Application of Wavelet Analysis Technology to Damage Detection of Acoustic Emission Signal

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Abstract: The technology of acoustic emission (AE) signal full waveform acquisition provides possibility of source location based on waveform analysis. According to fault character of AE signal, a new approach based on node-amplitude transform is introduced to locate AE sources, that is, the peak of amplitude is damage location. Meanwhile, using wavelet analysis and compress technology to manage extracting signal, then the image can show damage location directly, clearly and accurately. The experimental result proves that the method is effective and easy operation.

Keywords - acoustic emission (AE), wavelet transform, damage, location, node, amplitude

1. INTRODUCTION

The essence of the phenomenon of acoustic emission (AE) is a material under load the deformation, fracture, etc. Part of deformation energy in the form of stress waves in materials released into the real signal is the transient waveform. Different materials and different mechanism of acoustic emission, resulting in signals in different frequency ranges, while the performance of different frequency acoustic emission signal characteristics of the ability to source different from the key signal processing is an effective means of how to take into account from the collection of broadband signals identify the most representative of the source of the characteristics of acoustic emission signals. Detection of acoustic emission to determine the location of acoustic emission sources, assessment of the nature and seriousness of acoustic emission sources.

Wavelet analysis, in time domain and frequency domain, has a good localized nature at the same time, which can be expressed in the time-frequency domain signal characteristics. Wavelet analysis of localized space-time in nature, based on the analysis of transient non-stationary time-varying characteristics of signals, how to choose the optimal wavelet function, you can have the best time and frequency domain resolution of the original signal decomposition arising from the framework of time-frequency signal analysis.

Xue-jun Li², who proposed a rolling bearing ring for damage caused by the AE signal wavelet function, the experimental results verify the function of the type of the superiority of damage detection. In S. Olutunde Oyadiji, the signal is divided into two types of symmetric and asymmetric, thus pre-selected N / 2 signal sequence analysis, finite element model simulation results to obtain good results.

Shun-de Gao⁴, who used the adoption of high modulus maxima of wavelet coefficients to identify the singularity of the signal in order to determine the location of the injury. J.-C Hong Lee⁵ and others, through damage location index to monitor the experiment to verify its accuracy, but has large calculation and difficult to operate. Wang Bin⁶ and etc used pre-stressed reinforced concrete beams to study the damage process, the spectrum obtained at different stages of distribution and the distribution of the characteristics of contour lines, but its location on the injury did not give accurate location detection. In this paper, based on these, the use of wavelet analysis technology to beam damage detection to precise positioning for further study and analyze the process, and more easily to operate.

2. THE BASIC PRINCIPLES OF WAVELET TRANSFORM

For any square integrable signal \( f(t) \), continuous wavelet transform is defined as:

\[
W_f(a,b) = \frac{1}{\sqrt{a}} \int_{-\infty}^{\infty} f(t) \psi\left(\frac{t-b}{a}\right) dt
\]

(1)

Type \( a \) for the scaling factor, \( b \) for the time factor, \( \psi \) for the mother wavelet, it should be allowed to meet the following conditions:

\[
C_\psi = \int_{-\infty}^{\infty} |\psi(w)|^2 dw < \infty
\]

(2)

Type \( \psi(w) \) is for the Fourier transform \( \psi(t) \).

Wavelet transform owning time-frequency window has a good measure of automatic retractable feature: In the low frequencies, with a large scale; at high frequencies, with a very small scale. So, it can extract useful high-frequency signals from the local features.

Wavelet function and wave scale are the two important issues in wavelet transform’s choice. First of all, as far as possible, we limit the choice of frequency wavelet function, to ensure good local time-frequency domain analysis. Select the types of wavelet function, there is no basis for unity, but one thing is certain, it should be used with the original signal has a greater “similarity”. The choice of scale can be based on actual
analysis of the demand signal, the greater the scale, the more detailed of the frequency division. However, the calculation has increased correspondingly. Only the appropriate wavelet function and wavelet scale are selected, the advantages of wavelet transform in signal analysis can be realized. As the processed acoustic emission signal and wavelet function Db3 has more similar images\(^8\), so we use it for analysis.

