Research on Fault Diagnosis Method of Rolling Bearing

Zhou Huan, Wang Hao

School of Energy and Mechanical Engineering, Shanghai Electric Power University, Shanghai, 200090, China

*Corresponding Author

Abstract. Rolling bearings are often used as supporting parts in mechanical equipment. Its damage will often lead to the damage of related parts, resulting in the failure of the whole system and leading to shutdown and other accidents. From the point of view of diagnosis technology, rolling bearing is the key part of rotary machinery and the main object of monitoring and diagnosis. The reason for rolling bearing fault diagnosis is to ensure reliable operation of the bearing under various working environments, thus ensuring the working accuracy of the whole machine. When some component of the bearing works and produces defects, the bearing signal measured by the acceleration sensor has the characteristic of periodic impact. In this paper, the basic characteristics of bearing fault signals are analyzed, and the method of extracting fault symptoms of rolling bearings from vibration signals is discussed.

1. Introduction

Rotating machinery is a kind of machinery with the largest number and most extensive application among all kinds of mechanical equipment. If rotating machinery fails, the losses and impacts caused by it will be very serious [1]. Rolling bearings are the most commonly used supporting components in mechanical equipment. Its damage will often cause damage to related components, resulting in failure of the entire system and accidents such as shutdown [2]. Rolling bearings have a characteristic that their life span is very discrete, that is, they use the same materials, the same processing technology, the same production equipment and the same workers to process a batch of bearings, and their life span varies greatly. According to the characteristics of diagnostic signals of rolling bearings, appropriate sensors and monitoring methods can be selected to obtain characteristic signals of rolling bearing faults [3]. From the point of view of diagnosis technology, rolling bearing is the key part of rotary machinery and the main object of monitoring and diagnosis [4]. From the structure of the bearing, it can be seen that the bearing signal measured by the acceleration sensor has the characteristic of periodic impact when a certain element of the bearing works to produce defects [5]. Therefore, working condition monitoring and fault diagnosis should be carried out on the bearing, which not only can prevent the mechanical working accuracy from decreasing and reduce or eliminate accidents, but also can give full play to the working potential of the bearing and save expenses [6].

Equipment fault diagnosis technology is a technology to understand and master the status of equipment in use, determine whether the whole or part of the equipment is normal or abnormal, find the fault and its causes in early stage, and predict the development trend of the fault [7]. From the signal theory, it can be seen that transient and sharp impulse signals in the time domain must have the characteristics of wide frequency band when they are transformed into the frequency domain, while non-impulse interference signals do not have the above characteristics [8-9]. When the rolling bearing
has faults, it shows non-linear and non-stationary characteristics. The traditional signal processing method is based on the premise of signal stability, and gives statistical average results from time domain and frequency domain respectively. It cannot simultaneously consider the localization and panorama of signals in time domain and frequency domain [10]. There are many methods of rolling bearing fault monitoring and diagnosis, each of which has its own characteristics, of which vibration signal method is the most widely used [11]. In this paper, the basic characteristics of bearing fault signals are analyzed, and the method of extracting fault symptoms of rolling bearings from vibration signals is discussed.

2. Features and Practical Diagnostic Techniques of Rolling Bearings in Normal Operation

2.1 Basic Forms of Rolling Bearing Failure
Once the rolling bearing installed on the machine fails, it will produce various phenomena, such as increased vibration, temperature rise, noise increase, etc. The vibration signals collected by the sensors on the bearing seat not only reflect the working state information of the bearing itself, but also contain many contents about other moving parts and structures, belonging to the background noise for studying the working state and faults of the bearing. Due to the large background noise in practice, the information peculiar to rolling bearing faults is often submerged in the background noise and is difficult to be found and extracted. As far as the bearing itself is concerned, the causes of excitation are: manufacturing error, assembly error of each component of the bearing, and various faults during operation. For vibration signals with small vibration and complex frequency spectrum, when it is difficult to judge whether there is any fault on site, the vibration signals shall be collected and transmitted to the computer for precise analysis. As the carrier of bearing fault information, vibration signals can theoretically diagnose all fault types of bearings by analyzing and processing bearing vibration signals. When the fault point enters the bearing area, a fault impulse will occur. Therefore, the inner ring fault can be judged according to the occurrence period of the fault pulse. Figure 1 shows three cases of moving points on the switching surface.

![Figure 1 Switching the Movement Point on the Surface](image)

2.2 Vibration Diagnosis of Rolling Bearing Faults
Rolling bearings show strong regularity and good repeatability during their use. When normal high-quality bearings are put into use, the vibration and noise are relatively small, but the frequency spectrum is somewhat scattered and the amplitude is relatively small. During the operation of the bearing system, the vibration signals generated due to various reasons are very complex. The untimely discovery often leads to equipment shutdown or equipment damage, resulting in unnecessary losses in production. Reduce and reduce the probability of failure and the casualties and property losses. Monitoring and diagnosis of equipment faults has always been an important part of mechanical fault diagnosis. Wavelet transform has unique advantages in extracting weak signals [12]. Due to different excitation, the vibration response of the bearing system is also different. Therefore, as the carrier of
bearing fault information, vibration signals can theoretically diagnose all fault types of bearings by analyzing and processing bearing vibration signals.

