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Mine Ventilator Common Faults Analysis and Diagnosis

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ABSTRACT

Mine ventilator is the key equipment in the coal mine safety production. The safety performance of ventilator can be ensured by condition monitoring and fault diagnosis. In this paper, taking mine ventilation as a example to discuss the simple diagnosis of equipment by the vibration intensity. If an exception occurs, the vibration acceleration signal is collected through vertical and horizontal and axial in three directions on mine ventilator bearing, Fast Fourier Transform method is used for precise diagnosis of reason and the location of the fault. Practice shows that the combination of these two methods has a very great significance in the actual production.

KEYWORDS: Mine ventilator; Fault diagnosis; Vibration Analysis

INTRODUCTION

Ventilators are important equipment in the coal mines for safety production, similar to the human respiratory system. Therefore, it is of great economic and social value for coal mine safety to ensure ventilator’s safe operation and avoiding the occurrence of accidents by condition monitoring and fault diagnosis. There are some possible faults as frictions、 scratching and collision between rotating parts (main shaft, impeller etc.) and stationary parts (inlet, casing), rotor imbalance, rotor misalignment, rotor bending, foundation and assembly parts loosening, bearing damage, blade fault and so on[1, 2]. When these faults occur, it will seriously affect the normal operation of ventilators and even cause serious accidents. Therefore, it is necessary to monitor and diagnose the operating condition of the ventilators. In this paper, firstly the vibration intensity is applied to determine whether there are faults in the ventilators. Then the typical faults of ventilators are identified by the method of vibration spectrum analysis.

CHARACTERISTIC ANALYSIS OF TYPICAL FAULT OF THE VENTILATOR[3]

1. Rotor imbalance

Rotor imbalance includes the mass eccentricity of the rotor system and the defects of rotor parts. The rotor mass eccentricity is called the initial unbalance, which is caused by manufacturing error, assembly error and non-homogeneous of material. The rotor component defect refers to the rotor in operation due to abrasion, wear, medium scale and rotor fatigue labor, the rotor parts (blade) local damage, loss, debris flying out, causing a new rotor imbalance. Rotor mass eccentricity and rotor component defect are two different kinds of faults, but the imbalance vibration mechanism is the same. When the rotor imbalance occurs, the vibration characteristics are:

1) Characteristic frequency： Exciting frequency of vibration is mainly shaft rotation frequency, that is, the working frequency is f_r=n/60Hz, n for shaft speed (r/min).

2) With frequencies：$2\times f_r$, higher harmonics

3)Vibration direction： mainly the radial vibration

2. Shafts misalignment

The shafting by coupling between the ventilator shaft and the motor shaft, due to the error of the machine installation, after the bearing deformation and loosening machine foundation, will cause the shaft displacement, parallel axis angle displacement or displacement of the change in comprehensive shafting error, called rotor misalignment. When there is rotor misalignment, a series of harmful effect will be produced, such as machine coupler deflection, early damage, bearing oil film instability or shaft deflection, causing the machine abnormal vibration and noise． Its vibration characteristics are:

1) Characteristic frequency：Exciting frequency is mainly $2\times f_r$， that is doubling frequency

2) With frequencies：$1\times f_r$， $3\times f_r$， $4\times f_r$， $5\times f_r$， $7\times f_r$ higher harmonics, and so on;

3) Vibration direction：mainly radial and axial vibration.

3. Pedestal loosening

Pedestal loosening is always associated with rotor imbalance, and it shows nonlinear vibration characteristics. The vibration mode is mainly longitudinal vibration. Its vibration characteristics are: in addition to the fundamental frequency component f_r, but also with high harmonic components $3f_r$, $5f_r$ and fractional harmonic (0.3~0.5) f_r, sub harmonic $1.5f_r$, $2.5f_r$, and the triple frequency component is greater than doubling frequency. When the velocity increase, there is the jump phenomenon of amplitude， which is suddenly increased or decreased.

4. Blade faults

The blades are cracked, broken or deformed by the dynamic pressure of the gas when the ventilator works. These faults of the blade will cause the imbalance vibration of the ventilator. Its vibration characteristics are:

1) characteristic frequency: Exciting frequency of vibration is mainly Nf_r (N the number of blades);

2) Always frequency: A large number of f_r modulation sidebands emerge around the characteristic frequency, that is (N±m) f_r (m=1,2,…,);

3) Vibration direction: The vibration direction is mainly in the radial direction. When the blade deformation is serious, the axial vibration is large, and with large abnormal sound because of air current or deformation of different shapes.

