Feature Extraction of Acoustic Emission Signals from Low Carbon Steel Pitting Based on Independent Component Analysis and Wavelet Transforming

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Abstract

According to the characteristics of low-carbon steel pitting acoustic emission signal, one new characteristic analysis-WICA is proposed. The main idea of WICA is that based on the independent component analysis blind source separation technology as well as the wavelet transformation decomposition technology, proposed determines the low-carbon steel pitting source number according to the energy characteristic vector the method. The experiment results show that to some extent, WICA can overcome the difficulties caused by the uncertainty of low-carbon steel pitting independent source and get better results of low-carbon steel pitting acoustic emission signal pattern recognition.

Keywords : Wavelet transform, Independent component analysis (ICA), Pattern recognition

1.Introduction

The wavelet transformations (wavelet) which can withdraw the non-stable characteristic of the signal is also linear as the same as FFT. Moreover, wavelet transformation characteristic is often non-intuitional and non-auto-adapted[1].The traditional wavelet transformation on characteristic extraction is complex which is limited in a way for the extracted characteristic information is difficult to be qualified [2-3].

The independent component analysis (Independent Component Analysis, called ICA) is mixed in the repeat method unknown situation in which the observation data also the supply oscillator, with the statistical independence principle and decomposed certain mutually independent ingredients through the optimized algorithm, the signal power can recognized and the analyzed.

In this section the method that mixing wavelet transformation and ICA is discussed. The wavelet transformation has the characteristic in time domain and the frequency range localization, which is suitable

for analyzing and processing the non-steady signal. It can effectively pick-up characteristic signal in which detail component and the approximate component under different criterion were obtained [7-8]. The ICA method can further pick-up the independent information source from the observation data, and it describe the essential characteristic signal, as a result of enhancing signal identification [9]. The ICA method is used in the article to analyze the acoustic emission signal of low-carbon steel, then the independent components are picked up. Separated pitting acoustic emission signals are extracted by wavelet transform method at last. ICA is proved to be effective in the experiment.

2.Acoustic emission signal characteristic extraction based on ICA and WT (WICA) method

The link of the wavelet transformation and the independent component analysis

Although the frequency spectrum of signal produced by different independent source is mutual aliasing, the energy distribution of frequency spectrum is incompletely same. Generally speaking, spectrum distributions of identical source in different time are basic similar, but the spectrum distributions of different sources are of great difference [10].

First, natural gradient algorithm of the ICA separates the blind signal of the source, then the frequency spectrum distributed energy characteristic of the different sources are obtained by using the wavelet transformation, so as to determining the independence character of separated signal, thus obtaining the number of independent sources.

Because the different signals are of the obvious difference energy characteristic, it can be easily distinguished the independent signal source based on this energy characteristic. The ICA algorithm based on the wavelet decomposes is as follows:

① Using the ICA to process the observation data.

② When the number of separated samples is bigger than 127,using the wavelet to decompose signal, and calculating the energy of each separation signal component.

③Calculates the distance of various signals energy characteristic $d_{ij}\ (i=1,2,\mathrm{K},l,j\neq i)$;

$$d_{ij}(t)=[(P_i(t)-P_j(t))\times(P_i(t)-P_j(t))^T]^{1/2} \qquad (1)$$

④ Suppose the distance threshold is 0.1,when all is bigger than this threshold, it shows that all output component nearly mutually independent ,and Algorithm restraining convergence, otherwise extension②.

