Study on abnormal vibration caused by foundation settlement of a 650MW unit

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Abstract. An unplanned shutdown occurred in a 650MW unit after one year of commercial operation. In the subsequent start-up, due to the excessive rubbing vibration, the unit tripped many times. During the overhaul inspection, it was found that the foundation of the steam turbine had large uneven settlement. Through taking proper maintenance measures, the vibration problem was successfully solved.

1. Introduction
The unit is N650-24.2/566/566 type supercritical, single shaft, three cylinder four exhaust, one intermediate reheat, double back pressure condensing steam turbine. Under the rated power, the steam pressure in front of the main stop valve is 24.2MPa, and the main steam temperature and reheat steam temperature are 566 ℃. The shafting of the unit is composed of high and intermediate pressure rotors, low pressure A rotor, low pressure B rotor and generator rotor. There are 9 supporting bearings in the unit, among which #1-#6 bearings are steam turbine bearings and #7, #8 bearings are generator bearings. The shafting structure is shown in Figure 1.

![Figure 1. The shafting structural diagram of the unit.](image)

2. Operation parameters related to abnormal vibration
2.1 Operating parameters before the first start-up
Before the first start-up, the operation parameters of the unit were as follows: main steam pressure was 5.49MPa, main steam temperature was 431 ℃, reheat steam pressure was 0.44MPa, and reheat steam temperature was 426 ℃. The maximum temperature difference between upper and lower parts of HP cylinder was 14 ℃, maximum upper and lower temperature difference of IP cylinder was 12 ℃. The vacuum of condenser was -90.7KPa. The pressure of turbine lubricating oil was 0.11MPa and its temperature was 40 ℃.

2.2 Vibration data during the first start-up
When the turbine speed was 1333rpm, the maximum value of 1X shaft vibration was 227μm, 1Y 275μm, 2X 144μm, 2Y 220μm, and the unit tripped due to excessive shaft vibration. It was started
again after 1 hour, when the turbine speed was 1300rpm, the maximum value of 1X shaft vibration was 499μm, 1Y 424.6μm, 2X 244.8μm, 2Y 250.7μm. The unit shut down again.

2.3 Cause analysis of abnormal vibration
According to the existing vibration data of the unit, it was considered that the vibration was caused by the internal rubbing of the cylinder. According to the vibration of the unit during the first start-up, the start-up parameters of the unit should be adjusted at the next start-up by adopting the mode of low parameters, large flow and low vacuum, and the shaft seal temperature should be controlled at 230℃. At low speed, warm up the unit at 400rpm, 600rpm and 800rpm for 10-20 minutes, change the speed-up rate to 500rpm/min in the first critical speed region, and closely monitor the temperature of No.1 and No.2 bearings[1].

2.4 Operating parameters before the second start-up
Before the second start-up, the operation parameters of the unit were as follows: main steam pressure was 4.6MPa, main steam temperature was 420℃, reheat steam pressure was 0.2MPa, reheat steam temperature was 416℃. The maximum temperature difference between upper and lower parts of HP cylinder was 22℃, maximum upper and lower temperature difference of IP cylinder was 30℃. The vacuum of condenser was -83.8KPa. The shaft eccentricity was 38μm.

2.5 Vibration data during the second start-up
When the unit passed the first critical speed during the second start-up, the maximum value of 1X shaft vibration was 498μm, 1Y 306μm, 2X 246μm, 2Y 246μm. When the unit reached the working speed of 3000rpm, the 1X shaft vibration was 310μm. The unit shut down again. The BODE diagrams of 1X shaft vibration is shown in Figure 2.

![Figure 2](image)

Figure 2. The BODE diagram of No.1X shaft vibration during the second start-up.

3. Defects found in unit maintenance and treatment

3.1 Maintenance of no.1bearing
There were obvious rubbing marks on the contact surface of the lower bearing pad, as shown in Figure 3. After scraping, the contact area of the pad met the requirements, and each pad block contacted more than 75% and was evenly distributed.
3.2 Maintenance of main oil pump

The oil seal ring was found to have rubbing marks. After measuring, the gap was found to be 0.20mm, exceeding the installation standard of 0.05mm to 0.15mm. It was adjusted to the installation scope. The main oil pump orifice ring was found to be worn. It was replaced by new spare parts.

3.3 Journal raising-rate of HP-IP rotors

During the unit was disassembled for maintenance, after the coupling was released, the journal raising-rate of HP-IP rotors was measured, as shown in Table 1. The raising-rate of No.1 journal was 0.9mm/m forward and that of No.2 journal was 0.75mm/m forward. Compared with the journal raising-rate during installation, the raising-rate of HP-IP rotors had obvious changed[2-3].

|                | No.1 bearing (mm/m) | No.2 bearing (mm/m) |
|----------------|---------------------|---------------------|
| Installation data | 1.18                | 0.81                |
| Measured data    | 0.90                | 0.75                |

3.4 Foundation settlement and cylinder expansion inspection

The settlement of the unit foundation was measured, and it was found that the settlement of HP-IP cylinder foundation of steam turbine was obviously larger than that of LP cylinder and generator foundation. The uneven settlement of foundation led to the change of shafting center, the change of flow clearance of HP-IP cylinder and the disqualification of shafting raising-rate. Checked the front bearing box and found that the clearance on both sides of the lower longitudinal pin was zero, and the top clearance was about 1.2mm. The center of No.1 bearing was about 0.65mm lower than its original installation position.

3.5 Adjustment of shafting center and raising-rate

The test proved that the deviation caused by the uneven settlement of the foundation could be compensated by adjusting the center and raising-rate of the shafting. According to the installation parameters of the unit and the measured data after disassembly, the following adjustment schemes was determined through accurate calculation: the center of No.1 bearing pedestal was adjusted upward by 0.50mm and left by 0.15mm; the center of No.2 bearing pedestal was adjusted upward by 0.25mm and left by 0.20mm[4-5].

4. Vibration data of start-up after maintenance

The unit started again after maintenance, and the shafting vibration were always within 80μm from the start-up to the working speed of 3000rpm. The BODE diagram of No.1 shaft vibration is shown in Figure 4. After full load, the shafting vibration was still within the range of qualified standard.
5. Conclusion

Within only one year after the installation of the unit, uneven foundation settlement of the HP-IP cylinder appeared, which led to a large deviation of the shafting center and the flow clearance, and caused the abnormal vibration of the shafting. By properly adjusting the center and raising-rate of the shafting, the uneven settlement of the HP-IP cylinder was effectively compensated. The maintenance method in this paper can be used as a reference for solving similar vibration problems.

References

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