Using Hilbert-Huang Transform to Process and Analyze the Corrosion Acoustic Emission Signal of the Tank Bottom Plate

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Abstract. In this article, Hilbert-Huang transform (HHT) is applied to the tank bottom corrosion acoustic emission signal de-noising processing and decomposition, the effective signals are explored and extracted, and a new method of noise reduction for acoustic emission signal is proposed. The acoustic emission signal of corrosion of tank bottom plate is processed and decomposed by Hilbert-Huang transform, and the energy ratio of each sub-signal in the original signal is calculated, the source data of each sub-signal is extracted, and the effective acoustic emission signal in the original signal is extracted. Using the calculation formula of acoustic emission amplitude, the amplitude of each sub-signal is calculated respectively. The results show that the amplitude of each sub-signal is smaller than that of the original signal. This method can be used to reduce noise and extract effective acoustic emission signals. And it provides the foundation support, to form the method of noise reduction processing and effective signal extraction for corrosion acoustic emission signal on the tank bottom plate. It has some application value to improve the accuracy of the evaluation results of the corrosion state of the tank bottom plate.

1. Introduction
Acoustic Emission (AE) technology is a dynamic non-destructive testing method that can judge the damage position, damage stage, damage mechanism and severity of the structure by detecting and recording the stress wave released suddenly by the material structure under the stress state. It has the characteristics of real-time and online[1]. The acoustic emission sensor converts the mechanical wave generated by the acoustic emission source into a continuous electrical signal, which is amplified by the preamplifier and transmitted to the main processor in the acoustic emission instrument, which processes the acoustic emission signal and stores it in the memory for subsequent signal analysis and display. Therefore, the processing of acoustic emission signals is the basis for subsequent storage, analysis and result evaluation of acoustic emission signals. Currently the acoustic emission signal acquisition and processing method can be divided into two broad categories: first, there is the acoustic emission signal waveform characteristic parameters measurement directly, instrument only store and record the waveform characteristic parameters of acoustic emission signal, and then to measure the waveform characteristic parameters, instrument only store and record the waveform characteristic parameters of acoustic emission signal, and then analyzes the waveform characteristic parameters and processing, to get the material in the acoustic emission source information; The second type is waveforms that directly
store and record acoustic emission signals. In the future, waveforms can be directly analyzed, and characteristic parameters of these waveforms can be measured and processed[2]. At present, PAC and Vallen have developed corresponding software to collect and process AE signals[2]. However, in actual engineering applications, acoustic emission detection signals often contain a large number of interfering noises, which affect the accurate positioning and evaluation results of sound sources[3]. At present, how to separate noise from acoustic signal and extract acoustic signal is one of the difficulties in improving detection and evaluation results of acoustic emission technology.

At present, the signal processing method based on waveform analysis is mainly used in signal denoising, which can be divided into time-domain analysis and frequency-domain analysis[3]. Time domain analysis is to describe the complete information of signal in time domain. Spectrum analysis is a method to describe the characteristics of signal in frequency domain by mathematical transformation based on Fourier transform. In recent years, wavelet transform (wavelet analysis technology)[4], artificial neural network pattern recognition technology[3] and pattern recognition technology[3] have been applied in the signal denoising processing of various types of acoustic emission signals. In addition, as an empirical data analysis method, Hilbert yellow transform (HHT) is also applied in noise reduction processing of acoustic emission signals[5]. The expansion basis of HHT is adaptive and can obtain physical representations of the data generated by nonlinear and non-stationary processes. HHT consists of two parts, namely empirical mode decomposition (EMD) and Hilbert spectral analysis (HAS)[5,6]. This technique is feasible for the analysis of nonlinear non-stationary data, especially for time-frequency energy display, which has been tested and verified in many ways[5].

In this paper, HHT is applied to reduce noise and extract effective sound signals from corrosion signal of tank bottom plate, and the change of waveform time domain characteristic description parameter (maximum amplitude value) is discussed.

2. Signal acquisition and HHT software

2.1 Acoustic emission signal acquisition
PAC’s Sensor Highway III acoustic emission instrument is applied to detect the corrosion acoustic signal of tank bottom plate for collection and processing, and the impact waveform (ASCII waveform) of signal detection is derived from AEwin software.

2.2 HHT software
Commercial software DataDemon is used to analyze and process the sound signals. DataDemon, a signal processing tool developed by DynaDx, requires expertise, not familiarity with computer programs or even the mathematics of signal processing[5].

2.3 Analytical process
(1) Apply HHT transform to decompose the original signal waveform to obtain several component acoustic signal waveforms, compare the original signal and component acoustic signal waveforms and calculate the energy ratio of each component waveform, and determine the effective signal among component signals.

(2) Apply the amplitude calculation formula of acoustic emission detection technology to calculate the amplitude of the effective signal, and compare it with the amplitude of the original signal to clarify the difference between the effective signal and the original signal.

