

# Diagnosis and Treatment of Unbalance about Power Plant Rotating Auxiliary Equipment

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**Abstract.** This paper introduces the characteristics of unbalanced fault and the handling method of rigid rotor unbalanced fault, and expounds the handling process of large fan unbalanced fault through two balancing cases, which can be used for reference to the fault analysis and handling of the unbalanced fault of power plant rotating auxiliary equipment.

## 1 Introduction

According to the working status and mechanical characteristics, rotors can be divided into two categories: rigid rotors and flexible rotors[1]. Power plant rotating auxiliary equipments, such as some fans, motors, couplings, can be treated as the rigid rotors. As one of the most common types, the fault rate of fans is always high due to their poor operating conditions. This often leads to load reduction operation or unplanned outages of generator set. It is pivotal to deal with fan fault in time.

The fan vibration is one of the most common fault phenomena during the fan operation process, which is caused by many factors, such as rotor unbalance, abnormal rolling bearings, shaft misalignment, foundation loose, static and dynamic part friction, as well as rotating stall and surge. Among them, rotor unbalance is one of the most common faults, which accounts for more than 75% of the total faults[2]. Therefore, we should master the rotor unbalanced fault diagnosis method and technology. It is helpful to shorten the equipment maintenance time, improve the equipment reliability, and ensure the safe and stable operation of the electric generator unit.

## 2 Fault characteristics

The fan unbalanced fault is usually caused by uneven blade wear, dust accumulation, displacement or fall off of rotating parts, assembly error during overhaul and so on. The main characteristics of unbalanced fault are[3]:

- The vibration frequency is mainly 1 times rotation frequency, the peak value is very high, and other frequency is seldom accompanied.

- The ratio of peak values in horizontal and vertical directions of 1 times frequency is generally not more than 3:1.

- It has lower axial vibration (except cantilever rotor equipment).

- The phase data is relatively stable at constant rotation speed, the variation is less than 15°~20°.

- The vibration value increases with the increase of the rotation speed.

## 3 Fault handling

Unbalanced fault handling is different from experimental study. When the repair time is more generous, the blade wear needs to be repaired, the uneven ash accumulation powder should be cleared, rotating parts that have shifted or fallen off need to be restored or replaced, assembly errors must be re-assembled according to the manufacturer's drawings. But for the important fan in operation, as the overhaul time is short, the unbalanced fault is usually handled by the dynamic balance processing method during low load operation.

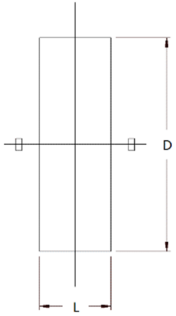
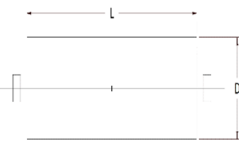
There are many dynamic balance methods, the common ones are the influence coefficient method, the mode balance method, and the modal parameter identification method. Among them, the rigid rotor generally adopts the influence coefficient method, the flexible rotor can adopt the influence coefficient method, the mode balance method, and the modal parameter identification method. Most rotors of the power plant rotating auxiliary equipments are rigid rotors, so the influence coefficient method is usually used.

The commonly used influence coefficient method is divided into the single plane influence coefficient method and the double plane influence coefficient method. The dynamic balance of the rigid rotor usually needs to be carried out on two planes, and the single plane dynamic balance is a special case of double plane dynamic balance[4]. If the rotor weight-loss plane is on a certain plane, such as coupling imbalance, fan impeller imbalance, the method of single plane dynamic balance can be used. The determination of the number of planes

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can be referred to the empirical formula provided by the French Framatome, as shown in Table 1.

**Table1.** The empirical formula under ideal conditions.

Types of the rigid rotor	L/D	Conditions (rpm)	The number of planes
	≤0.5	n≤1000	1
		n>1000	2
	>0.5	n≤150	1
		n>150	2

### 3.1 Single plane dynamic balance

Acquire the vibration data  $\vec{A}_0$  in the original state.