SPECTRAL ANALYSIS METHOD

FFT (Fast Fourier Transformation) frequency spectrum analysis is used. Frequency spectrum is a method of spectral analysis to extract diagnostic information. Spectrum maps are: amplitude spectrum, phase spectrum, power spectrum. The following mainly introduces the amplitude spectrum analysis method.

Suppose X(*f*) to be the Fourier Transform of vibration signal, that is:

$$X(f) = F[x(t)] = \int_{-\infty}^{+\infty} x(t)e^{-i2\pi ft}dt \quad (1)$$

In general, X(*f*) is a complex function:

$$X(f) = U(f) + iV(f) = |X(f)|e^{i\emptyset(f)}$$

$$|X(f)| = \sqrt{U^2(f) + V^2(f)} \quad (2)$$

$$\emptyset(f) = arctg[V(f)/U(f)] \quad (3)$$

where, |X (*f*) | is called amplitude spectrum or FFT spectrum, and it shows the distribution of the amplitude of each frequency component in the signal along the frequency axis. $\emptyset(f)$ is called the phase spectrum, it shows changes in the phase of each frequency component of signal along the frequency axis. In this paper, amplitude spectrum is adopted for fault diagnosis of the ventilator. Amplitude spectrum can provide the following diagnostic information:

1) vibration signal is mainly composed of which frequency components and harmonic components.

2) the amplitude of which components of the harmonic component is the most prominent, which suggests a link with the fault.

THE FAULT DIAGNOSIS AND ANALYSIS OF THE MAIN FAN IN A COAL MINE [4]

Vibration method (including simple and precise diagnosis) is used to monitor operating condition and fault diagnosis . The measuring points are arranged on the bearing seat which is the most concentrated force.

1. Ventilator system structure and main technical parameters

(1) Transmission schematic and measuring point layout as shown in Fig. 1.

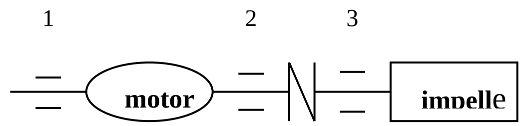


Figure 1: Schematic of a main fan drive

Notes: ①Each measurement point can pick up the vertical, horizontal and axial three directions of the vibration signal;

②The bearings of the 1st -2nd measuring points are sliding bearings, and the 3rd is arranged on the rolling bearing seat of the ventilator rotor.

③No. 1 and No. 2 main fans parameters are the same.

(2)Fan model: axial flow fan AGF606-2.20-1.30-2

Speed: 988r/min, rotating frequency fr:16.47Hz

rotating blades numbers N=16; series: 2

(3) The asynchronous motor model: YR1000－10/1430, speed is 988 r/min, rated power: 1000KW

(4) The characteristic frequencies of the ventilators are as shown in Table 1 and the bearing characteristic frequencies are as shown in table 2.

Table 1: characteristic frequency (Hz)

Rotational frequency f_r	$2f_r$	$3f_r$	$4f_r$	Blade fault characteristic frequency $f_N=16f_r$	$2f_N$
16.47	32.94	49.4	65.87	263.47	526.94

Table 2: Bearing characteristic frequency（Hz）

bearings Model / characteristic frequency	NU330	7330	7334
outer Characteristic frequency	100	90.7	111.7
Inner characteristic frequency	131.5	122.7	151
Rolling characteristic frequency	61.9	46.2	46.2
Holding characteristic frequency	7.1	7	7

2. Simple diagnosis of main fan

Simple diagnosis is a detect, using portable vibration meter on the main measuring points of the ventilator. The measuring points are mainly arranged in the most concentrated part of the bearing seat, and the physical parameters are detected as the root mean square value of the vibration velocity, vibration intensity of v_{rms}.

Table 3 is the vibration intensity value of the No. 1 ventilator (mm/s), using the simple vibrometer of BZ－8701A, measuring point for vertical direction (V) and horizontal (H) and axial (A).