⑤ When the threshold $d_{ij}(t)$ is smaller than assigns, it shows that $x_i(t)$ and $x_j(t)$ are the coherent signals, therefore delete $x_i(t)$ or $x_j(t)$, and changes DNN the structure and make the output value to

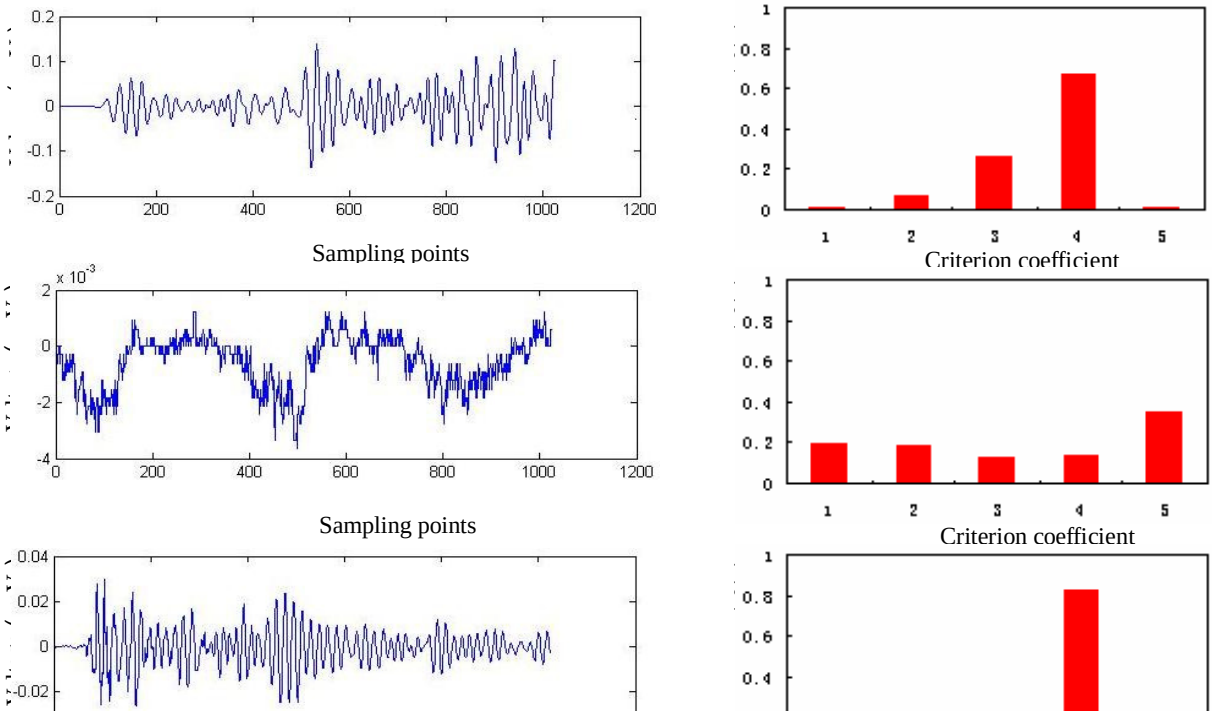
reduce 1. In order to delete some output signal component (supposition $x_i(t)$) to retain other output component, the simple method is to make all elements of i-st line in $W(t)$ is a zero. Repeat this deletion process, until all signals are separated.

The simulation experiment studies carries on the pitting acoustic emission signal simulation experiment based on the wavelet transformation and the independent component analysis

Do the simulation experiment to the algorithm in the article, and separate the blind mixed signal of the source which is composed with 3 independent signals. The primitive oscillogram of these 3 independent signals is as follows figure 1, using the wavelet transformation obtained the energy characteristic (figure 2).

Taking 'A' is the 3*6 uniform distribution stochastic matrix, mixed the stochastic matrix 'A' with three original signals, six impure signals are acquired, the profile of which are like figure 3. Then separate these six composite signals using ICA, the separated signals are listed as follows Figure 4. From Figure 4, it shows that the separated signal oscillogram and the 4th profile primary signal oscillogram are similar; however, it can not be determined whether the separated signals are three absolute sources or not. Energy characteristic of three absolute sources need to be extracted by the wavelet analysis and is as shown in Figure 5. From Figure 5, Energy characteristic of the separated signal and primary signal are just the same, illustrating that the separated signals using ICA are three absolute signal sources. From the simulation experiment, it can be found that unifies ICA and the wavelet transformation algorithm can well determine the unknown source number.

