Fault diagnosis method of rolling bearing based on A_{dB} value

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Abstract. In order to better identify the fault type of locomotive running of rolling bearings, through experiment and analysis, the article improves a new method by combining the value of A_{dB} and fault bearing fault characteristic frequency, then through the virtual instrument software to analysis the diagnosis method. Firstly, the extracted data are filtered by two-dimensional Gabor band-pass filter, and then the cepstrum analysis is performed on the filtered data. Through the analysis of the characteristic information, the fault frequency can be obtained, and the fault range is given according to the inherent characteristic frequency of the rolling bearing, and then the final fault level is given by calculating the A_{dB} value. This method can give more accurate fault types and give warning signs in advance, which greatly improves the safety of the locomotive.

1. Introduction

Rolling bearings are the most common mechanical parts of reciprocation and rotational motion, and also have a very important role in the mechanical system. The normal operation of the rotating machinery is largely dependent on the rolling bearing to achieve, so the quality of rolling bearing is directly related the normal use of machinery, and some even related to the company or corporate property security, more seriously will be directly related to the life of the operator. Especially in the field of locomotive, bearing safety is even more important [1].

With the continuous lifting of our train speed, the relevant departments of the safe use of locomotives, especially on the safety of the traffic department to an unprecedented height. Axle box bearings, motor bearings, and transmission gears and wheel treadmills and so on need to carry out fault diagnosis and monitoring. And some also require early warning information to stop the locomotive half-way parking accidents and major accidents [2].

2. Two - dimensional Gabor Band - pass Filter

Its unit impulse response function (Gabor function) is the production of the Gaussian function and the complex exponential function. In practical application, a plurality of Gabor filters with different radical center frequencies and different direction angles are used to form a filter bank to process the image. Normally, Gabor filter group on the image processing in two ways to achieve, one is the use of discrete Fourier transform convolution theorem, the other way is directly in the spatial domain using convolution template convolution operation [3].

$$\mathrm{G}(x_0, y_0, \theta, \omega_0) = \frac{1}{2\pi\theta^2} exp\left[-\frac{x_0^2+y_0^2}{2\sigma^2}\right] \times [\exp(j\omega_0 x_0) - \exp(-\omega_0^2\sigma^2/2)] \quad (1)$$

Among them: $x_0 = xcos\theta + ysin\theta$

$$y_0 = -xsin\theta + ycos\theta \quad (2)$$

Among x and y are the location of the spatial pixel; ω_0 is the center frequency of the filter; θ is the direction of the wavelet; σ is the standard variance along the two axes; $\exp(j\omega_0 x_0)$ is the exchange composition; $\exp(-\omega_0^2\sigma^2/2)$ is the DC compensation. Using this filter method satisfies the lower limit of the effective duration and effective frequency bandwidth product, which means that it can be optimally localized in both the time domain and the frequency domain.

3. Cepstrum Analysis

The cepstrum technique can be used to analyze the periodic structure on the spectrum, and can separate and extract the periodic in the dense frequence spectrum signal. It is widely used in noise and vibration source identification and fault diagnosis. The experimental signal can be more easily observed by cepstrum analysis and more convenient to determine the frequency of failure [4].

3.1 The Theory of Cepstrum Analysis

Let the self-power spectral density function of a time signal be $S_x(f)$, and the power down cepstrum function C_q defines as:

$$C_q = (f^{-1}[\ln S_x(f)])^2 \tag{3}$$

That means the power down cepstrum function C_q is the square of the inverse Fourier transform of the logarithm. In engineering applications, the square root is usually used as the effective amplitude of the signal cepstrum.

$$C_X(q) = f^{-1}[\ln S_x(f)] = f[\ln S_x(f)] \tag{4}$$

3.2 The Meaning of the Spectrum

The cepstrum is the spectrum of the power spectrum logarithm, and the power is logarithmically processed, which is equivalent to the weighting of its logarithm and the result is a weighting of the low frequency component. Its advantages conclude [5]:

① The signal energy after transformation is more concentrated, easier to identify the signal; ② More convenient for the signal convolution integration; ③ More conducive to identify the spectral properties of the spectrum.

4. Experimental Indicators

4.1 Bearing Characteristic Frequency

Bearing in the course of the work, when a component of the bearing failure, the rolling body in the inner ring and the outer ring may be between the occurrence of the impact of the phenomenon, so as to induce the inherent vibration of the bearing components, the natural frequency of the size and components its own shape, quality and material related, but has nothing to do with the shaft speed. The calculation formula is shown in Table 1:

Tab 1. Rolling bearing fault characteristic frequency calculation table

Fault location	The frequency of shock vibrations
Inner ring	$f_i = \frac{1}{2} f_a \left[1 + \frac{d}{D}\cos\alpha\right] z$
Outer ring	$f_o = \frac{1}{2} f_a \left[1 - \frac{d}{D}\cos\alpha\right] z$
Rolling body	$f_b = \frac{1}{2} f_a \left[1 - \frac{d^2}{D^2}\cos^2\alpha\right] z$

