International Journal of Advanced Engineering and Management Research
Vol. 2 Issue 3, 2017

www.ijaemr.com ISSN: 2456-3676

THE OPTIMUM SELECTION OF WAVELET PACKET BASIS FUNCTION IN MAGNETIC FLUX LEAKAGE SIGNAL PRETREATMENT

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ABSTRACT

In order to figure out the optimum selection of wavelet packet basis functions in magnetic flux leakage signal pretreatment, some theoretical analysis about the selection of wavelet packet basis function of signal petreatment of magnetic flux leakage testing of petroleum pipeline defects is made.T he innovation of this paper lies in that we make the energy coefficient, the extreme value of floating error and the mean value of error of peaks and valleys be the three criteria. After screening, the optimum selection is obtained from frequently-used wavelet packet basis functions. Experimental results show that this method Conveniently deals with the selection of wavelet packet basis functions in high efficiencies, which is more suitable for the selection of wavelet packet basis function in magnetic flux leakage signal petreatment.

Key Words: wavelet packet basis funtion; the energy coefficient; the extreme value of floating error; the mean value of error of peaks and valleys

CLD number: TP372 **Document code:** A

INTRODUCTION

The traditional methods of signals processing are Fourier Transformation, Short-Time Fourier Transformation and Wavelet Transformation. More precisely, Analysis of Fourier Transformation is mainly about frequency domain of signals, overlooking the information of frequency domain in time domain and the information of frequency domain in frequency domain. Therefore, the conjoint analysis of time domain and frequency domain can not be realized[1-3].Compared with Fourier Transformation, Short-Time Fourier Transformation have some progress, however, that the window function has a certain width makes a certain amount of overlap. Therefore, the conjoint analysis of time domain and frequency domain can not be realized one hundred percent. However, Wavelet analysis is capable of realizing the totally conjoint analysis. Meanwhile, it does not analyze the high frequency part of signals[4-6].

Wavelet packet analysis makes more analysis of the high frequency part of signals on the basis of Wavelet analysis[7-9].

So, in this paper, the theory of Wavelet packet analysis is used in the pretreatment of magnetic flux leakage signals. In the process of magnetic flux leakage signal pretreatment, the selection of Wavelet packet basis function will directly affect results of signal pretreatment. Throughout the domestic and foreign references, most of them are about the selection of the basis functions of one-dimensional wavelet transformation, and the selection of the basis functions of two-dimensional wavelet transformation. And there exists little research on the selection of the basis function of two-dimensional wavelet packet transformation[13-14]. The innovation of this paper lies in that the selection criteria of the basis function of the two-dimensional discrete wavelet packet transformation is based on the energy coefficient, the extreme value of floating eror and the mean value of error of peaks and valleys. Experimental results show that this method can effectively solve the problems of the optimum selection of Wavelet packet basis function in the pretreatment of magnetic flux leakage signals and improve the accuracy of the optimum selection.

1. basic theory of wavelet packet analysis

Wavelet packet analysis is based on wavelet analysis. It decomposes the low-frequency part into two components, including the high frequency part. At the same time, the corresponding frequency band can be adaptively selected according to the characteristics of signals, so as to matches the signal spectrum and then, improves the time frequency resolution.

The'S'in the formula(1) represents the original signal,'A'represents the low frequency component, 'D'represents the high frequency component, and the ordinal number after'A'and'D'represents the number of layers of the wavelet packet decomposition. The decomposition follows the following relation:

S=A1+D1=AA2+DA2+AD2+DD2 (1)

2.1 introduction of wavelet packe transform

In the experiment, the MFL (Magnetic Flux leakage) signal is the axial defect leakage magnetic field signal, and they are discrete, so the discrete wavelet packet transform is adopted.

The $f(t)$ is the magnetic leakage signal, and $P_j^i(t)$ is the i wavelet packet coefficient on layer j, and G and H are wavelet packet decomposition filters:

$$P_0^1(t) = f(t) \qquad (2)$$

$$P_j^{2i-1} = \sum_k H(k-2t) P_{j-1}^i(t) \qquad (3)$$

$$P_j^{2i-1} = \sum_k G(k-2t)P_{j-1}^i(t) \quad (4)$$

T is a time parameter, in units per second /s

The formula (2), formula (3) and formula (4) represent the decomposition process of the wavelet packet, and formula (3) represents the decomposition process of the low-frequency component of the signal, and formula(4) represents the decomposition process of the high frequency component of the signal.

The magnetic leakage signal is $f(t)$, that is, $P_0^1(t)$. In the jlayer, there are 2^j wavelet packet coefficients, and the first $2i-1$ wavelet packet coefficients are the i wavelet packet coefficients on layer $j-1$ and the low-pass filter H convolution, and then the point sampling is obtained.

2.2 wavelet packet transform.