Try to add a counterweight  $\vec{P}_0$  on the rotor and then measure the vibration data  $\vec{A}_1$ .  
 Calculate the influence coefficient.

$$\vec{\alpha} = \frac{\vec{A}_1 - \vec{A}_0}{\vec{P}_0} \quad (1)$$

Calculate the counterweight  $\vec{Q}$  which should be added on the rotor.

$$\vec{Q} = -\frac{\vec{A}_0}{\vec{\alpha}} \quad (2)$$

### 3.2 Double plane dynamic balance

Measure the vibration data  $\vec{A}_0$  and  $\vec{B}_0$  of the two planes in the original state.

Try to add a counterweight  $\vec{P}_1$  on the plane A and then measure the vibration data  $\vec{A}_{01}$  and  $\vec{B}_{01}$  of the two planes.

Try to add a counterweight  $\vec{P}_2$  on the plane B and then measure the vibration data  $\vec{A}_{02}$  and  $\vec{B}_{02}$  of the two planes.

Calculate the influence coefficients.

For the counterweight  $\vec{P}_1$ :

$$\vec{\alpha}_{11} = \frac{\vec{A}_{01} - \vec{A}_0}{\vec{P}_1} \quad (\text{for the plane A}) \quad (3)$$

$$\vec{\alpha}_{21} = \frac{\vec{B}_{01} - \vec{B}_0}{\vec{P}_1} \quad (\text{for the plane B}) \quad (4)$$

For the counterweight  $\vec{P}_2$ :

$$\vec{\alpha}_{12} = \frac{\vec{A}_{02} - \vec{A}_0}{\vec{P}_2} \quad (\text{for the plane A}) \quad (5)$$

$$\vec{\alpha}_{22} = \frac{\vec{B}_{02} - \vec{B}_0}{\vec{P}_2} \quad (\text{for the plane B}) \quad (6)$$

Suppose that the plane A is counterweighted  $\vec{Q}_1$  and the plane B is counterweighted  $\vec{Q}_2$ , then solve the following equations[5].

$$\begin{cases} \vec{\alpha}_{11}\vec{Q}_1 + \vec{\alpha}_{12}\vec{Q}_2 + \vec{A}_0 = 0 \\ \vec{\alpha}_{21}\vec{Q}_1 + \vec{\alpha}_{22}\vec{Q}_2 + \vec{B}_0 = 0 \end{cases} \quad (7)$$

## 4 Case verification

### 4.1 Case one: dynamic balance test with unknown influence coefficient

The #1B blower of a factory adopts the ASN-2884/1400 single-stage adjustable-blade blower produced by Shenyang Blower Factory, the blower is a cantilever blower, the supporting bearings are all rolling bearings, the structure diagram is shown in Figure 1. The vibration of the blower exceeded the standard value after examination of overhaul, the vibration speed measured at the No.4 bearing was up to 6.5 mm/s.

### 4.1.1 Fault diagnosis and analysis

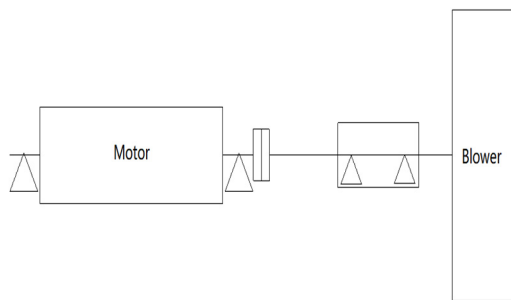


Fig 1. The structural diagram of the blower.

To exclude the influence caused by loose bolts, the state of bolt was checked firstly. The vibration sensor and the photoelectric sensor were arranged, and the reflective band (to measure the phase of vibration) was pasted on the rotating shaft. As the No. 4 bearing is closest to the blower, the vibration data measured at the No. 4 bearing can best reflect the vibration condition of the blower. The following analysis mainly focuses on the vibration data of the No. 4 bearing. The vibration speed of 1 times rotation frequency was measured to be 5.97 mm/s  $\angle$ 93.5 in the horizontal direction. The vibration spectrum of the No.4 bearing was shown in Fig. 2. The vibration spectrum of the No.3 bearing was shown in Fig. 3.