4.2 Failure Value

In the locomotive running section monitoring, mainly through a calculated value of the fault (dB) to diagnosis and determine the degree of bearing damage. Different value of the fault will give the bearing corresponding to the running state, more convenient for staff to view. The impact diagnostic criteria are shown in Table 2 below:

Tab 2. Impact diagnostic criteria

Bearing state	In good condition	There is a tendency to deteriorate	Poor state in time	Bearing serious damage
Rolling body	≤20.0dB	20.0-35.0dB	35.0-50dB	≥50.0dB
Inner ring	≤20.0dB	20.0-35.0dB	35.0-50.0dB	≥50.0dB
Outer ring	≤25.0dB	25.0-40.0dB	40.0-55.0dB	≥55.0dB

Evaluate the calculation of the magnitude of the fault:

$$A_{\mathrm{dB}} = 20\log\frac{2000\cdot SV}{N\cdot D^{0.6}} \tag{5}$$

A_{dB}— Failure value;
SV— Impact value;
N— Bearing the speed of the shaft;
D— Bearing shaft diameter of the shaft.

$$\mathrm{SV} = 10[\log S_x(f)]^2 \tag{6}$$

$S_X(f)$—Bearing power value

Through the calculation of the magnitude of the fault, the rolling bearing failure level can be further refined. It has a better reminder for some of the installation error due to bearing failure, failure to reach the life of the rolling bearing and the staff. It is conductive to the staff timely processing. As while it can improve the utilization of bearing, and achieve better economic results.

5. System Software Program Design and Experimental Testing

5.1 System Software Programming

The detection method based on the frequency and fault value of the bearing fault mainly includes the following signal processing parts: band-pass filter, cepstrum, fault frequency analysis, fault magnitude calculation, fault type determination.

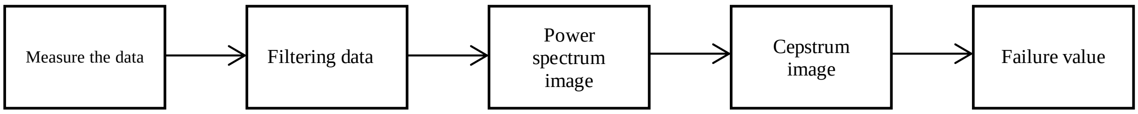

Fig.1 Experimental flow chart

The experiment flow is shown in Figure 1 above. The two-dimensional Gabor band-pass filter can keep the signal information in the center frequency range in order to carry on the next step signal processing, filter out other redundant high and low frequency signals, reduce the unnecessary interference information. The cepstrum is actually the spectrum of the power spectrum logarithm, which can transform the time domain signal into frequency domain signal, and makes it easier to index the fault information. It is more convenient to analyze and judge the fault information. In the fault frequency analysis, the information of the index in the cepstrum is further analyzed, and a more accurate fault range is obtained to facilitate the determination of the fault type. In order to calculate the value of the fault, the fault information of the index is first transformed into the micro impact value SV, and the SV value is converted to the fault value A_{dB}. The fault type is determined by the last fault magnitude to give the fault information of the detected rolling bearing and to give a prompt for the corresponding fault level.

5.2 Experimental test

The experimental selection of the bearing type is N205EM. When the bearing speed is 900 rad/min, the calculated characteristic frequency of the bearing is shown in Table 3.

Tab 3. N205EM fault characteristic frequency

Fault type	Inner ring defect $\boldsymbol{f_i}$	Outer ring defects $\boldsymbol{f_o}$	Rolling body defects $\boldsymbol{f_b}$
Characteristic frequency	116.25Hz	78.75Hz	82.13Hz

The data collected by the experiment will be noise and other interference, so the data collected by the experiment first in the virtual instrument by filtering, and then the collected data for signal analysis.

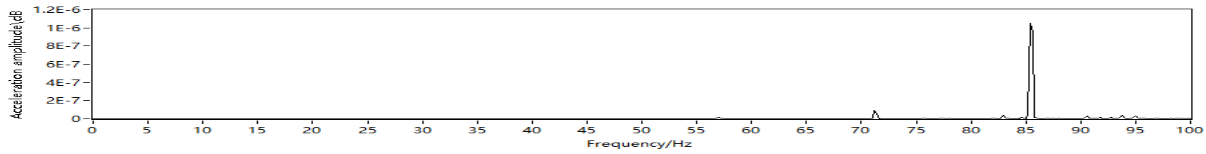

Fig.2 Power spectrum of normal rolling bearing

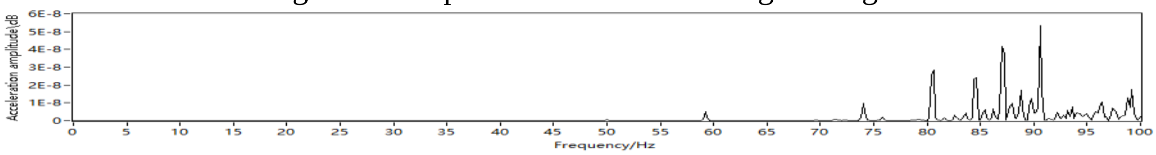

Fig.3 Power spectrum of rolling bearing

Figure 2 and Figure 3 are the normal rolling bearing and experimental rolling bearing power spectrum image, through the comparison between the two figures can be seen between the two figures there are significant differences, which can be initially learned that the experimental rolling bearing there is a defect.

