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Research of Amplitude-Frequency Domain Parameters Analysis for Condition Detection and Fault Diagnosis

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Abstract: According to incomplete statistic, about 30% of the machinery fault is caused by the rotating component. But, the rotating machinery vibration testing and fault diagnosis has the problems of collecting useful information containing the noise, etc. So, this study adopted the time-frequency analysis technology to realize the rotating machine condition test and fault diagnosis. The actual rotation machinery vibration data after pretreated is used to identify the work conditions of the rotating machinery equipment through analyzing the parameters of the time domain and frequency domain, which accurately judge the rotating machinery equipment fault condition. After finding the fault starting time by using the time domain parameters, the frequency spectrum analysis is used to grasp the fault type by comparing the vibration signal character of the energy frequency spectrum. Through the simulation we can see, time domain parameters can judge the rotating machinery equipment fault occurs time accurately and exactly find the fault type by the frequency spectrum energy.

Keywords: Condition detection, fault diagnosis, frequency domain parameter analysis, rotating machine, time domain parameter analysis

INTRODUCTION

Rotating machine has more quantity and widely used in all kinds of rotating machinery, especially some large rotating machinery, such as the steam turbine, compressor, generators, blower, aviation engine and pumps, etc. Which is the key equipment in the large production enterprise. They usually have the characteristic of large, high speed and continuous work, its operation condition directly impact the production of the enterprise, once the equipment has fault, the loss and influence will be very serious. Therefore, in recent years, the rotating machine condition monitoring and fault diagnosis technology is more and more attention by academics and engineering (Wang, 2001).

Vibrational condition and fault diagnosis analysis: In the process of the rotating machinery vibration monitoring and fault diagnosis, the vibration signal is collected and the character is extracted, which is the key to measure the health condition of the rotating machinery characterization. However, in the actual production environment, the site of the measured rotating machinery vibration signal usually contains more random noise and other interference, it causes the signal to noise ratio in low value or the negative value, which brings the difficulties in accurately predicting the fault character information extraction and correctly judging the difficulties of the fault diagnosis. The classic vibration signal processing method usually includes a signal pretreatment, amplitude domain analysis, analysis of time domain and frequency domain analysis, etc. This study mainly introduced the classic vibration signal processing method and used the pretreatment signal of rotating machinery equipment to analyze the time domain parameters and got the equipment fault starting time, then adopted the frequency spectrum analysis to realize the equipment fault type Qin and Nan (2011).

TRADITIONAL ANALYSIS METHOD

Amplitude domain analysis: All kinds of process to the signal amplitude is called amplitude domain analysis. He *et al*. (2007) amplitude domain parameter includes mean value $\bar{x}$, effective value X_{rms}, absolute maximum value $|X|_{max}$, wave pattern index S_f, peak value index C_f, pulse index L_f, margin index CL_f and kurtosis index K_v, etc. Effective value X_{rms} is the mean square value of the vibration amplitude, which expresses vibration instantaneous value continuous changing according the time; it can be used to monitor the crowfoot cracks unusual of the equipment surface. The various treatment to the signal amplitude called amplitude domain analysis. If we get a group of sampling discrete data $\{x_i\}$ = (i = 1, 2, ..., n) for to signal x(f) , the signal amplitude domain parameters

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including an average value $\bar{x}$, it is the average of the signal and describe the data of the static component, also named as dc component. X_{rms} reflects the signal energy size, measuring the vibration magnitude. The absolute maximum $|X|_{max}$ is usually used in the inspection structure strength, especially at low frequency structure damage and it is directly relationship. All these parameters in front of stability is good, but is not sensitive to the early fault signal.

The other amplitude indexes are belong to the nondimensional parameters index and having not sensitive characteristics to the signal amplitude and frequency variation. The number of coefficient has strong recognition ability for impact fault, especially when fault early occur, they have significantly increased, but rise to a certain degree, fault with the gradual development, it may decline, which show that they have higher sensitivity to early fault, but have bad stability. In fact, all kinds of amplitude domain parameters essentially depend on the probability density function of random signal. In order to get more accurate judgment, usually on the above amplitude domain both have sensitivity and stability parameters selection, which is the basis as aircraft engine fault diagnosis.