Wavelet packet transformation and inverse transformation are reciprocal process, reconstruction filter corresponding to g(BPF) and H (low pass filter), On the basis of the corresponding inverse transform type formula(5) of:

$$P_j^i(t) = 2(\text{A+D}) \quad (5)$$

$$\text{A}=\sum_k h(t-2k)P_{j+1}^{2i-1}(t) \quad (6)$$

$$\text{D}=\sum_k g(t-2k)P_{j+1}^{2i}(t) \quad (7)$$

dasda

In MFL signal pretreatment, wavelet packet transform , compared with the Fourier transform and wavelet transform, decompose the high frequency part of signal of the corresponding number, and improve the reconstruction accuracy in the high frequency part of the signal and reduce the error.

2.3 basis function introduction

Wavelet basis function and wavelet function are essentially the same, applied in different algorithms. A wavelet packet basis function's basic features are: The vector space is squared and integrable. As the '$\Psi(\omega)$' in formula (8), and satisfy the admissibility condition. The 'C_ψ' is infinite, as shown in formula(8):

$$C_{\psi}=2\pi\int_{R^*}|\omega|^{-1}|\Psi(\omega)|^2\, d\omega<+\infty \qquad (8)$$

When the wavelet packet function image symmetry on the Y axis, namely wavelet absorption formula(9), is shown in:

$$|\Psi(\omega)|^2=|\Psi(-\omega)|^2 \qquad (9)$$

Thus, the absorption wavelet domain can make the calculation of original definition domain reduced by half. If the absorption of wavelet meet the stability conditions, it is called the binary wavelet, and it makes computation halved again. Stability conditions are as shown in (10):

$$0<A\le\sum_{j=-\infty}^{+\infty}\left|\Psi(2^{-j}\omega)\right|^2\le B<+\infty \qquad (10)$$

A and B were constant. It is because of being binary wavelet that it can carry out a series of two wavelet packet transformation, inverse transformation and so on.

3.basis function selection analysis

As for signal transforming, the most important is to select the best wavelet packet basis function, which will directly affect the success or failure of signal reconstruction, and indirectly effects of the signal feature extraction and quantitative recognition results. The commonly used wavelet packet functions include Haar wavelet, Coiflet wavelet (divided into 5 types based on vanishing moment) , Symlets (divided into 8 types based on vanishing moment) , Morlet wavelet, Mexican hat wavelet, Daubechies wavelet (divided into 10 types based on vanishing moment) and so on. The referrnce[15] makes detailed description on wavelet feature information. In the experiment, we will use the Morlet Mexican wavelet, hat wavelet, Haar wavelet, Coif4 wavelet, Sym8 wavelet and Db7 wavelet packet as selection database to select the optimum selection .

3.1 Basis function selection ideas and results

MFL signals In the experiment are discrete, so we will use the discrete wavelet packet transform as analysis method. Morlet wavelet, Mexican wavelet hat does not support the discrete wavelet packet transform, So after a preliminary screening, Haar wavelet, Coif4 wavelet, Sym8 wavelet and Db7 wavelet to meet the conditions.

The better compactness is, the smaller the calculation amount of wavelet packet decomposition and reconstruction will be. Compact support is defined as follows: Compact support for a range of functions in the image, this function does not exist for zero function values, and in this interval, the constant function value is zero.

Then we screen wavelets based on the size of compactness. We need to screen the wavelets which have smaller compactness.

Assuming that the compactness of Haar wavelet is A, the compactness of Sym8 wavelet is B, the compactness of Coif4 wavelet is C, the compactness ofDb7 wavelet is D.

The calculation method of compactness are as follow:

1.To capture all of the extreme points of graphics by MATLAB.

2.Capture coordinates of the two extreme points of the maximum and minimum of abscissa.

3.Capture all coordinates whose function value is 0, and gets abscissa values of all the corresponding coordinates.

4.Subtract the maximum abscissa value in the second step from all abscissa value whose function value is 0 one by one, and select the the minimun absolute value of subtracting, and mark it as abscissa 1.

5.Subtract the minimum abscissa value in the second step from all abscissa value whose function value is 0 one by one, and select the the minimum absolute value of subtracting, and mark it as abscissa 2.

6.Subtract the abscissa 1 from abscissa 2, and get the the absolute values of subtracting. The absolute values is equal to the value compactness. So the compactness is worked out.

A=1.0000；B=0.6368；C=0.6438；D=0.8016

The calculation results can be compactly supported wavelet Haar, so it can be directly screening.

