The Application of Wavelet Analysis in Ultrasonic Nondestructive Testing

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Abstract: Ultrasonic detection during the operation is inevitably influenced by ambient temperature and the noise, causing the received ultrasound signal low signal-to-noise ratio, great error in actual and theoretical waveform. For getting right ultrasonic feedback energy and the acquired signals, in this paper, the wavelet singularity detection method is used to detect mutation signal and threshold value to noise method is used to remove noise, meeting the nature of the time-domain and frequency-domain simultaneous analysis, and the MATLAB simulation is used to compare the advantages of Fourier denoising method and the wavelet denoising method, showing that the wavelet denoising method has incomparable advantages in bridge detection to noise processing.

1 INTRODUCTION

Ultrasonic detection is ultrasonic excited by interference source, it is changed according to the detection principle of acoustic characteristics using the object itself or the internal defects of the ultrasonic propagation, in the case of damage detection, object internal and surface defects in shape, size, shape and distribution in determination of material characteristics, can be positioned on the workpiece, the surface and internal defects assessment, detection and diagnosis. However, in practical engineering applications, most of the environmental incentives are non-stationary, and the frequency part of the response signals varies according to time. For the nonstationary signals, are now commonly used in frequency domain and time domain identification methods can not meet the signal in time and frequency domain at the same time, two partial analysis of the demand (Chen, 2010), wavelet analysis algorithm can effectively overcome this shortcoming, it is realized through analyzing the time-varying characteristic of the systems according to the wavelet analysis and denoising the image can display the presence of damage. Introducing wavelet analysis into the damage identification of civil engineering structure can improve the accuracy and accuracy of damage identification. It has become the main means of health inspection for engineering structures.

2 WAVELET TRANSFORM AND THE THEORY OF SINGULARIT

2.1 Wavelet transform and the theory of singularity

Set $\Psi(t) \in L^2(\mathrm{R})$. Its Fourier transform $\widehat{\Psi}$（ω）,when$\widehat{\Psi}$（ω）Meet the permissible conditions:

$$C_\Psi = \int_{-\infty}^{\infty} \frac{|\widehat{\Psi}(\omega)|^2}{\omega} d\omega < \infty \quad (1)$$

We call$\Psi(t)$as a basic wavelet or Mu Xiaobo.
The generating function$\Psi(t)$dilation and translation after we get:

$$\Psi_{a,b}(t) = \frac{1}{\sqrt{a}}\Psi\left(\frac{t-b}{a}\right) \quad a, b \in \mathrm{R}; a \neq 0 \quad (2)$$

This is a wavelet sequence, in the case of different scales. The duration of the wavelet widened with the increase of a. The amplitude decreases with the increase of $\sqrt{a}$, but the basic shape of wave (Lin, 2011) remain unchanged.

For any function $x(t) \in L^2(R)$, The definition of continuous wavelet transform is:

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$$w_x(a,b)=\left\langle x,\Psi_{a,b}\right\rangle=\int_{-\infty}^{\infty}x(t)\Psi^*(t)dt=$$
$$\int_{-\infty}^{\infty}\frac{1}{\sqrt{a}}\Psi^*\left(\frac{t-b}{a}\right)dt \rhd (3)$$

The representation of the inner product mathematically is $x(t)$ and $\Psi_{a,b}(t)$ of of similar degree

When the scale a increases, expressed by stretching $\Psi(t)$ Waveform to observe of the whole $x(t)$; on the contrary, when the scale of a is reduced, indicated by compression the only $\Psi(t)$ waveform to observe the $x(t)$ of the local, therefore, can be used as a signal to the different scales of the wavelet transform in general analysis (Zhang, 2007).

Lipschitz exponent is used to characterize the singular properties of singularity (Ren, 2005). The Lipschitz index is defined as: Set n as an integer, n≤ α ≤n+1, The signal $x(t)$ is Lipschitz a at t(0). If there are A and h0>0and N sub polynomials pn (h), so that all h<h0, there are:

$$\left|x(t_0+h)-p_{n(h)}\right| \le A|h|^{\alpha} \qquad (4)$$

In which pn(h) is the former n term of the Taylor series of X (T) at t0.