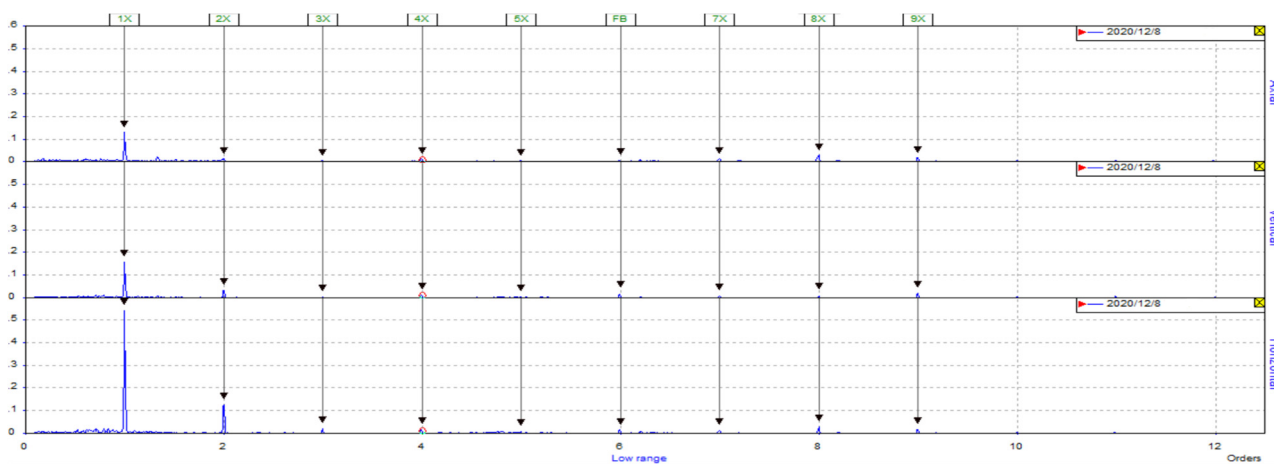


Fig 2. The vibration spectrum of the No.4 bearing.

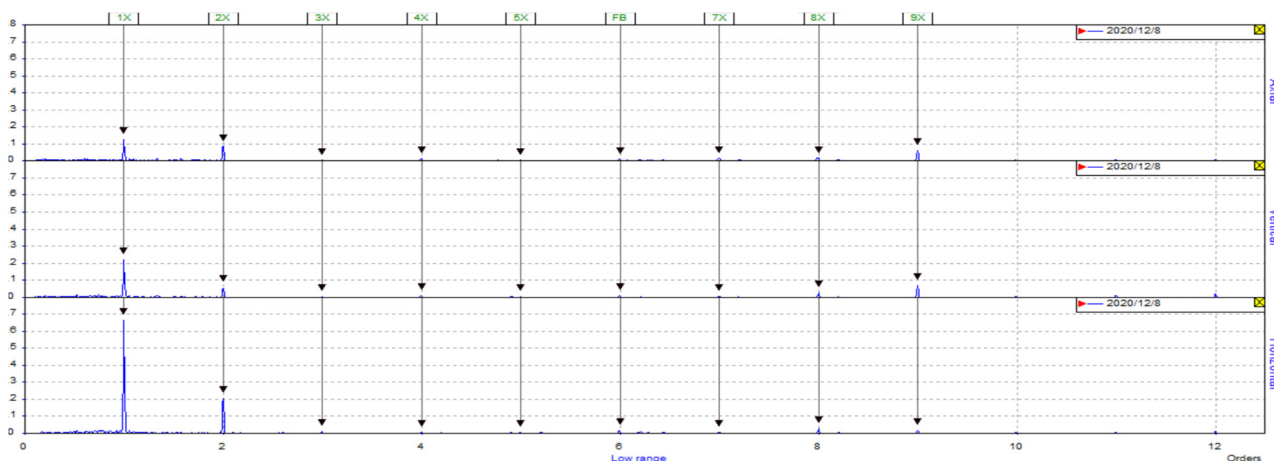


Fig 3. The vibration spectrum of the No.3 bearing.

The analysis showed that the vibration of the blower was dominated by 1 times rotation frequency. The amplitude in the horizontal direction was bigger than the amplitude in the vertical direction and the ratio of the peak values was less than 3:1, at the same time, the vibration phase was basically stable. Therefore, the main reason of the blower fault was imbalance.