Table 3: No.1 ventilator vibration intensity value (mm/s)

Measuring points / terms	1#			2#			3#		
	V	H	A	V	H	A	V	H	A
	0.7	1.9	2.0	1.5	4.4	4.3	1.2	3.0	3.8

Table 4: No.2 ventilator vibration intensity value (mm/s)

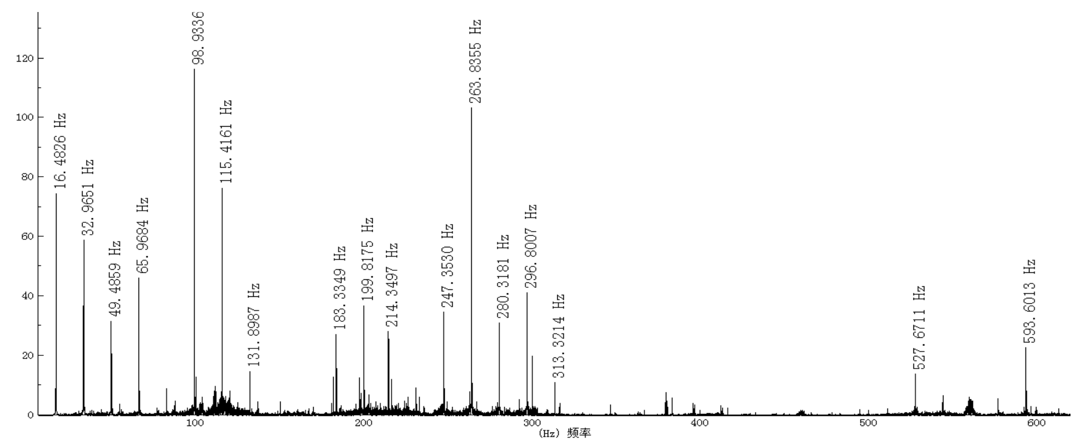
Measuring points / terms	1#			2#			3#		
	V	H	A	V	H	A	V	H	A
	0.6	1.2	0.6	1.4	2.6	1.9	1.9	2.0	2.7

V—Vertical direction、H—Horizontal direction、A—Axial direction

According to the ISO10816-3:1998 and GB/T6075.3-2001, the vibration intensity of each measuring point of the NO.1 ventilator is less than 4.5mm/s which belongs to the B area. But the vibration intensity of the measuring point 2, 3 is larger, which indicates that the NO.1 ventilator may be an early failure and need to notice.

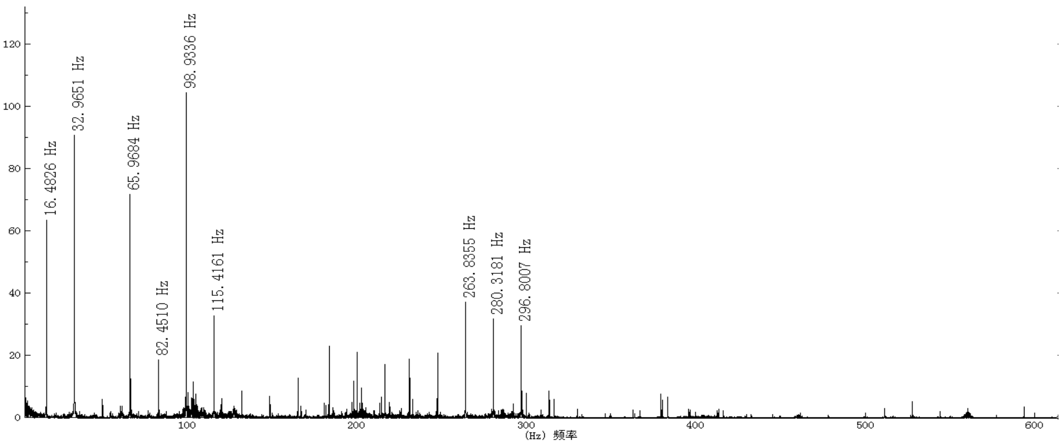
3. Precision diagnosis and analysis of No.1 main fan[5,6]

It is necessary to carry out vibration precision diagnosis to determine whether there is a fault. By using the method of FFT, the amplitude spectrum of is analyzed only on the measuring point 2 of the 1 ventilator.