The greater the Lipschitz exponent α the higher the smoothness of the function at this point; the lower the smoothness, the greater the singularities, the greater the . The Lipschitz index defines the accurate information of the signal $x(t)$ in the $x(t)$ point, that is, smoothness, which effectively improves the accuracy of identification of damage. Change schematic diagram.

2.2 Wavelet threshold de-noising algorithm

The wavelet threshold de-noising algorithm can get the best estimation in Besov space which is more accurate than other linear estimation methods.

A one - dimensional model of noise - containing signals can be expressed as:

$$s(i) = f(i) + \sigma e(i) \qquad i=0,1,...,n-1 \qquad (5)$$

Type, $f(i)$ represent useful signals, $e(i)$ represent noise signal, σ is noise level coefficient.

The wavelet threshold denoising algorithm includes hard threshold denoising and soft threshold de-noising, and the hard threshold is defined as:

$$y=\begin{cases}x, & |x|\ge\lambda\\ 0, & |x|<\lambda\end{cases} \qquad (6)$$

The soft threshold is defined as:

$$y=\begin{cases}\operatorname{sgn}(x)f(|x|-\lambda), & |x|\ge\lambda\\ 0, & |x|<\lambda\end{cases} \qquad (7)$$

Among, λ is threshold or threshold value.Our noise is roughly as follows: select the appropriate wavelet decomposition of noise signal; after wavelet decomposition, the noise signal will be included in the high frequency coefficients in the selection of appropriate threshold; the decomposed high frequency coefficients of high-frequency coefficients of wavelet decomposition of signal reconstruction process, finally completed the noise reduction.

3 DETECTION OF CRACKS IN BRIDGES IN CIVIL ENGINEERING BY USING WAVELET TRANSFORM

3.1 The establishment of mechanical model of simple supported beam

In order to replace a simple supported beam with a crack with an elastic hinge, a mechanical model with a simple supported beam with a crack, is established. Stiffness of elastic hinge is K_r : $K_r=\frac{1}{C}$, $C=\left(\frac{5.346h}{EI}\right)J(\delta)$, $\delta=\frac{a}{h}$, among, a is fracture depth, h is cross section height, E is modulus of elasticity, I is section inertia moment , $J(\delta)$ is:

$$J(\delta)=1.8624\delta^2-3.95\delta^3+16.37\delta^4-37.226\delta^5+76.81\delta^6-126.9\delta^7+172\delta^8-143.97\delta^9+66.56\delta^{10} \qquad (8)$$

The cracks in the model divide the beams into two parts,(9),(10) formula represent respectively the two parts of the free vibration is(To the left as the origin of coordinates):

$$\eta_1(x)=A_1ch(Kx)+A_2sh(Kx)+A_3\cos(Kx)+A_4\sin(Kx) \qquad (9)$$

$$\eta_2(x)=B_1ch(Kx)+B_2sh(Kx)+B_3\cos(Kx)+B_4\sin(Kx) \qquad (10)$$

Among, K^4 = (ω^2 ρA)/EI, ω is vibrational circle frequency, ρ is material quality, A is cross section area, $A_1, A_2, A_3, A_4, B_1, B_2, B_3, B_4$ is coefficient, x is calculation of the distance from the cross section to the left support. The boundary of the simple supported beam is in accordance with:

$\eta_1(0)=0$, $\eta_1'(0)=0$, $\eta_2(l)=0, \eta_2'(l)=0$.

The crack section should be satisfied:

$$\eta_1(l_c)=\eta_2(l_c) \qquad (11)$$
$$\eta_1''(l_c)=\eta_2''(l_c) \qquad (12)$$
$$\eta_1'''(l_c)=\eta_2'''(l_c) \qquad (13)$$
$$\eta_1'(l_c)+\frac{EI}{K_r}\eta_1''(l_c)=\eta_2'(l_c) \qquad (14)$$

Among, l represents the total length of a beam, l_c represents the gap between the crack section and the left bracket.

Bring the formula(9),(10) into the boundary condition(11)~(14), you can get a set of equations on $A_1, A_2, A_3, A_4, B_1, B_2, B_3, B_4$, the coefficients of the equation of vibration can be known.

