Research on the Application of Rolling Bearing Fault Diagnosis based on Order Cepstrum Analysis

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Abstract. In order to extract the fault characteristic from vibration signal of a rolling bearing with variable rotate speed, the order cepstrum analysis approach is proposed in this paper. In this approach, the rotate speed signal is measured by optical-electricity transducer, the angular domain signal is obtained by even angle sampling to the original vibration signal. The order cepstrum analysis can be used to identify the bearing fault featurs from interferences accurately and extract the features of the bearing. Simulation and application example show that the proposed approach is an effective way to diagnosis the bearing fault. So it is more valuable in engineering application.

1. Introduction

Rolling bearing is an important part of rotating machinery. The working condition of this kind of machine is largely dependent on the rolling bearing. Once there are any faults happening in bearing, it may not only interrupt the manufacturing process, but also lost lots of money, even become a huge threaten to the safety of the workers. Therefore, the scientists and researchers conduct many experiments in signal processing field to find an efficiency method to diagnose the bearing faults. In practical, due to the load fluctuation, the running condition may hardly maintain a constant speed, especially with the rotating machine. But most of the signal processing methods are proposed based on the constant speed, in this paper, we propose a means by using order cepstrum analysis to diagnose rolling bearing fault in variable speed[1,2].

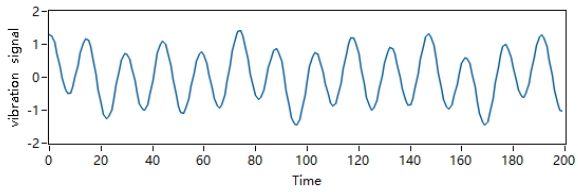
Order analysis is a method which can overcome the bad influence cased by rotation speed[3]. The basic idea of order analysis is resampling the vibration signal using a constant angle increasing, transforming the signal from time domain into angle domain, then using fourier transform to calculate the signal. Cepstrum is a way of spectrum analysis, it is also a very useful method to diagnose the bearing faults. Order cepstrum, combined with order analysis and cepstrum, with all the advantages of the two methods, it can avoid efficiently the frequency smear phenomenon and diagnose bearing faults in variable rotating speed.

2. Resampling in angle domain

The order analysis theory is proposed to overcome the shortcomings of the traditional measurement methods when dealing with the variable rotating speed. And the whole theory is based on the angle resampling. For rotating machine and reciprocating machine, even if the operator set it into a state speed, it will be variable rotating speed due to the impact of the speed fluctuation. So in time domain, the signal is a nonstationary signal, by using a constant angle increasing to resample the signal, it will become stationary in angle domain. The resampling flowchart is shown in figure 1.

Fig 1 the flowchart of resampling in angle domain

This paper use the compute order tracking method, the continuous vibration signal and the continuous rotating speed signal were acquired at same time. As shown in figure 2, there is an example to explain the steps in resampling.



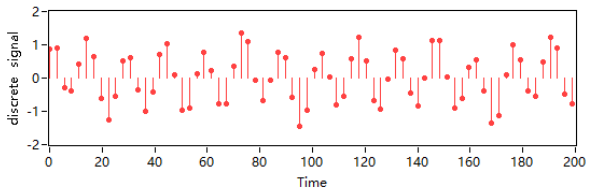


Fig2(a)Simulation Signal Fig2(b)Discrete Signal

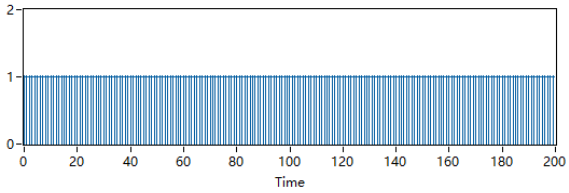


Fig2(c) The Time-domain Waveform Signal of Sampling Point

Firstly, acquiring the vibration signal by using vibration sensor, acquiring rotating speed signal by using photoelectric sensor, then sampling the continuous vibration into discrete vibration, interpolating the speed signal. Using the speed signal to resampling the vibration. During this processing, using Langrange interpolation method, the formula is

$$x(T_n) = x(t_i) + \frac{x(t_{i+1}) - x(t_i)}{t_{i+1} - t_i}(T_n - t_i) \quad (1)$$

3. Cepstrum analysis

Power spectrum analysis is widely used in signal processing, cepstrum is deeper analysis based on power spectrum analysis. It can tell the period information of power spectrum by showing the single line in the graph[4]. A cepstrum is the result of taking the inverse Fourier transform of the logarithm of the estimated spectrum of a signal.

4. Experiment

In order to test the order cepstrum theory, conducting a experiment based on the QPZZ-Ⅱ Rotating Machinery Vibration Analysisand Fault Diagnosis Experiment Platform(as shown in figure 3) with LabVIEW[5].

