Analysis and treatment of abnormal increase of bearing temperature of 600MW steam turbine

Lyuzhou Ma
Shandong Electric Power Research Institute, Jinan 250002, P.R. China
moasis@sina.com

Abstract. During the normal operation of a 600MW turbine in a power plant, the temperature of no.2 bearing rises to the alarm value, which seriously affects the safe operation of the unit. The reason of bearing temperature rise is found by analyzing the change of steam exciting force, and the problem is solved by optimizing the governor valve sequence to diagonal admission mode.

1. Introduction
For a large capacity unit, under the sequential valve operation mode, the steam not only produces a couple on the governing stage impeller, but also generates a force passing through the rotor’s center. Due to the different opening sequence of the governor valve, the exciting force generated by partial steam admission will cause the center position of the shafting to shift, and the bearing load will change. This change will lead to the abnormal temperature rise of the HP/IP rotor’s bearings, which will affect the safe and economic operation of the unit, and become an urgent problem to be solved.

2. Two different steam admission modes for large capacity units
Single valve operation and sequential valve operation are two different steam admission modes for large capacity units. Under single valve operation mode, the opening of each nozzle group is consistent, the full cycle steam admission of the governing stage is beneficial to the stress control of the rotor’s blades, and the load of the unit can be changed quickly. On the other hand, because all the nozzle groups are not fully open, the throttling loss is unfavorable to the unit economy. Therefore, the single valve mode is more suitable for the unit start-up phase. Under the sequential valve operation mode, some valves are in full open state, so the throttling loss is reduced and the economy is improved. This method is suitable for stable operation phase under high unit load. The purpose of switching to sequential valve operation mode from single valve operation mode is to ensure the stability and economy of the unit[1].

3. Characteristic analysis of the steam exciting force on HP/IP rotor caused by sequential valve operation
For large capacity steam turbine, except for the governing stage of the HP/IP cylinder, on all other pressure stages, steam inlets are always full open. If the non-uniform factors such as the extraction opening are omitted, the steam force on the rotor’s blades can be considered to be consistent in the circumferential. Therefore, the tangential steam force acting on the rotor’s blades only makes the rotor rotate and has no effect on the bearing load. However, on the governing stage of steam turbine, because the opening of each nozzle group is different, the non-uniform tangential steam force on the
rotor’s blades not only makes the rotor rotate, but also makes the center of rotor offset, and resulting in the change of bearing load.

Figure 1. The circumferential steam force diagram of the 600MW unit.

This 600MW unit is equipped with 4 sets of high-pressure governor nozzle groups, including 1, 2, 3 and 4. From the turbine to the generator, the rotation direction of the shafting is clockwise[2].

As shown in Figure 1, the directions of the steam force generated by the two diagonal nozzle groups are opposite. Under single valve operation mode, the opening of the nozzle group is consistent, the steam force of the governing stage will completely cancel each other except for the torque of driving rotor rotation, and there is no other residual steam force. However, under the sequential valve operation mode, the steam admission of the governing stage is asymmetric, there is no steam force in the nozzle group without steam flow admission, and the steam force cannot completely offset each other, and the center of HP/IP rotor will be affected by residual steam force.

4. The influence of non-uniform steam flow force on the position of rotor’s center
The original governor valve sequence of the unit is (3+4) →1→2. At the low load phase, the no.3 and no.4 nozzle groups which are located in the upper half of the governing stage open simultaneously. Due to the symmetry of the no.3 and no.4 nozzle groups in the vertical center direction, the total tangential steam force of the governing stage rotor’s blades cancel with each other in the vertical direction. The horizontal steam force to the right is superimposed on each other and increases with the opening of no.3 and no.4 nozzle groups. The horizontal steam force reaches the maximum when the opening reaches the maximum[3-4].

Because the non-uniform steam force is generated in the governing stage, the influence on the center deviation of the HP/IP rotor which is near to the governing stage is more obvious. According to field measurements, with the gradual increase of the horizontal residual steam force, the horizontal deviation of the HP/IP rotor's center can be up to 300 microns.

5. The effect of sequential valve mode on bearing temperature and treatment method
Under the action of non-uniform steam flow force, the HP/IP rotor will produce center deviation, which will reduce the local clearance of the bearing pad and increase the oil film stiffness. The exciting force of the rotor acts on the bearing bush through the oil film, which increases the local load of the bearing and thus increases the temperature of the bearing pad.

