Application of wavelet analysis in the vibration signal of diesel engine noise reduction techniques

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Abstract: Because of the low entropy, multi resolution, correlation, and flexibility of the wavelet transform, it is a powerful tool in the field of signal denoising. In this paper, wavelet threshold de-noising and wavelet packet denoising method are used to deal with the surface vibration signal of diesel engine, and the method of wavelet analysis is used to deal with the traditional Fourier analysis method, and wavelet analysis is a powerful tool to deal with non-stationary signals.

Keywords: Wavelet Analysis, Denoising, Threshold, vibration, diesel engine.

1. Introduction

Diesel engine is a very complicated mechanical system, the vibration of the cylinder, the pressure of the cylinder, the reciprocating inertia force of the piston, the side thrust, the unbalanced force of the crankshaft, the gas threshold impact, the exhaust gas, the main bearing and so on. So the vibration information including a variety of components and interference, is a non-stationary vibration signal. It is possible to improve the diagnostic accuracy and obtain reliable analysis results only if the interference and noise signals are effectively filtered.

The traditional noise reduction method of signal processing is based on the low pass filtering method which is based on Fu Liye analysis. The signal is filtered from the frequency domain and the low frequency part is preserved. Because the general situation of the useful signal is concentrated in the low frequency part, the noise distribution in the high frequency part, it can be used for the low pass filtering method. The filtering method based on Fu Liye analysis is suitable for stationary signals, but it can not be used to distinguish the high frequency part and the high frequency interference caused by noise. If the cutoff frequency of the low pass filter is too high, there is still a lot of noise in the filtered signal, and the other part is a part of the useful signal as the noise filter, which will cause the loss of useful information.

2. Wavelet analysis of signal characteristics

Orthogonal wavelet decomposition has adaptive time-frequency localization function. In the part of the signal, the performance of some wavelet components is large, and it has a clear contrast with the uniform performance of the noise in the high frequency part, so that the partial and noise of the signal can be effectively decomposed by orthogonal wavelet decomposition. Similarly, the orthogonal wavelet packet decomposition can not only show the high frequency of the signal, but also can clearly show the high frequency of the noise in the low frequency signal. Therefore, wavelet decomposition and wavelet packet decomposition can effectively reduce the non-stationary signal.

Using the noise of the square wave signal (such as Figure 1) simulation, the use of DB2 wavelet orthogonal wavelet decomposition, the signal at different scales of the details of the part of the wavelet transform value is shown in figure 2. It can be seen that with the increase of the scale, the details of the signal, with the increase of the size of the signal, the wavelet transform of the signal is significantly increased, while the noise of the wavelet transform is basically unchanged, useful signal and noise is effectively separated. In the details of the signal, the use of appropriate threshold, the absolute value is less than the threshold value of the wavelet transform zero, it can be useful in the retention of high-frequency signal at the same time, eliminate most of the noise signal. The principle of wavelet packet noise reduction is the same as that of wavelet denoising.
3. The process of wavelet threshold noise reduction

In practical engineering, the useful signal is usually low frequency signal or some relatively stable signal, while the noise signal is usually expressed as high frequency signal. The signal de-noising process can be divided into three steps:

(1) wavelet decomposition of the signal. Select a wavelet, and determine the number of wavelet decomposition, and then the signal is decomposed by Ceng Xiaobo;

(2) threshold quantization of high frequency coefficients of wavelet decomposition. The high frequency coefficients of each layer of the first layer to the layer are selected, the appropriate threshold is selected and the threshold is quantified.

(3) reconstruction of one-dimensional wavelet. Based on the low frequency coefficients of the first layer of wavelet decomposition and the high frequency coefficients of the first layer to the first layer, the wavelet reconstruction of the signal is carried out.

In these three steps, the key is how to select the threshold and how to quantify the threshold, which is directly related to the quality of the signal de-noising.
4. Wavelet de-noising and low pass filtering noise reduction

By using low pass filter based on Fu Liye analysis, if the cut-off frequency is too large, there is still a large amount of noise, but too small can make the signal due to excessive smoothing and distortion, some useful signal is treated as a noise filter. And the use of wavelet denoising method to get the information noise is basically filtered, the effect is very good. Wavelet de-noising can effectively distinguish the high frequency part and the high frequency interference caused by noise, and can save the spike and the mutation of the useful signal. Therefore, wavelet analysis has the advantage of Fu Liye's analysis of the non stationary signal de-noising. Fig. 4 and Fig. 3 compare the noise reduction effect of different methods for the different methods of the noise and the square wave signal containing five pulse components. It can be seen that the low pass filtering method, if the cut-off frequency is low, the signal to noise ratio is improved, but the signal is also used as a useful signal of the noise is filtered; if the cut-off frequency is high, although the mutation signal can be saved, but a lot of noise still exists. While the wavelet and wavelet packet threshold denoising method is useful to retain the mutation signal at the same time, greatly improving the signal to noise ratio.

Fig. 4 wavelet de-noising and wavelet packet noise reduction of square wave signal with noise and pulse
5. Application of wavelet packet on the surface vibration signal of diesel engine

Using wavelet packet to reduce the surface vibration signal of the diesel engine, the process is as follows:
(1) the noise signal is decomposed by a layer of a layer of noise signal;
(2) the best subtree to calculate the initial tree according to the given standard entropy;
(3) for each of the wavelet packet coefficients (except for the low frequency part), a threshold is selected for the threshold processing. If the selected threshold is not appropriate, the threshold can be quantified, until the threshold value is obtained.
(4) wavelet reconstruction through the initial signal of low frequency coefficients and high frequency coefficients after processing.

This processing method makes the noise elimination, and the edge information is better preserved.

This paper adopts DB2 wavelet, the cylinder head vibration signal of the four layer wavelet packet decomposition, threshold denoising. Because the noise signal of the diesel engine is unknown, the heuristic threshold is used to process the signal. Figure 5 is using wavelet packet threshold denoising methods were compared before and after noise waveform, denoised retains the useful signal spikes and mutation, whereas the tick in addition to the noise of the diesel engine.

![Figure 5 Comparison before and after wavelet denoising of vibration signal waveform](image)

6. This article summarized

This paper mainly introduces the commonly used wavelet de-noising algorithm and wavelet packet based signal decomposition denoising algorithm, and wavelet thresholding denoising method and wavelet packet decomposition noise reduction algorithm applied to diesel engine surface vibration signal decomposition and noise reduction. Examples show that: compared with the traditional Fu Liye analysis of the low pass filtering noise reduction technology, wavelet analysis in the non-stationary signal to show the superiority of the incomparable.
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8. References


