Study on the dynamic balancing method for eliminating horizontal vibration of turbine bearing pedestal

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Abstract. A new method of field dynamic balancing for double rotor turbo-generator set is studied in this paper. According to the vibration mode characteristics of the shaft system of this type of unit, this method creatively uses the balancing slot of the fan at the rear end of the generator rotor as the only balancing plane, and uses a specific calculation method to eliminate the vibration of the shaft system in the horizontal direction caused by the deviation of the coupling and mass imbalance by applying the counterweight only once.

1. Introduction

Double rotor steam turbo-generator sets are commonly seen in small capacity units. The shafting is composed of turbine rotor and generator rotor. There are four bearing pedestals in total, among which #1 and #2 are turbine rotor bearing pedestals, #3 and #4 are generator rotor bearing pedestals. The shafting structure diagram of this type of unit is shown in Figure 1.

Figure 1. The shafting structural diagram of the unit.

The most common vibration problem of this type of unit is the abnormal vibration of bearing pedestals #2 and #3 in horizontal direction. This kind of vibration is usually caused by coupling deviation and mass imbalance. The traditional treatment method is to take the bolt for coupling as the balancing position to carry out field dynamic balancing test[1]. Since the turning gear of this type of unit is installed on the box of #2 and #3 bearing pedestals, it is necessary to disassemble the complex turning gear repeatedly when the counterweight is applied to the coupling between #2 and #3 bearings. Dynamic balancing work consumes a lot of manpower and material resources, which makes maintenance difficult, and often causes economic losses due to the extension of maintenance period[2-3].
Based on the above reasons, this paper studies a simple, fast and practical dynamic balancing method. This method can solve the abnormal vibration problem of this type of unit with less startup times and less maintenance workload.

2. Application scope and basis of this dynamic balancing method
The characteristics of abnormal vibration of bearing pedestals #2 and #3 of this type of double rotor turbo-generator set are as follows: the vibration phase angles of bearing pedestals #2 and #3 in vertical and horizontal directions are close to the same (the difference of phase angles is within 30°), and the vibration amplitude in horizontal direction is obviously higher than that in vertical direction[4-5].

Through a large number of field dynamic balancing tests, it is found that the unbalance response on the coupling between the turbine rotor and the generator rotor can be effectively reduced by applying the counterweight in the balancing slot of the fan at the rear end of the generator rotor, and a very significant dynamic balancing effect can be achieved after once balancing. Combined with the theory of rotor dynamics and a large number of field dynamic balancing test data, a specific dynamic balancing phase calculation method suitable for this type of unit is summarized.

When the counterweight is applied in the balancing slot of the fan at the rear end of the generator rotor, only one side end cover of the rear end of the generator rotor needs to be disassembled. The maintenance workload is much smaller than the disassembly of the turning gear, which is conducive to the rapid completion of the on-site maintenance work.

3. Contents and steps of this dynamic balancing method
The key point of this method is that the vibration of each bearing pedestal, especially the horizontal vibration of #2 and #3 bearing pedestals, can be reduced to the acceptable range by applying counterweight in the balancing slot of the fan at the rear end of the generator rotor. The main contents and steps are as follows.

3.1. Installation position of transducers
Before the start up of the unit, vibration measurement transducers are installed in the vertical and horizontal directions of bearing pedestals #2, #3 and #4. The photoelectric phase transducer for measuring phase should be installed at the horizontal position of the split plane of the exposed journal surface, and the reflective tape is pasted on the facing position on the journal. Pay attention that the reflective tape must pass through the photoelectric phase transducer from top to bottom when the rotor rotates. The horizontal vibration transducers and photoelectric phase transducer should be installed on the same side of the rotor. The transducers installation diagram is shown in Figure 2.

![Diagram of transducers installation position.](image)

3.2. Vibration measurement method
Start the unit to the working speed of 3000 rpm, after the speed is stable, measure the amplitude and phase of the vertical and horizontal vibration of #2 and #3 bearing pedestals every 5 minutes, measure for half an hour, and take the average value as the vibration value of each measuring point.
3.3. Calculation method of reference phase angle $\alpha_1$

Based on the amplitude and phase data of vertical and horizontal vibration of bearing pedestals #2 and #3, reference phase angle $\alpha_1$ is calculated according to the following formula:

$$\alpha_1 = \phi - \phi_1 - \phi_2 - \phi_3$$  (1)

Among them:
- $\phi$ is the average value of vertical vibration phase of #2 and #3 bearing pedestals.
- $\phi_1$ is the difference between #2 and #3 vertical vibration phases, ranging from 0° to 30°.
- $\phi_2$ is the lag characteristic angle of the instrument system used for measurement.
- $\phi_3$ is the difference between the phase difference of vertical and horizontal vibration of #3 bearing pedestal and 90°.