Fig 3 QPZZ-Ⅱ Experiment Platform

This system can simulate vary fault conditions, like the different defects from the outer race, the inner race, the roller and the cage. The formulas of bearing pass frequency of out race(BPFO),

bearing pass frequency of inner race(BPFI), ball spin frequency(BSF), and fundamental train frequency(FTF) have been given as fowllowing:

$$BPFO = \frac{nf_r}{2}\left(1 - \frac{d}{D}\cos\emptyset\right) \quad (2)$$

$$BPFI = \frac{nf_r}{2}\left(1 + \frac{d}{D}\cos\emptyset\right) \quad (3)$$

$$BSF = \frac{D}{2d}\left[1 - \left(\frac{d}{D}\cos\emptyset\right)^2\right] \quad (4)$$

$$FTF = \frac{fr}{2}\left(1 - \frac{d}{D}\cos\emptyset\right) \quad (5)$$

Where fr is the shaft speed, n is the number of rolling elements, Φ is the angle of the load from the radial plane, d is the ball diameter and D is the pitch diameter. The parameters of the testing bearing is given at table 1.

Table 1 testing bearing parameters list

Type	Inner diameter	Outer diameter	Ball diameter	Pitch diameter	Ball number
N205EM	25mm	52mm	7.5mm	39mm	13

Using all the parameters given at table 1 to calculate the order of inner race defects is about 7.75, and its order cepstrum is about 46° .The order cepstrum of the roller defects is about 144° 。

Set the rotating speed running up from 0 to 1500r/min, get the vibration signal in time domain, as show in figure 4.

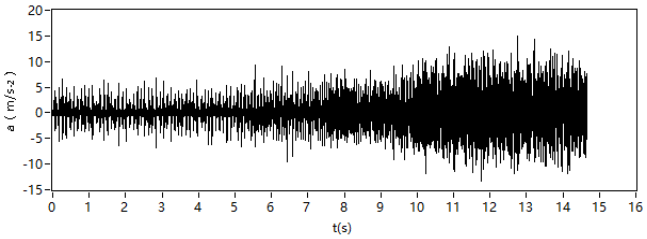


Fig 4 vibration signal in time domain of inner race defects

If we directly conduct the FFT based the vibration signal in time domain, we will get a graph with frequency smear. So we resample the vibration signal based the speed profile and get the order spectrum graph as show in figure 5.

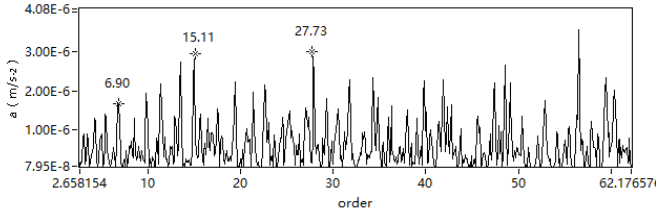


Fig 5 Order spectrum of inner race defects

We can clearly get the information of the 6.90、15.11and 27.73 is 1,2,5times of the basic defect order. By now, it is just conducting the fourier transform. We conduct the cepstrum transform of the vibration signal, then we can get the order cepstrum spectrum graph as show in figure 6.

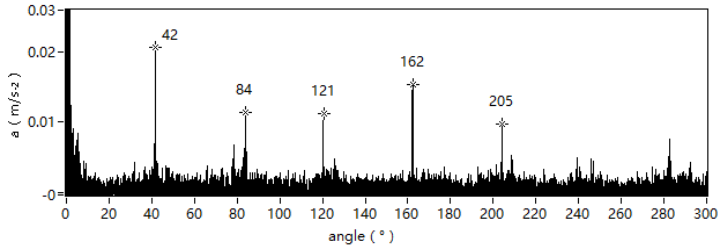


Fig 6 Order cepstrum spectrum of inner race defects

In the figure 6, the peaks are clearly shown at 42,84,121,162,205, they are the 1,2,3,4,5times of the basic order cepstrum of inner race fault. To further certify the theory, we test the bearing with defect of its roller, and we get the order cepstrum graph as shown in figure 7.

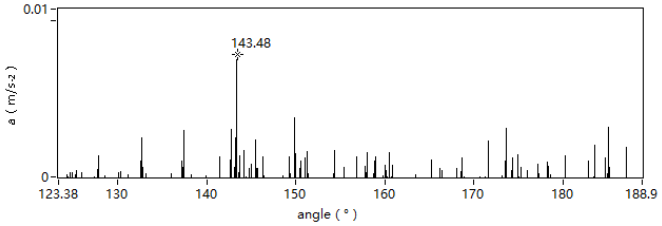


Fig 7 Order cepstrum spectrum of roller defects

The peak in figure 7 is about 143, it is very close to 144 which we calculated before based the formula. So far, the theory of using order cepstrum analysis to diagnose the fault of bearing is available.

5. Summary

Using resampling to change the signal from time domain to angle domain, is a effective method to change nonstationary signal to stationary signal.

Using order cepstrum analysis can tell the different fault type and fulfill the purpose of fault diagnosis.

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