#### 4.1.2 Determination of the fault handling method

The blower rotor is rigid, the length to diameter ratio of the rotor is less than 0.5, the working rotating speed is less

than 1000 rpm, according to the empirical formula provided by the French Framatome, the single plane dynamic balance was carried out.

#### 4.1.3 Implementation of dynamic balance

Because the influence coefficient and the hysteresis phase lag are both unknown, after the counterweight is completed, it is best to ensure that the amount of vibration change exceeds 20% or the amount of phase change exceeds 20°. The radius of the counterweight is about 1.2 m, the weight of the rotor is 2256 kg, the rotating speed is

990 rpm, and the above data is substituted into the following formula[6].

$$m = \frac{1}{N} \times \frac{1}{r} \times \frac{M}{10} \times \frac{9.81 \times 3600}{4\pi^2} \times \frac{1}{v^2} \quad (8)$$

The calculated weight is 172 g, the selected counterweight is 181 g, based on experience, the phase is selected as 330°. The blower was restarted after the counterweight was completed, the vibration speed of 1 times rotation frequency was measured to be 5.39 mm/s ∠ 105.2 in the horizontal direction. The calculated influence coefficient was 0.007 g ∠ 245.838 and the calculated counterweight was 835.283 g ∠ 27.662. The corrected counterweight was 850 g ∠ 30 after the initial counterweight was removed.

The blower was restarted, and the vibration speed was reduced from 5.97 mm/s ∠ 93.5 to 3.54 mm/s ∠ 66.7. The result was unsatisfactory and then the above operations were repeated. The vibration speed of 1 times rotation frequency dropped to 2.7 mm/s ∠ 25.5, the vibration speed measured at the No.4 bearing reached the standard range.

**Table2.** Dynamic balance test of the #1B blower.

No.	Vibration data	Notes
1	5.97 mm/s ∠ 93.5	The original vibration speed
2	5.39 mm/s ∠ 105.2	The vibration speed after the blower was counterweighted 181 g ∠ 330
3	3.54 mm/s ∠ 66.7	The vibration speed after the blower was counterweighted 850 g ∠ 30
4	2.7 mm/s ∠ 25.5	The vibration speed after the blower was counterweighted 1400 g ∠ 0

#### 4.2 Case two: dynamic balance test with known influence coefficient

The #2A blower of the factory is also a cantilever blower, the supporting bearings are all rolling bearings, it has the same structure as the above blower. The vibration of the blower was tested and analyzed, the vibration of the blower exceeded the standard value, after eliminating other causes of the fault, the result showed that it had obvious dynamic imbalance characteristics.

At the No.4 bearing, the original vibration speed of 1 times rotation frequency was measured to be 4.6 mm/s ∠ 353 in the horizontal direction. It is known that the influence coefficient of the #2A blower was 0.004 g ∠ 273.095, the calculated counterweight was 1074 g ∠ 260. After the blower was counterweighted, and the vibration speed was reduced from 4.6 mm/s to 0.72 mm/s.

It can be seen that, for the power plant rotating auxiliary equipment with the certain structure, under the

condition with the influence coefficient, unbalance fault can often be solved by one time counterweight.

**Table3.** Dynamic balance test of the #2A blower.

No.	Vibration data	Notes
1	4.6 mm/s ∠ 353	The original vibration speed
2	0.72 mm/s ∠ 81.6	The vibration speed after the blower was counterweighted 1074 g ∠ 260

## 5 Conclusion

There are many reasons for the vibration of the power plant rotating auxiliary equipments, and the unbalanced mass is one of the main reasons. Due to the particularity of the structure of the rotating auxiliary machinery of the power plant, the rotor is usually a rigid rotor, so the influence coefficient method is generally adopted.

For the rotating equipment without the influence coefficient, the influence coefficient should be obtained according to the initial counterweight, and then the effective counterweight should be calculated according to the influence coefficient. For the rotating equipment with the influence coefficient, the effective counterweight can be calculated directly.

The unbalance about power plant rotating auxiliary equipment can generally be effectively solved by the single plane dynamic balance. After the dynamic balance is implemented, the most accurate influence coefficient should be selected and recorded, which is helpful to deal with the unbalance fault of the equipment.

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