such as when the corrosion reaches to a certain extent, can cause serious accidents such as leakage and explosion, caused a great loss to people's lives and property, serious environment pollution and destruction of ecological balance hinder the sustainable development of national economy. Periodic inspection is a necessary measure to ensure the safe operation of oil storage tanks. Many potential accidents can be detected and eliminated through periodic inspection of oil storage tanks in service [1]. At present, the periodic testing technology of storage tank includes non-destructive testing method for opening the tank and non-destructive testing method on line. Acoustic emission detection technology has unique advantages over other non-destructive testing methods or technologies, such as dynamic testing, defect sensitivity, overall detection and evaluation, etc. [2,3]. Since the 1990s, the research and application of acoustic emission detection technology in China have been developing rapidly.

At present, China's domestic acoustic emission detector is mainly used in university teaching, laboratory demonstration and other civil departments' material research and small part detection, which cannot guarantee the accuracy requirements in actual detection, and is more difficult to be used in the detection of large components. In China, acoustic emission research and tank testing are mainly carried
out by PAC acoustic emission instrument. In addition, a small number of domestic research institutions and units use Vallen acoustic emission instrument for basic research.

In this paper, PAC acoustic emitters and Vallen acoustic emitters, which are widely used in China, are selected for comparative tests to explore the advantages and disadvantages of the two instruments in tank detection projects such as corrosion, active defects, vibration and leakage.

2. Test scheme design

2.1 Acoustic emission equipment and test tanks
The two acoustic emitters selected are respectively Sensor Highway III of PAC and AMSY 6 of Vallen.

The test tank is simulated. The design parameters of the simulated tank are the tank bottom plate diameter of 600mm, height of 700mm, thickness of 4mm, and the corrosive medium is the deposited water of the port crude oil tank (Fig.1).

2.2 Sensor arrangement
Two instrument layout on the sensor (see figure 2), the No. 1, No. 2 position for Vallen’s sensors (including No. 1 position sensors for No.1, No.2 position sensors for No.2), the No.3, No.4 position sensors for PAC’s sensors (including No.3 position sensors for No.1, No.4 position sensors for No.2).

2.3 Threshold setting
The threshold is 30dB (under laboratory conditions).

2.4 Test items
The test items have corrosion test[5], activity test[6], leakage test[7] and vibration test[8] respectively.

In the activity test, the simulated source (broken lead) was used to replace the activity defect. According to the standard Nondestructive testing of pressure equipments - Part 9: & emission testing (NB/T 47013.9-2012), 5.3.2 simulation source: with analog calibration source to test the detection sensitivity and location. The simulated source should be able to emit elastic waves repeatedly. Acoustic emission signal generator can be used as the simulation source, and the broken signal of pencil core with a hardness of 0.3mm and 2H can be used as the simulation source (broken lead). The extension length of the lead core is about 2.5mm, the Angle between the lead core and the surface of the tested piece is about 30°, and the lead core is broken away from the center of the sensor (100±5) mm. The response amplitude should be taken as the average of three or more responses. That is, the elastic wave emitted by the active defect is similar to the elastic wave emitted by the simulated source, and the simulated source can be used to replace the active defect.
The tank leak detection is carried out by simulating the opening and closing of the faucet on the side wall at the bottom of the tank. The whole process is from intermittent dripping, rapid continuous dripping, continuous flow of the leaking liquid, and then to the process of stopping the leakage.

The vibration of the tank is detected by striking the simulated tank wall. A small hammer was used to simulate the tank wall near the measurement point of the storage tank, and the frequency of striking was changed to observe the change of the collection signal, such as one time striking, several times striking, multiple times striking, continuous striking, etc., with obvious interval time left in the middle.

3. Test results

3.1 Corrosion test

As can be seen from the Fig.3, Vallen can detect the corrosion signal of the storage tank, and the amplitude of the corrosion signal is mainly distributed between 30dB and 60dB, rarely more than 60dB.

![Fig.3 Vallen corrosion test results](image1)

As can be seen from the Fig.4, PAC can detect the corrosion signal of the storage tank, and the amplitude of the corrosion signal is mainly distributed between 30dB and 60dB, rarely more than 60dB.

To sum up, PAC’s detection effect on tank corrosion is similar to that of the German Vallen acoustic emission instrument. In other words, PAC’s detection effect on corrosion is at the same level as that of the Vallen acoustic emission instrument.

3.2 Active test

Lead breaking was carried out for 4 times, respectively at measuring points 4, 3, 2 and 1.

It can be seen from the Fig.5 that the amplitude of the two channels of the Vallen acoustic emission instrument is the same as that of the detection result of four lead breaks, which is nearly 88dB (no obvious size change).

As can be seen from the Fig.6, the detection results of 4 lead breaks are obviously different in the 2 channels of PAC, and the detection results of 4 lead breaks in each channel are also different. At the same time, except that the amplitude detected by 1 channel for the first lead break is less than 90dB, the amplitude detected by other channels is all greater than 90dB.
3.3 Leak test
As can be seen from the Fig.7, the detection results of the Vallen acoustic emission instrument well reflect the process of leaking liquid from intermittent dripping, rapid continuous dripping, continuous flow, and then to stop leaking, and the above process is obviously distinguished. And when the leak stops, no signal appears.