The failure of cage is characterized by random intervals of impact pulses and long periods. A certain high frequency natural fault can be selected as the research object, and natural frequency filters can be used to separate natural faults. Rolling bearings are continuously improving their intelligence. Failure detection of system model method can be defined as the sample path of product performance degradation, namely:

\[ p(x|\alpha, \beta) = \frac{\beta \eta(\alpha, \beta)}{2\Gamma(1/\beta)} \exp\{-[\eta(\alpha, \beta)]x\} \]

Assume that for any one sample, there is the following non-stationary process:

\[ \left( \alpha_{MMSR}, \beta_{MMSR} \right) = \left( \frac{M}{k}, \frac{M}{k(d-k+1)} \right) \]

Using the Poisson process to approximate this process, then there are:

\[ C = \sum_{i=1}^{m} \sigma_i \]

For a fixed time indicator, the parameters of the Poisson process are:

\[ P = \frac{\sigma_j^2}{\sum_{i=1}^{m} \sigma_i^2} \]

In order to test the fault dimension of maximum likelihood estimation, the classical principal component analysis method is used to extract the main fault feature vectors. Then the samples are classified according to the extracted fault features. Judging the effect of extracted fault features of different dimensions on classification through classification, as shown in Table 1.

| Serial number | Number of fault features | Classification accuracy (%) |
|---------------|--------------------------|----------------------------|
| 1             | 5                        | 72.32                      |
| 2             | 6                        | 61.86                      |
| 3             | 3                        | 67.55                      |

It is necessary to determine a detection cycle that can efficiently complete the gear fault detection task and the duration of each detection. The variation of amplitude extremum of decomposed low frequency signals is consistent with the evolution process of equipment faults. As shown in Figure 2, the decomposed waveforms of each frequency band in the normal state can be seen, and the low frequency signal is stronger.
3. Fault Feature Extraction

Due to the large background noise in practice, the information peculiar to rolling bearing faults is often submerged in the background noise and is difficult to be found and extracted. Due to improper design, or parts processing and installation process is not good, or equipment working conditions are not good. All kinds of defects will occur after the equipment is loaded and operated for a period of time. It is very important to analyze the cause and location of the fault for troubleshooting. The spiral motion of the rolling body or sliding in the raceway will cause deterministic or random phase modulation and amplitude modulation of the characteristic signals in the circumferential period, thus causing failure of discrimination [13]. Traditional Fourier transform can analyze the frequency information contained in the signal, but it cannot analyze the time domain information corresponding to a certain frequency segment at the same time. It is analyzed that piezoelectric acceleration sensor should not be used as resonator for resonance demodulation in fault diagnosis of low speed and heavy load equipment. Its natural frequency varies slightly according to different installation positions.

In the actual measurement, the resonance frequency of the sensor under the actual measurement can be recorded by hammering method. Traditional spectrum analysis, thinning spectrum and cepstrum techniques cannot effectively extract potential fault features from strong background noise. The hardware demodulation manufacturing process is complex and the application environment is harsh, so it has not entered the practical stage at present. The fault feature vector contains too much redundant information to affect the classification accuracy. Fault features extracted by noise reduction self-coding neural network are shown in Figure 3. Fault features extracted by packet analysis are shown in Figure 4.
The severity of the fault is mainly judged from the impact energy and the duration of the time, especially from the duration. The wavelet analysis method is used to perform five-layer decomposition on the fault signal collected by the monitoring system. Because the pulse lasts for a period of time to reflect the size of the fault. The longer the duration, the larger the fault point and the more serious the fault. After introducing the concept of cross-correlation, the problem of extracting the same periodic components from the processed signals of each layer in parallel stochastic resonance is solved. However, due to the characteristics of the cross-correlation itself, if the two signals processed by the cross-correlation are processed, the period is different. The statistical work of various data at the production site, the product quality management work, and the decision-making work of the production process capability are all carried out manually. Acquisition is the foundation, data is the basis, how to collect data, how to manage data is a very important issue. Quality inspection generally adopts full inspection or sampling inspection, and business activities include inspection program design and inspection process execution. During the operation of the bearing, when it is subjected to the load, it must strike the surface of other components interacting with it, and generate shock pulse
force, so that the vibration signal obtained by the sensor is abnormal, that is, the peak of the peak appears after the waveform is separated for a period of time.

4. Conclusion
There are many fault diagnosis methods of rolling bearing, each method has its own characteristics. The energy distribution of vibration signals of normal rolling bearing and outer or inner ring fault rolling bearing varies with different scales. In this case, the amplitude and shape of wavelet energy spectrum of rolling bearing scale are obviously different. When the rolling bearing fails, the time wavelet energy spectrum of bearing vibration acceleration signal changes periodically. By measuring the acceleration signal to capture the high frequency impact energy of the equipment fault, the fault of rolling bearing can be diagnosed well. In the future, we should establish the database of all kinds of defect signals of rolling bearing rotating mechanism, and collect the data of rolling bearing in various situations. It is an ideal feature extraction method of low frequency fault to classify the signal data of rolling bearing rotating mechanism under different conditions and classify the defect signals.

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