From the above calculation results, Haar wavelet, Sym8 wavelet, Coif4 wavelet and Db7 wavelet Still meet the conditions. Next, we have third steps to screen, The third step is the standard screening energy coefficient. The following formula (11) is shown:

$$\mathrm{a} = \frac{\sum_{i=1}^{m} F_i + \left|\sum_{j=1}^{n} G_j\right|}{\sum_{i=1}^{m} S_{fi} + \left|\sum_{j=1}^{n} S_{gj}\right|} \sum_{k=1}^{\mathrm{m}+n} B_k \qquad (11)$$

‘a’ is the energy coefficient. ‘F’ is the peak value of signal. ‘G’ is the value of valley. ’S’is the area of peaks and valleys. ‘m ’ is the number of peaks and ‘n’ is the number of valleys. ‘Bk’ is the maximum width of any wave crest or trough. The degree of similarity between the signal and the time domain waveform of the wavelet packet basis can be measured by the energy system values of the signals. The bigger the value of ‘a’ is, the higher the degree of similarity will be, the latter can extract more effective features. Therefore, wavelet packet basis functions can be used to screen.

The idea of using MATLAB to calculate energy coefficient ‘a’ is as follows:

1.Get all the peak value function, then the summation is performed and get $\sum_{i=1}^{m} F_i$

2.Gets the function value of all the valley values, then makes the summation, and then calculates the sum of the absolute values and get $\left|\sum_{j=1}^{n} G_j\right|$.

3.Obtain the defined region of each wave crest, and then integrate to obtain the area of the corresponding wave crest and get $\sum_{i=1}^{m} S_{fi}$.

4.Obtain the defined domain intervals of each wave trough, and then integrate them to obtain the area enclosed by the corresponding peaks, and accumulate the summation. And find the sum of absolute values and get $\left|\sum_{j=1}^{n} S_{gj}\right|$.

5.in like manner, get the $\sum_{k=1}^{\mathrm{m}+n} B_k$.

6.Calculate the ‘a’ value according to the formula.

The results are as follows:

Tab.1 the energy coefficients of Sym8-Coif4-Db7

小波包基	原始信号	Sym8	Coif4	Db7
能量	1.221	1.471	1.309	1.543

系数	3	0	3	7

Based on the energy coefficient calculation results, the wavelet energy coefficient Coif4 is most similiar to the original signal. Therefore, Coif4 can be selected as the best choice momentarily.

Finally, we screened the final verification. We use the extreme value of floating error and the mean value of error of peaks and valleys of the original signal and the reconstructed signal as the selection criteria. The extreme value of floating error and the mean value of error of peaks and valleys are as follows:

$$e_{fdzz} = e_{\max} - e_{\min} \qquad (12)$$

$$e_{fgjz} = \frac{(\sum_{i=1}^{m} e_{fi})}{m} + \frac{(\sum_{j=1}^{n} e_{gj})}{n} \qquad (13)$$

e_{fdzz} is the extreme value of floating error. $e_{\max}$ is the maximum peak value of the error of graph of reconstructed signal and the original signal. $e_{\min}$ is the maximum value of the valley. e_{fgjz} is the mean value of error of peaks and valleys. m is the total number of peaks of error of graph of the reconstructed signal and the original signal in a particular wavelet packet basis function.

The smaller the e_{fdzz} is , the higher stability will be obtained by using the corresponding wavelet packet basis functions. The mean value of error of peaks and valleys are used to measure the average degree of error. The smaller the e_{fgjz} is , the higher accuracy of the corresponding wavelet packet basis functions' processing will be obtained.

The result is as follows:

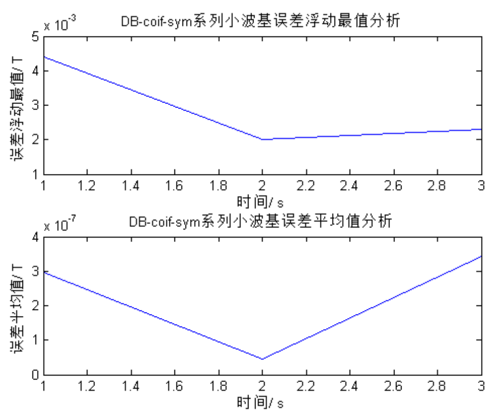

Fig.2 errors of Sym8-Coif4-Db7

Coif4 is the best selection after selecting the extreme value of floating error and the mean value of error of peaks and valleys. To sum up, in the four step screening, the Coif4 wavelet is the best wavelet packet basis function in the preprocessing of magnetic flux leakage signal.

4. Conclusion

In this paper, the selection of wavelet packet basis function in magnetic flux leakage signal pre-processing of oil pipeline defects is studied. The experiment uses the Morlet wavelet Mexican wavelet, hat wavelet, Haar wavelet, Coif4 wavelet, Sym8 wavelet and Db7 wavelet. The selection of norm is Energy coefficient, the energy coefficient and the extreme value of floating error; the mean value of error of peaks and valleys. Finally, we figure out that Coif4 wavelet is the best selection. You can only further increase the species number of wavelet packet basis functions for wavelet selection in the actual needs. The method is also applicable. The experimental results show that the method is most suitable for the selection of wavelet packet basis function in pre-processing of magnetic flux leakage signal.

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