3. Signal analysis and processing

3.1 Noise reduction and decomposition
HHT transform is applied to decompose the original signal, obtaining 9 sub-signals and a residual (shows in Figure 1), and separately calculating the energy proportion of 9 sub-signals in the original signal (shows in table 1).
As can be seen from Figure 2, IMF-2, the second sub-signal, is most similar to the original signal, and its energy is 82.5% of the original signal energy. Therefore, it can be preliminarily determined that the second sub-signal is the effective signal of the original signal.

| No. | sub-signal | Power(%) | No. | sub-signal | Power(%) |
|-----|------------|----------|-----|------------|----------|
| 1   | IMF-1      | 0.495    | 2   | IMF-2      | 82.5     |
| 3   | IMF-3      | 15       | 4   | IMF-4      | 1.81     |
| 5   | IMF-5      | 0.0677   | 6   | IMF-6      | 0.0334   |
| 7   | IMF-7      | 0.0529   | 8   | IMF-8      | 0.0234   |
| 9   | IMF-9      | 0.00183  | 10  | IMF-residual | /        |

3.2 Amplitude calculation
The amplitude of acoustic emission signal is usually expressed as dB$_{AE}$, defined as 0dB when the sensor outputs 1μV, then the amplitude of acoustic emission signal whose amplitude can be calculated by following formula[7]: $dB_{AE} = 20 \log (V_{AE}/1\mu V)$ (1). The following table lists the voltage output by the sensor corresponding to the commonly used integer amplitude dB$_{AE}$.
The amplitude of the original signal waveform measured by the acoustic emission instrument is 46dB. After the original signal is decomposed by HHT transform, the waveform parameter value of component IMF-2 waveform can be derived. By applying formula (1), the amplitude of IMF-2 waveform can be calculated as 44.76dB, and the difference between it and the original signal is 1.24dB.

| dB_{AE} | 0  | 20 | 40 | 60 | 80 | 100 |
|---------|----|----|----|----|----|-----|
| V_{AE}  | 1μV| 10μV| 100μV| 1mV| 10mV| 100mV |

### 4. Discussion

As can be seen from the above, there is a certain difference between the amplitude of the effective signal obtained after the original signal is de-noised and decomposed by HHT transformation and the amplitude of the original signal, and it is obviously lower than the amplitude of the original signal.

In order to further verify the above results, 22 original signals are selected, the original signals are denoised and decomposed by HHT transformation, and the effective signals are extracted, then the effective signals are calculated by amplitude, and compared with the amplitude of the original signals (shows in table 3). Through comparison, it is found that the amplitude of the extracted effective signal is reduced to different degrees after applying HHT to reduce the noise and decompose the original signal (shows in Figure 3).

The results of the study, for the subsequent acquisition of acoustic signal de-noising processing of acoustic emission instrument, acoustic signal extracted effectively, and corrosive nature of the sound source, sound signal waveform characteristics analysis provides a new train of thought, in order to further formation of tank floor corrosion inspection based on HHT transform acoustic signal noise reduction and acoustic signal extraction method provides a foundation to support effectively, may also for tank floor corrosion evaluation results accurate provide a new research direction, optimization, to promote the formation of core storage tank floor corrosion evaluation technology in China provide the basis for testing support.

| No. | Original waveform amplitude (dB) | Effective waveform amplitude (dB) | Difference Value(dB) | Energy Ratio(%) |
|-----|---------------------------------|---------------------------------|----------------------|-----------------|
| 1   | 97                              | 94.7                            | 2.3                  | 79.5%           |
| 2   | 96                              | 94.14                           | 1.86                 | 90.1%           |
| 3   | 96                              | 94.81                           | 1.19                 | 96.5%           |
| 4   | 98                              | 96.97                           | 1.03                 | 96%             |
| 5   | 97                              | 94.7                            | 1.3                  | 92.1%           |
| 6   | 35                              | 34.26                           | 0.74                 | 86.20%          |
| 7   | 35                              | 32.62                           | 2.38                 | 93.20%          |
| 8   | 36                              | 33.39                           | 2.61                 | 90.90%          |
| 9   | 36                              | 34.89                           | 1.11                 | 93.10%          |
| 10  | 36                              | 32.74                           | 3.26                 | 73.70%          |
| 11  | 37                              | 31.48                           | 5.52                 | 53%             |
| 12  | 39                              | 34.98                           | 4.02                 | 83.50%          |
| 13  | 41                              | 35.79                           | 5.21                 | 59.50%          |
| 14  | 43                              | 41.2                            | 1.8                  | 68.20%          |
| 15  | 46                              | 44.76                           | 1.24                 | 82.50%          |
| 16  | 46                              | 42.22                           | 0.78                 | 94.80%          |
| 17  | 49                              | 46.85                           | 2.15                 | 82.20%          |
| 18  | 52                              | 47.96                           | 4.04                 | 69.90%          |
| 19  | 57                              | 54                              | 3                    | 89.20%          |
| 20  | 62                              | 55.71                           | 6.29                 | 79.80%          |
5. Conclusion

(1) Used Hilbert-Huang transform, to decompose the corrosion acoustic emission signal of tank bottom plate, Successfully decompose the acoustic emission signal into 9 sub-signals and one margin. At the same time, the energy ratio of each sub-signals is calculated, the source data of each sub-signals is exported. The waveform of each sub-signal is compared with the original signal, and the waveform of the sub-signal with the largest energy ratio is similar to the original signal. It can be determined that the sub-signal with the largest energy ratio is the effective signal of the original signal.

(2) Using the calculation formula of acoustic emission amplitude, respectively, to calculate the peak amplitude of each sub-signal. The amplitude of each sub-signal is less than the amplitude of the original signal. That is, through HHT decomposition and extraction, the amplitude of the effective signal is significantly lower than the original signal.

(3) Through this noise reduction and extraction process, the acoustic emission signal that is originally above the threshold can be determined as a non-effective signal. Then, the hits of the corrosion acoustic emission signal of tank bottom plate can be reduced, and the accuracy of the evaluation of the corrosion state of the tank bottom plate can be improved.

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