Time domain analysis: The most important features of the time domain analysis is the signal time sequence, namely the data creating priorities. In the amplitude domain analysis, although all sorts of amplitude domain parameters can be used to calculate by the time waveform, its time order is out of operation. We often use the time domain analysis methods, such as the autocorrelation function, mutual close function, envelope analysis and track analysis, etc., (Hu, 2003).

The autocorrelation function can be used to test the certainty signal mixed in the random noise signals. Because of periodic signal or any certainty data all have their autocorrelation function in all the time, but the random function is not. The autocorrelation function can not only help to build the any moment value influence to the future moment. The different signal has a different autocorrelation function, which is the basic of fault diagnosis by using the autocorrelation function. The normal operation of the machine, the autocorrelation function of the vibration signal in the steady condition usually has broadband random noise. And when having fault, especially appear the periodic impact, the autocorrelation function can appear bigger peak.

The cross-correlation function $R_{xy}(\tau)$ is function to τ. It describes the dependence between the two groups of data. The cross-correlation function can used to monitor signal mixed in the outside noise signal. Envelope analysis is a kind of effective method on the fault diagnosis of large rotating machine. Its wideband characteristics often cause system natural frequency resonant, thus produce side band in character fault frequency near the wideband and this side band can be regard as the result of the fault signal modulatory. This sideband can be considered as a fault signal modulation analysis. The purpose of demodulation is to get modulation signal and get the envelope, which can realize the frequency domain features analysis and achieve the requirement of fault diagnosis.

Axis path is one of important time domain analysis to the rotating machinery vibration signal, because the total amplitude fluctuations or amplitude frequency curve of the rotating part center position can more reflect the movement of the axis. It can be simple and intuitive expressed the equipment operation, which is the most important fault diagnosis graphic signs. The shape of the axis path, movement direction and stability are the important signs parameters of the fault diagnosis. And the different axis path reflects the different rotor motion condition or the basic information of the malfunction Jian and Li (2007).

Frequency domain analysis: In the engineering, the measured signal is commonly time signal, however, because the fault occurring and development often cause the signal frequency structure change, in order to understand and observe the object's dynamic behavior, we often need the frequency domain information. The purpose of the frequency spectrum analysis is to get single harmonic component from the complex time process waveform by the Fourier transform, which to obtain the frequency of the signal and the harmonic structure amplitude and phase information. According to different character and transform method of the signal, we can express them in the amplitude spectrum, phase spectra and power spectrum, etc., (Cheng *et al*., 2011).

Amplitude spectrum reflects the distribution circumstance of each frequency component along the frequency axis. The phase spectral reflect the change circumstance of each frequency component along the frequency axis, also reflect the phase differences of each frequency component. Amplitude spectrum provides many vibration signal information, for example, the vibration signal is consisted by the basic frequency components and the high order harmonic component of 2f, 3f, 4f, ... and low order harmonic component of 1/2f, 1/3f, 1/4f, ... In addition, we can know whether the equipment has fault or not through the frequency components characters and judge the fault type Wang and Xie (2009).

The auto power spectrum describes the structure of the frequency, to the vibration signal, it reflects the vibration energy distribution circumstance in each frequency, so, in engineering, its application is very extensive. The so-called power spectrum can have three kinds of means, namely the mean square spectrum, root mean square spectrum and logarithmic spectrum. The mean square spectrum reflects the energy distribution and the mean square root spectrum reflects the vibration amplitude also called amplitude spectrum. The auto

Table 1: Comparing with the amplitude domain parameter

Amplitude index	X_{rms}	S_f	C_f	CL_f	L_f	K_v
Normal condition	0.4587	1.2114	3.8271	2.7603	3.8720	3.0123
Fault condition	0.5520	1.3063	5.5708	4.1266	5.2059	4.8842

power spectrum analysis has advantage to the correlation analysis. In the related analysis, we can find the periodic signal, but in mixed frequency components, correlation analysis is not easily distinguished and spectral analysis can distinguish many frequency components, but can not only carry out the qualitative analysis, but also can quantitative analysis.