stochastic matrix : $$A=\begin{bmatrix} 0.98 & 1.33 & 0.65 & 1.35 & 1.2 & 4.0 \\ 5.11 & 3.23 & 1.59 & 2.10 & 1.6 & 1.5 \\ 2.10 & 0.98 & 1.65 & 3.10 & 0.6 & 3.2 \end{bmatrix}$$



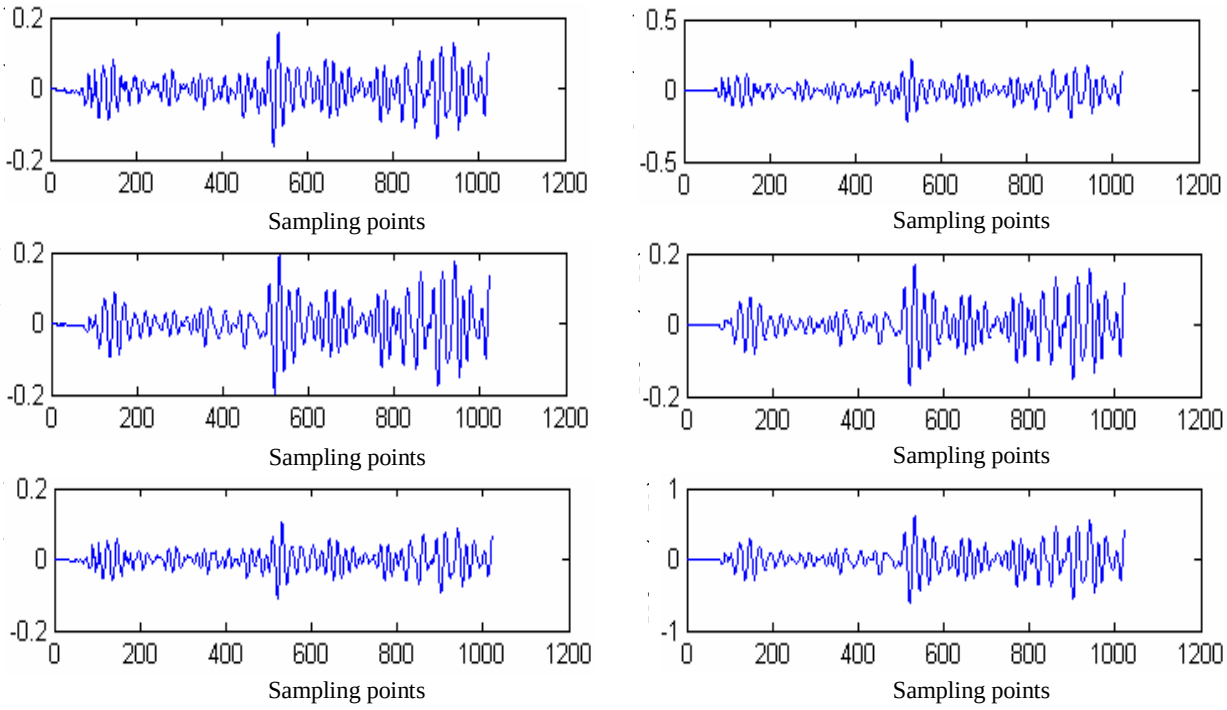


Figure 3 mixed signal oscillogram

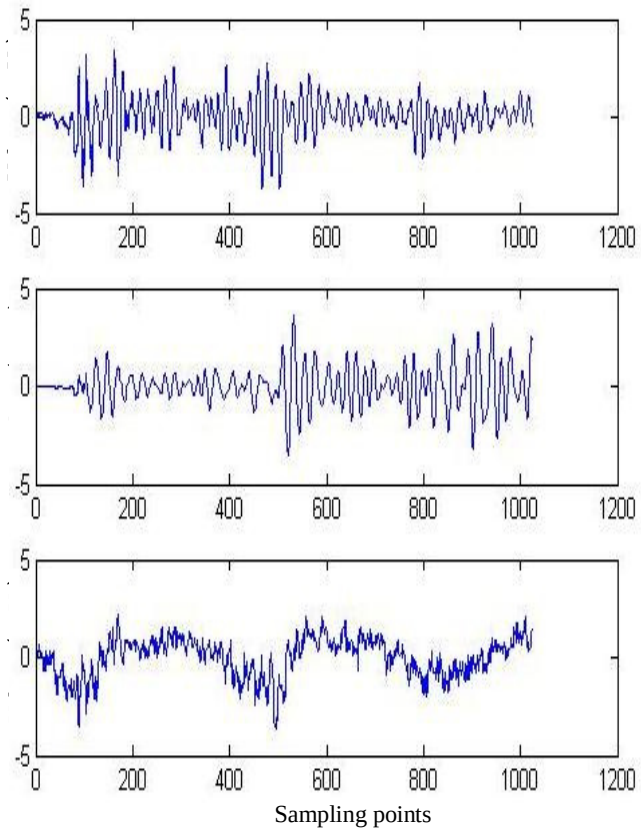


Figure 4:After separation signal oscillogram

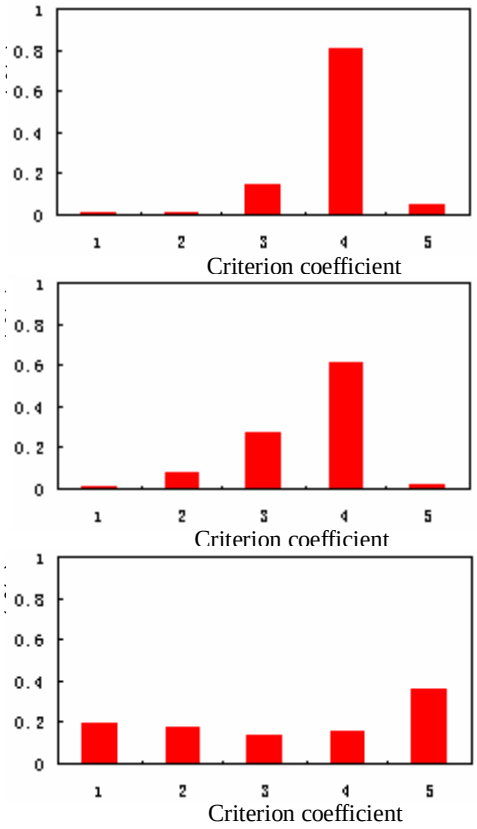


Figure 5:After separation signal energy

3.Discussions

As to the blind source separation, the multichannel pitting acoustic emission signal includes the multitudinous concealment independent source, the number of which is generally more than the multichannel observation pitting acoustic emission signal number. Just because the ICA blind source separation algorithm requires that the number of observation signals must be more than or be equal to the number of the concealment independent source, if ICA analysis is directly carried on to the primitive multichannel pitting acoustic emission signals, the effect is often not ideal. The results indicate that in the condition that the observation signal number is less than the independent source number, some independent source ingredient with high energy can be separated by the ICA. Therefore, WICA can get the characteristic of the good pitting acoustic emission signal The reason of these experiment results can be explained as follows.(1)The low-carbon steel pitting acoustic emission signal contains some useful ingredients which are generally the transient state weak signal. The wavelet transformation strengthens signal ingredient that is ready to be examined, and weakens the non-target signal ingredient and the noise disturbance. (2)In the inner tube reorganization multichannel ICA input signal, the non-target signal ingredient and the disturbance ingredient have become weak, therefore the WICA algorithm can effectively separate the relative strong target signal ingredient.

4.Conclusions

According to their characteristic in the signal characteristic extraction, characteristic analysis and extraction of the acoustic emission signal by WICA is proposed. The experimental result indicated that WICA is better than ICA in the usage on extraction of the low-carbon steel acoustic emission signal. The wavelet transformation and the independent component analysis are two methods that extremely represent single channel and the multichannel signal analysis method. It will be a new research direction in the signal processing field to union these two methods.

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