In this unit, after switching from single valve mode to sequential valve mode, the temperature of two radial bearing pads of HP/IP rotor increased significantly. When the load reached to 450MW, the temperature of no.2 bearing (left side) suddenly increased from 88°C to 107°C within 5 minutes. During this process, the temperature of lubricating oil inlet was 37°C, the return oil temperature was 58°C. The operator immediately switched to (1+2+3) single valve operation mode to increase load.
When the load increased to 600MW, the temperature of no.2 bearing (left side) dropped to 80℃. Due to the high bearing temperature, this unit cannot be put into operation in sequential valve mode for 5 months.

The radial bearings of the HP/IP rotor of this unit are 4-pad tilting-pad bearings. The bearing clearance during installation has been enlarged by 0.14mm–0.20mm than the original design value. If the bearing clearance is further enlarged in order to reduce the bearing temperature, the bearing vibration will increase. Therefore, in this unit, in order to reduce the bearing temperature, it is not suitable to increase the bearing clearance.

![Figure 2. The original valve sequence diagram of the 600MW unit.](image)

According to the comprehensive analysis of the steam force exerted on the HP/IP rotor, the valve sequence is changed from (3+4)→1→2 to (2+3)→1→4, as shown in Figure 2. and Figure 3. That is to say, the no.2 and no.3 governor valves in the diagonal direction are opened at the same time. In this case the horizontal deviation of the HP/IP rotor's center could be minimized. And then when the opening of no.1 governor valve is increased, the HP/IP rotor will be subject to the upward force, and the load exerted by the rotor on no.2 bearing will be correspondingly reduced, thus reducing the temperature of no.2 bearing[5].

![Figure 3. The valve sequence diagram after adjustment.](image)

The disadvantage of diagonal admission mode is that the periodic force of steam flow on the governing stage rotor’s blades may increase. Because the influence of various frequency components has been fully considered in the strength design of the governing stage rotor’s blades, therefore the diagonal admission mode of the governing stage generally has no significant effect on the strength of the rotor’s blades. With the consent of the steam turbine manufacturer, the test of changing the opening sequence of the governor valve to the diagonal admission was carried out on the unit. The test results showed that the temperature of no.1 and no.2 bearings decreased significantly. After the load change test, it was shown that the shaft vibration and the temperature of each bearing were within the normal range. The unit could be operated in sequential valve control mode.
After the valve sequence was changed, the unit smoothly switched from single valve operation to sequential valve operation. When the unit load is 604MW, the opening of GV1 is 43.6%, the opening of GV2 and GV3 are 100%, and the opening of GV4 is 0%, parts of bearing temperatures are shown in Table 1.

| Left | Right |
|------|-------|
| No.1(℃) | 61.8 | 66.2 |
| No.2(℃) | 79.6 | 81.9 |
| No.3(℃) | 68.2 | 66.6 |
| No.4(℃) | 76.7 | 72.8 |
| No.5(℃) | 75.4 | 72.6 |
| No.6(℃) | 78.8 | 74.5 |

When the unit was overhauled next year, the HP/IP cylinder was opened to check the rotor’s blades of the governing stage, and no abnormality was found. It proved that diagonal admission mode is safe to this unit.

6. Conclusion
The diagonal admission valve sequence in this 600MW unit can minimize the uneven steam flow force in the circumferential direction of the governing stage and minimize the variation range of the center deviation of the HP/IP rotor in the whole load adjustment phase. This kind of sequential valve operation can significantly reduce the temperature of the bearings, and improve the economy of the unit.

References
[1] Wu, P., Li, Q.M., Bai, Y.H., Zhang, R.F., Pang, W.T., Wang, Z., Sheng, D.R. (2018) Analysis of unbalanced steam flow force during single sequence valve switching of steam turbine. Turbine Technology, 2018,60(03): 221-224.
[2] Chang, D.F., Jia, H.J., Jiang, H., Gu, W.W. (2016) Influence of steam distribution mode on blade disc safety of governing stage. Thermal Power Generation, 2016,45(10): 89-93+103.
[3] Liu, J.W., Fu, X.J., Guo, R., Jiang, H. (2015) Numerical simulation of residual steam force in supercritical steam turbine unit. Turbine Technology, 2015,57(05): 333-336.
[4] Li, D., Gao, J.L., Chen, X.L., Zhang, J.Y. (2014) Analysis and dispose of bearing bush high temperature of the feed water pump turbine in power plant 1000 MW units. Northeast Electric Power Technology, 2014,35(06): 59-62.
[5] Xiang, L.H., Pang, Y.N. (2007) Influence of steam admit mode of unit on vibration of shafting and temperature of bearings. North China Electric Power, 2007(02): 48-51.