3.2 Identification of simple supported beam cracks by wavelet analysis

Span of simple supported beam is 800mm, Cross section size is 20mm*40mm, it is known that there is a crack at the left support 300mm, The depth of the crack $\delta = \frac{a}{h}$ respectively is 0.1、0.2、0.3、0.4、0.5、0.6. Continuous wavelet transform from scale 1 to 25, from this, we can get the maximum value of the wavelet coefficients at the fracture section of each scale, The modulus maximum of the wavelet coefficients increases with the increase of the scale, and is nonlinear. The Lipschitz α exponent can be obtained by the logarithm of the modulus maximum of the wavelet coefficients, and the Lipschitz α exponent decreases with the increase of the depth of the crack.(Zhu, 2008) The crack singularities can be obtained from the Lipschitz α exponent, the damage degree of the crack beam can be judged.

4 SIMULATION CONTRAST OF FU LIYE DE-NOISING AND WAVELET DENOISING

The traditional way of Fourier denoising is to transform the signal to Fourier transform first, then low-pass filter, and finally reconstruct the (Shyu, 1996) of the signal after Fourier transform. This method has very obvious shortcomings, the useful signal is mainly concentrated in the low-frequency part, the noise signal is mainly concentrated in the high-frequency part, but also the useful signal is a high frequency part, if using a simple low-pass filter, high frequency part will be a useful signal with noise signal to filter out, if using low pass filter in order to save the narrow high-frequency part of the useful signal, then the signal is filtered will still exist a lot of noise signal, and the whole process is performed in frequency domain, without time domain information. Wavelet analysis can effectively combine the time domain with the frequency domain(Zhang, 2008), In the previous chapter, the wavelet threshold denoising algorithm is introduced. To verify the superiority of the wavelet denoising method, we select a segment of Doppler signal, add white noise to it, then the Fourier denoising and wavelet denoising are used respectively,in this example, we use the MATLAB7.0 platform for simulation,use Sym8 wavelet decompose three layers, wavelet coefficient threshold quantization is quantified by heursure soft threshold.

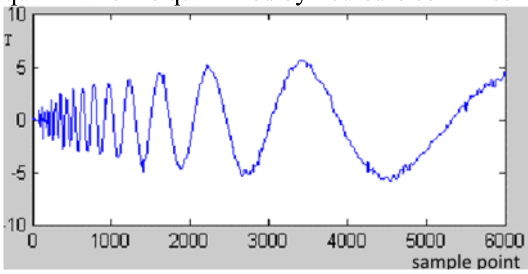

Fig.1 Effect of Wavelet Denoising

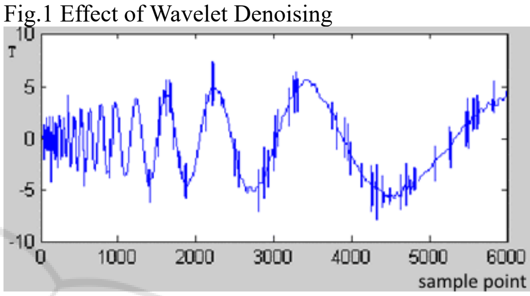

Fig.2 Effect of Fourier Denoising

It can be seen from the diagram, compared to the Fourier denoising method, it is ideal to obtain the overall trend of the signal by the wavelet transform de-noising method. Its basic idea is the function of the bandpass filter based on the wavelet transform, The signal is decomposed into different translation and scaling wavelet or base functions and the wavelet analysis has the window function is not the same, with the local analysis ability is very good, can be found that no other signal analysis methods of the observed discontinuity and the breakpoint, thus removing burr noise the.

5 CONCLUSIONS

In this paper, the method of ultrasonic sampling is studied, and the theory of wavelet transform is used as the main research method.,the damage degree of the cracked simple supported beam is judged, and the wavelet threshold de-noising of the sampled signal is carried out. Through MATLAB simulation, the Fu Liye denoising method and wavelet analysis denoising method are compared. It shows that the wavelet analysis has the advantage that Fu Liye can not get rid of noise in bridge detection and denoising. The research method has been applied to the design of virtual wavelet de-noising instrument and the design of ultrasonic nondestructive flaw detector. It effectively improves the accuracy and accuracy of damage identification, and effectively maintains the ultrasonic signal.

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