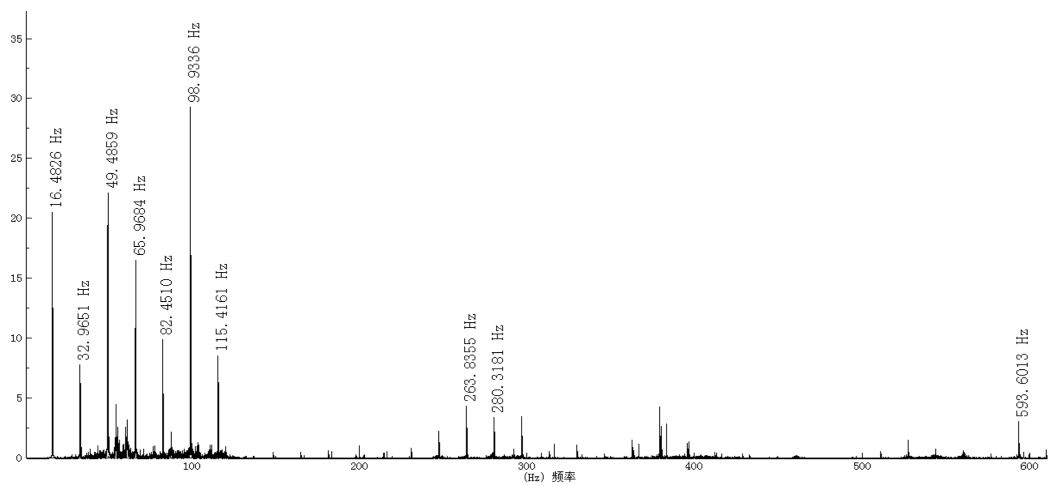


(a) Vertical amplitude spectrum at the 2nd measuring point

Figure 12: *Continues on the next page*



(b) Horizontal amplitude spectrum at the 2nd measuring point

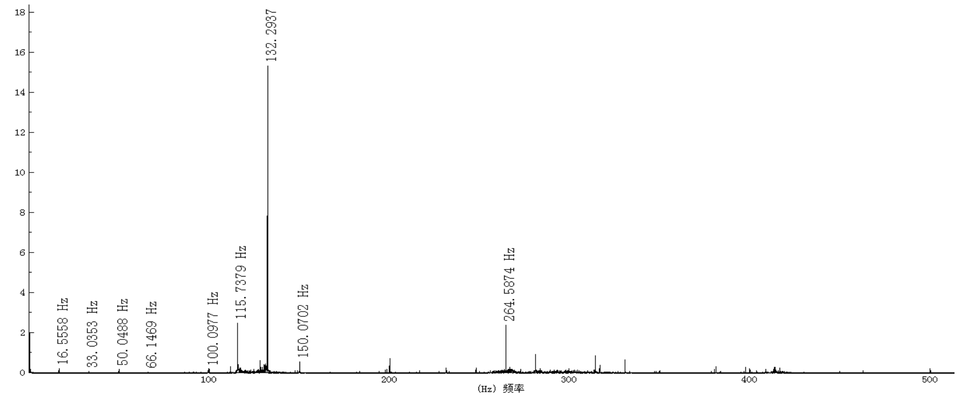


(c) Axial amplitude spectrum at the 2nd measuring point

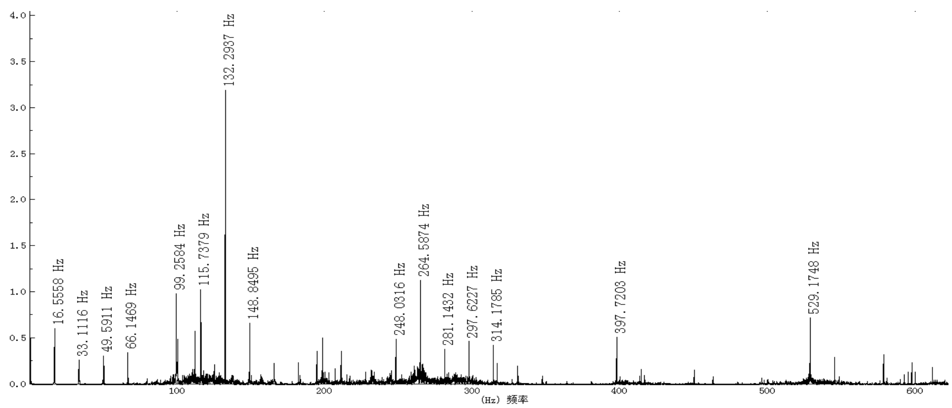
Figure 2: Amplitude spectrum analysis at the 2nd measuring point