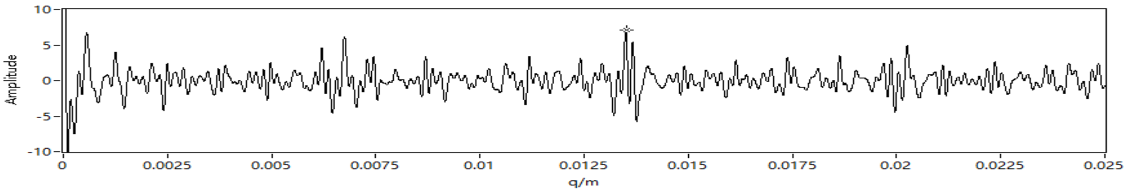

Fig.4 Experimental bearing cepstrum

By further cepstrum analysis, it can be concluded that the fault peak of the bearing is at the position of the reciprocating frequency of 0.0134s, and it can be concluded that the cepstrum image has a very obvious periodic characteristic. The location of the fault peak is about 74.627Hz after calculating and analyzing. According to the characteristic frequency analysis of the bearing failure, it can be seen that the fault frequency of the bearing experiment is near the characteristic frequency of the bearing fault 78.75Hz, which can be used to get the outer ring fault defect of the rolling bearing. In order to further confirm the type of bearing failure, continue to test the value of the experimental data calculation.

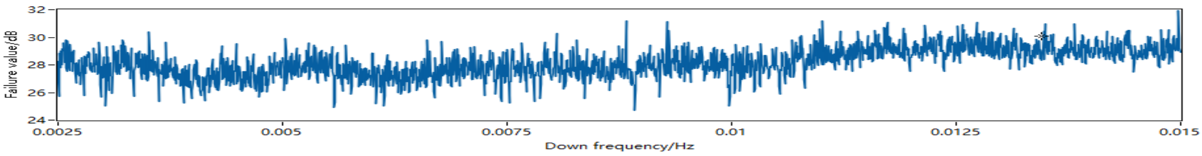

Fig.5 Normal bearing fault value map

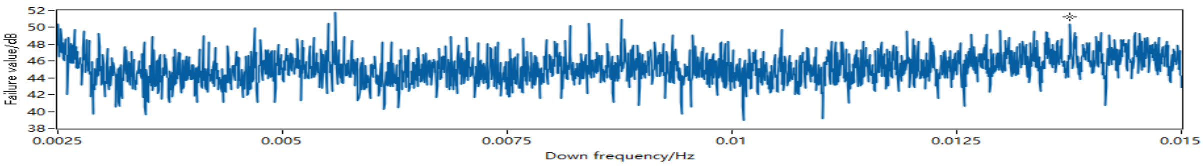

Fig.6 Experimental bearing failure value map

After analyzing the analysis of the magnitude of the damage Figure 5 and Figure 6 can be learned, normal bearing failure value is about 29 up and down, but the experimental value of rolling bearing failure A_{dB} is distributed at 47.5dB. Especially, in the detection of faulty feature frequency near the fault value has reached 50dB. Therefore, by comparing the impact of diagnostic criteria can be drawn, the current state of the bearing needs to be timely treatment.

6. Summary

Through the analysis of the experimental data can clearly distinguish whether the bearing fault, through further cepstrum analysis and processing can clearly determine the location of the bearing failure, and finally calculated the value of the fault can be clear the exact fault level when the current bearing are running. In addition, it can also give the staff more direct adjustment program. Through the comparison with the normal rolling bearings can be clearly diagnosed whether the bearing failure, with a certain degree of feasibility.

References

[1]. Lin Na. Research and implementation of fault diagnosis for rotating machinery. Master's degree, Beijing University of Posts and Telecommunications, China 2013.
[2]. Xiaodan Yang. Fault analysis and improvement of locomotive bearing[J]. Engineering Technology: Citation Edition, 2016(4): 251-252.
[3]. Runping Han, Surong Sun, Ling Jing. Method for obtaining two-dimensional convolution template of Gabor filter[J]. Microcomputer information. 2007, 23(6):241-242.
[4]. Jinliang Xue, Yan Wang, Yan Wen, etal. Study on fault vibration signal analysis and feature extraction method of gear reducer [J]. Journal of Qingdao Technological University. 2013, 34(4):109-114.
[5]. Yanjun Guo. Research on Intelligent Cepstrum and its application in fault diagnosis[D]. Master's degree, Zhengzhou University, China 2015