It can be seen from figure 8 that the detection results of PAC well reflect the process of intermittent dripping, rapid continuous dripping and continuous flow of leaking liquid, and the above process is obviously distinguished. And when the leak stopped, there were still signals.

By comparing the test results of the two instruments, when the leakage started, both instruments had signals. Both instruments can clearly reflect and distinguish the process of intermittent dripping, rapid continuous dripping and continuous flow of leaking liquid. When the leak was stopped, the test results of the two instruments were significantly different. Vallen had no signal, but PAC still had a signal (lasting a certain time).

3.4 Vibration Test
As can be seen from the Fig.9, the detection results of Vallen acoustic emission instrument clearly distinguish the percussion frequency, and as the percussion frequency increases, signals with high amplitude begin to appear intensively, with the maximum amplitude approaching 90dB.
As can be seen from Fig.10, PAC has a distinct distinction on the percussion frequency, and a signal with a high amplitude appears from the beginning of percussion, with the maximum amplitude approaching 80dB.

By comparing the test results of the two instruments, the vibration of the storage tank can be detected by the two instruments, and the striking frequency is obviously distinguished. The signal with high amplitude appeared from the beginning of vibration, and the maximum amplitude of the signal with high amplitude was less than 80dB. However, Vallen high-amplitude signal appeared later, only when the frequency of vibration was higher, and the amplitude of high-amplitude signal was significantly larger than that of PAC detection result. In other words, PAC could easily tell when the vibration started from the test results, but Vallen acoustic emission instrument could not.

Fig.9 Vallen Vibration Test results  Fig.10 PAC Vibration Test results

4. Discussion

Through the test, the following results were obtained (Table 1 and Fig.11):

Table 1 PAC and VALLEN were compared for comparative analysis

| Test Items   | Vallen                                                                 | PAC                                                                 |
|--------------|------------------------------------------------------------------------|----------------------------------------------------------------------|
| Corrosion    | 30dB ≤ peak amplitude ≤ 60dB, 60dB rarely appears.                   | 30dB ≤ peak amplitude ≤ 60dB, 60dB rarely appears.                   |
| Active Test  | All peak amplitudes are nearly 88dB.                                   | All peak amplitudes are greater than 90dB except one.                |
|              | PAC is more sensitive to distance, reflects that PAC's positioning is more accurate. |                                                                       |
| Leak Test    | Leak at various stages clearly distinguish, leak stop immediately no signal. | Leak at various stages clearly distinguish, leak stop immediately still exists signals. |
|              | VALLEN is more sensitive to leak stopping.                             |                                                                       |
| Vibration    | The frequency of vibration is clearly distinguished, and the higher frequency of vibration is the higher peak amplitude. | The frequency of vibration is clearly distinguished, The high peak amplitude occurs from the moment the vibration is generated |
| Test         |                                                                       | It's easy for PAC to judge out when to start vibrating.             |

For corrosion test, the detection results of the two acoustic emission instruments are similar. The amplitude of the acoustic signal is mainly distributed between 30dB and 60dB, and the signal with the amplitude greater than 60dB is rarely seen. PAC's detection effect on tank corrosion is similar to that of the German Vallen acoustic emission instrument, in other words, PAC's detection effect on corrosion is at the same level as that of the Vallen acoustic emission instrument.

For the activity defect test, the results of the four tests showed that the amplitude of Vallen’s acoustic signal was the same and about 88dB, and the amplitude of PAC's acoustic signal was different and was mainly above 90dB. That is to say, PAC is more sensitive to the distance of active defects, while Vallen
is relatively weak, which reflects that PAC is more sensitive and accurate to the location of active defects, while Vallen is relatively poor.

In the leak test, PAC and Vallen's test results well reflect the process of intermittent drip, rapid continuous drip, continuous flow, and stop leakage, and clearly distinguish the above process. However, when the leakage was stopped, the test results of the two instruments were significantly different. Vallen had no signal, but PAC still had a signal that appeared and lasted for a period of time. That said, Vallen has a higher sensitivity to stopping leaks.

In the vibration test, PAC and Vallen's test results clearly distinguished the percussion frequency. The signal with high amplitude appeared at the beginning of vibration generation, and the maximum amplitude of the signal with high amplitude was less than 80dB. However, Vallen high amplitude signal appeared later, only when the frequency was higher. That said, it's easy to tell when the vibration started from the PAC results, but Vallen can't.

### Fig. 11 The PAC and Vallen contrast

|                  | Corrosion test | Active Defect Test | Leak Test | Vibration test |
|------------------|----------------|--------------------|-----------|----------------|
| Similar          | PAC Vallen     | PAC Vallen         | PAC Vallen| PAC Vallen     |
| Positioning      | Positioning    | More sensitive     | More sensitive|
| more accurate    | PAC Vallen     | to leak stopping   | to leak stopping|
|                  | PAC Vallen     |                    |           |
|                  | PAC Vallen     |                    |           |
|                  | PAC Vallen     |                    |           |
|                  | PAC Vallen     |                    |           |

Five test items were compared and analyzed

### 5. Conclusion

Through comparative experimental analysis, PAC and VALLEN acoustic emission apparatus have their respective advantages in corrosion test, activity test, leak test and vibration test. Among them, corrosion test results of the two types of acoustic emission instruments are similar, PAC is more accurate for positioning and vibration start, and VALLEN is more sensitive to leak stop.

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