From the amplitude spectrums of 2 measuring point, the components of the transmission shaft rotation frequencies are 16.48Hz and higher frequencies The harmonic amplitudes are larger and more obvious in the horizontal direction and the axial direction. In addition, There are 132.2Hz (corresponding to the NU330 bearing the inner ring fault characteristic frequency) and 2 frequency 264.4Hz, and the surrounding a small amount of 16.48Hz with the modulation of the side band. Therefore, there is misalignment fault of the drive shaft due to bearing wear or misalignment fault of coupling . And there is wear or early pitting failure on NU330 inner ring, because if the fault is serious, it should appear high frequency peaks in the amplitude spectrum surrounding with a large number of modulation sidebands.

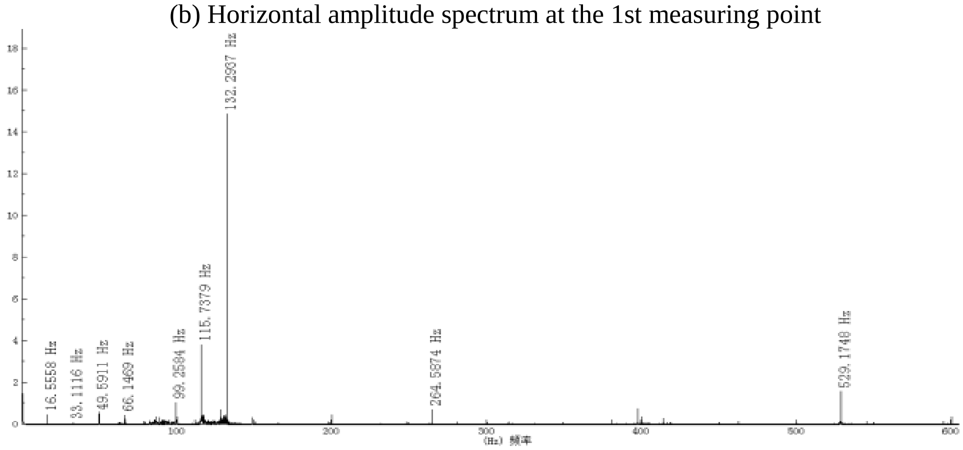
4. Precision diagnosis and analysis of No.2 main fan



(a) Vertical amplitude spectrum at the 1st measuring point



(b) Horizontal amplitude spectrum at the 1st measuring point



(c) Axial amplitude spectrum at the 1st measuring point

Figure 3: Amplitude spectrum analysis at the 1st measuring point

The amplitude spectrum analysis of three directions on measuring point 2 shows that the frequency components are mainly NU300 bearing inner ring characteristic frequency 132.3Hz, and the amplitude spectrum performance is more obvious in the horizontal and axial. There are no other high-frequency components in the spectrum. This shows that the main No.2 ventilator runs normally horizontal direction and axial vibration, And FFT is used to analyze、compare the signal spectrum on the vibration acceleration signal spectrum of three directions. It is diagnosed that there is misalign fault caused by bearing inner ring wear on the No. 1 fan drive shaft. Practice shows that the application of vibration analysis method can accurately diagnose the fault of fan and combining the simple diagnosis method and precise diagnosis method greatly improves the efficiency of equipment monitoring, cost savings, has very important practical value.

CONCLUSIONS

Mine ventilator is the core equipment to ensure the safe production of the mine, and its working condition has great influence on the safety production of the mine. In practical engineering application, firstly, the operating conditions of ventilators are diagnosed initially with the intensity index to determine whether the equipment fault. If anything is found, collecting the vibration acceleration signal of the vertical direction, horizontal direction and axial vibration, And FFT is used to analyze、compare the signal spectrum on the vibration acceleration signal spectrum of three directions. It is diagnosed that there is misalign fault caused by bearing inner ring wear on the No. 1 fan drive shaft. Practice shows that the application of vibration analysis method can accurately diagnose the fault of fan and combining the simple diagnosis method and precise diagnosis method greatly improves the efficiency of equipment monitoring, cost savings, has very important practical value.

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