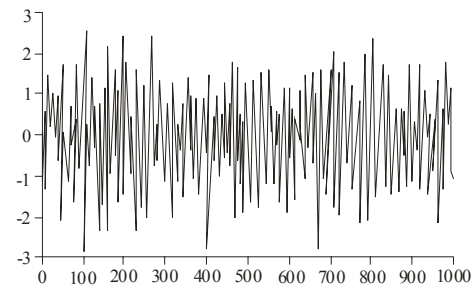
COMBINING ANALYSIS OF AMPLITUDE DOMAIN PARAMETER AND FREQUENCY DOMAIN PARAMETER

In order to prove the time frequency analysis has function to obtain the fault starting time and the fault type, we carry out the time domain analysis to the vibration signal pretreated to find the start time of the equipment fault in order to convenient for the fault type detection and analysis. The vibration signal waveform diagram under the normal work condition is shown as Fig. 1a and the vibration signal waveform diagram under the fault condition is shown as Fig. 1b.

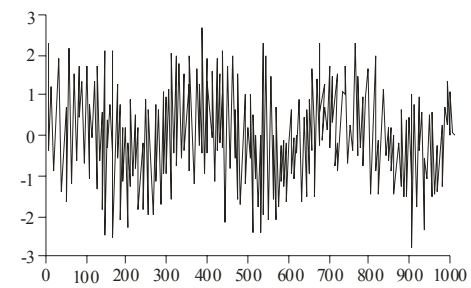
The time domain index is shown as Table 1. Through the Table 1, we can see the amplitude domain index has more change between the normal condition and the fault condition of the rotating machine equipment working. And the index value of the X_{rms}, S_f, C_f, CL_f, L_f, and K_v in the fault condition is obviously larger than the normal condition index value. So, we can decide that the rotating machine equipment in fault work. In addition, we can complete the fault diagnosis through the frequency domain analysis.

By using the frequency analysis to the fault signal of the rotating machine equipment, we can get the vibration signal frequency spectrum diagram, which is shown as Fig. 2. Among the Fig. 2a is the useful signal of the vibration signal and (b) is the frequency spectrum of the noise separation signal.

Through the frequency spectrum diagram, we can find out the high harmonic frequency feature nf of the rotor normal rotation frequency f, so, we can find out the cause of the equipment fault according to the equipment fault frequency characteristics. Through comparing with the characters of the rotating machine equipment, when the nf (n = 1, 2, 3...) harmonic appearance, which expresses that equipment has the initial collision-friction fault and when the action rubbing serious of the friction spreading throughout the circle, the rotor system will have redundant additional supporting role, thus the high frequency vibration is reduced gradually and the rubbing condition of the undamental frequency will be outstanding, which can cause the sub-frequency nf $(n = \frac{1}{2}, \frac{1}{3}, \frac{1}{4} \ldots)$.

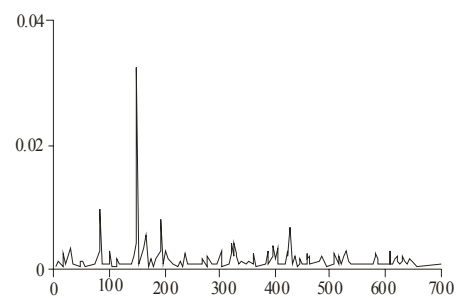


(a) The vibration signal waveform under the normal work condition

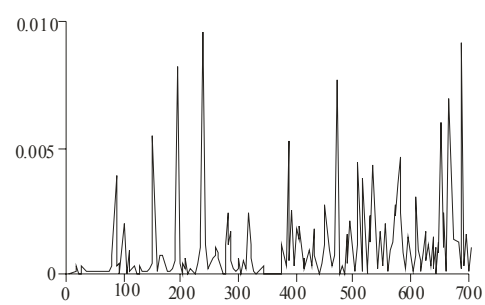


(b) The vibration signal waveform under the fault condition

Fig. 1: The vibration signal waveform diagram



(a) The frequency spectrum of useful separation signal



(b) The frequency spectrum of noise separation signal

Fig. 2: Spectrum diagram of the fault signal

Through the analysis we can see, at present, this fault is not serious and need to carry out the necessary maintenance protection, which can prevent the major accident appearance.

CONCLUSION

This study carried out the time domain and frequency domain parameters analysis to the rotating machinery equipment fault. By using a normal condition and the fault occur condition of the equipment in time domain and the frequency domain analysis, we can quickly find out the fault occurring starting time by the time domain properties and by using the frequency domain analysis, we can judge the fault type, which can also for the safe operation of the equipment maintenance and provide an effective assistant method Shen and Yin (2003).

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