3.4. Calculation method of phase angle $\alpha_2$ of first counterweight

Firstly according to the vibration mode characteristics of the #3 and #4 bearing pedestals of the generator rotor, it is judged whether the vibration mode belongs to the first-order unbalance or the second-order unbalance. Then calculate the phase of the counter weight applied in the balancing slot of the fan at the rear end of the generator rotor according to the following formula:

If the vibration mode of the generator rotor is dominated by the second-order unbalance, then:

$$\alpha_2 = \alpha_1$$  (2)

If the vibration mode of the generator rotor is dominated by the first-order unbalance, then:

$$\alpha_2 = \alpha_1 + 180^\circ$$  (3)

3.5. Further optimization of counterweight

First, according to the dynamic balancing experience data of this type of unit, the weight of the first counterweight can be obtained. Then the phase can be calculated according to the above formulas. Add the counterweight into the balancing slot of the fan at the rear end of the generator rotor. In general, the vibration can be significantly reduced after once counterweight. When the original vibration value is very large, and the residual vibration cannot meet the requirements of the relevant vibration standards after the first counterweight is added, the size and direction of the further optimized counterweight can be calculated by using the influence coefficient method according to the vibration data before and after the first trial counterweight.

4. Application and analysis of a practical example of this dynamic balancing method

Take a 6000kW steam turbine generator set as an example, the shafting structure of the unit is shown in Figure 1. Firstly according to the requirements in Figure 2, the position of vibration measuring points of #2, #3 and #4 bearing pedestals was determined, the vibration transducers and photoelectric phase transducer were installed. The vibration measuring instrument used was 208DAIU produced by Bentley company in America, and the lag characteristic angle of the instrument system was 227°. Started the unit to the working speed of 3000rpm, the measured average vibration value is shown in Table 1.

| #2     | #3     | #4     |
|--------|--------|--------|
| (μm/°) | (μm/°) | (μm/°) |
| Vertical Vibration | 13/218 | 30/234 | 2/210 |
| Horizontal Vibration | 77/314 | 89/306 | 5/205 |

According to the vibration measurement data, the vibration characteristics of the unit are: the vertical and horizontal vibration phases of bearing pedestals #2 and #3 are close (the phase difference is within 16°), and the vibration amplitude in the horizontal direction is significantly higher than that
in the vertical direction. This is a common vibration characteristic of this type of unit, and the above
dynamic balancing method can be used for this unit. The calculation process is as follows:

\[ \phi = \frac{(218^\circ + 234^\circ)}{2} = 226^\circ; \phi_1 = 234^\circ - 218^\circ = 16^\circ; \phi_2 = 227^\circ; \phi_3 = 90^\circ - (306^\circ - 234^\circ) = 18^\circ. \]

Therefore,

\[ \alpha_1 = \phi - \phi_1 - \phi_2 - \phi_3 = 226^\circ - 16^\circ - 227^\circ - 18^\circ = -35^\circ \quad (4) \]

According to the vibration phase of #3 and #4 bearing pedestals, the vibration mode of generator rotor at working speed is mainly the first-order unbalance, so:

\[ \alpha_2 = \alpha_1 + 180^\circ = 145^\circ \quad (5) \]

According to the above calculation, a counterweight of 350g/145° was applied in the balancing slot of the fan at the rear end of the generator rotor. Started the unit again to the working speed of 3000rpm, and measured the vibration value of bearing pedestal. As shown in Table 2.

|               | #2 (μm/°) | #3 (μm/°) | #4 (μm/°) |
|---------------|-----------|-----------|-----------|
| Vertical Vibration | 2/60      | 3/315     | 7/190     |
| Horizontal Vibration | 26/288   | 28/280    | 11/283    |

Above test showed that, by using this calculation method, the abnormal vibration of #2 and #3 bearing pedestals of the 6000kW turbo-generator set had been successfully eliminated.

5. Conclusion
The faster dynamic balancing method for eliminating horizontal vibration of bearing pedestal of double rotor turbo-generator set is presented. It can effectively solve the problem of abnormal horizontal vibration of bearing pedestal before and after the coupling. This method avoids adding counterweight on the coupling and does not need to dismantle the turning gear for maintenance. It is a new dynamic balancing calculation method which has been verified by practice.

References
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