![Fig.1 Db3 Wavelet Basic Function Picture](image1)

3. EXPERIMENTAL DATA AND WAVELET ANALYSIS

In this article, sample is fixed at both ends of the pre-stressed concrete beams, pre-stressed steel wire diameter of the spiral rib is 5\(\text{mm}\) (negative pattern), the tensile strength of standard values is \(f_{\text{pk}} = 1670\text{N/mm}^2\), the elastic modulus is \(E = 2.09 \times 10^5\text{pa}\). Experimental process: at the middle of the beam, we imposed jack load slowly until the cracks have deepened to the specimen and completely broken. At the end of the experiment, we got the acoustic emission signals in the process of acoustic emission instrument during the entire process\(^6\).

Selecting the test specimen before the instant destruction of an analysis of the signals, we have 2048 sampling points (sampling points can detect more accurate location). We use Matlab Wavelet software engineering software package\(^7\), loading data analysis and processing. The following table given the partial node of the signal data can be seen clearly in 409 nodes, the amplitude of the largest (2.801) that is the location for the injury. (N-node, A-amplitude)

<table>
<thead>
<tr>
<th>N</th>
<th>400</th>
<th>401</th>
<th>402</th>
<th>403</th>
<th>404</th>
<th>405</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>-0.023</td>
<td>-1.865</td>
<td>-2.715</td>
<td>-1.992</td>
<td>-0.785</td>
<td>-0.129</td>
</tr>
<tr>
<td>N</td>
<td>406</td>
<td>407</td>
<td>408</td>
<td>409</td>
<td>410</td>
<td>411</td>
</tr>
<tr>
<td>A</td>
<td>0.143</td>
<td>0.83</td>
<td>2.092</td>
<td>(\mathbf{2.801})</td>
<td>2.068</td>
<td>0.545</td>
</tr>
<tr>
<td>N</td>
<td>412</td>
<td>413</td>
<td>414</td>
<td>415</td>
<td>416</td>
<td>417</td>
</tr>
<tr>
<td>A</td>
<td>-0.488</td>
<td>-0.639</td>
<td>0.525</td>
<td>-0.652</td>
<td>0.795</td>
<td>-0.518</td>
</tr>
<tr>
<td>N</td>
<td>418</td>
<td>419</td>
<td>420</td>
<td>421</td>
<td>422</td>
<td>423</td>
</tr>
<tr>
<td>A</td>
<td>-0.082</td>
<td>0.502</td>
<td>0.471</td>
<td>0.068</td>
<td>-0.463</td>
<td>-0.775</td>
</tr>
<tr>
<td>N</td>
<td>424</td>
<td>425</td>
<td>426</td>
<td>427</td>
<td>428</td>
<td>429</td>
</tr>
<tr>
<td>A</td>
<td>-0.691</td>
<td>-0.441</td>
<td>-0.359</td>
<td>-0.375</td>
<td>-0.164</td>
<td>0.238</td>
</tr>
</tbody>
</table>

Table 1 Partial Node and its Corresponding Peak Value

In this paper, we use Db3, import data and analyze it. The effect can be seen in the following figure.

![Fig.2 Pictures of Original Signal and Damage Location](image2)

From image analysis (abscissa indicate the number of nodes, longitudinal coordinates indicate the amplitude), we can see the location of damage, more or less, in the 400-node-right, but not yet a clear positioning. In order to get more clearly reflect the damage location, we use five steps of the Db3 wavelet decomposition, then, from the details of the analysis of signal amplitude in the damage location, we can see it in the vicinity of 410 nodes. The following figure (3) got clear information.

![Fig.3 Detail 5 of Db3 Wavelet Decompose](image3)

In order to be more intuitive, clearly seen from the map results, this paper applied wavelet package functions for signal compression. Experimental results are shown as following figure (4). Image is very clear and accurate to diagnose the results.

![Fig.4 Signal Compression Picture of Db3 Wavelet](image4)

4. CONCLUSION

Based on the acoustic emission signal analysis received from the sensor signal, a node - amplitude analysis method for sound source location is proposed: the maximum amplitude of the corresponding node is the location of injury. Application of wavelet technology: wavelet decomposition and wavelet compression technology to the signal analysis, which clearly...
shows the location of the injury. Experimental results show that this method can get an accurate location and easy to operate. This work has practical significance and the prospects for broad application, also the method can be applied to the complex structure of the damage detection.

REFERENCES


