Research on Faults and Maintenance Methods of Steam Turbine in Thermal Power Plant

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Abstract. The steam turbine is one of the most critical equipment in the power generation system of thermal power plants, its daily operation condition and maintenance work will directly affect whether the power generation system can operate safely and stably. Therefore, it is necessary to strengthen the management of the steam turbine, ensure the continuous and full operation of the steam turbine unit, and ensure the power transmission of the power grid. However, some faults unavoidably appear in the steam turbine in the long-term operation, if these faults are not handled in time and effectively, the influence scope of the fault will be expanded, which causes the turbine to fail to operate normally and affect the normal work of thermal power plants. This paper analyses the common faults of steam turbine in thermal power plants, and further studies the maintenance methods for common faults of steam turbine in thermal power plants.

1. Introduction
The steam turbine is the most important component in the power generation system of a thermal power plant, and the reliability of its operation is a key factor to improve the operational safety of the thermal power plant. Due to the relatively complicated structure, the steam turbine has higher requirements on the surrounding environment in the operation process, and it is often affected by various external factors, once these factors develop in an unfavorable direction, it causes steam turbine to break down and cannot operate normally, affects the normal production of thermal power plants and causes certain economic losses. Therefore, we must accurately judge the common faults of steam turbine in thermal power plants and take correct methods for maintenance to ensure long-term stable operation of the steam turbine and improve the production efficiency of thermal power plants.

2. Overview of Steam Turbine
The steam turbine generator set is shown in Fig.1; it can convert steam into kinetic energy, it uses the heat energy released by steam liquefaction as a power source. Because the steam turbine generates abundant and continuous energy, it is widely used in today's thermal power plants. The steam turbine is mainly composed of a rotating portion (rotor) and a fixed portion (stator). The rotating parts include rotating parts such as cascade, impeller, main shaft, coupling, and fastener. The fixed components include cylinder, steam chamber, nozzle chamber, bulkhead, steam seals, bearing, and engine base,
sliding pin system, and related fastening components. In short, the structure of the steam turbine is complex and operates in a high-intensity environment, once the machine is improperly used or maintained, it will affect the operation of the thermal power plant and cause economic losses, it threatens the safety of the staff.

Fig. 1 steam turbine generator set

3. Working Principle of Steam Turbine
The steam turbine is one of the important production equipment in thermal power plants, steam turbine can be classified into back pressure type, extraction type, steam type and condensing type according to thermodynamic properties. The function of the steam turbine is to convert the internal energy generated by the combustion of fossil fuel into mechanical energy that can make the rotor rotate, and finally convert it into electric energy through the generator. In the specific operation process, the fossil fuel needs to be burned first, water is added to the boiler, the heat caused by fossil fuel combustion is turned into water vapor, and then the steam is introduced into the steam turbine to cause gas expansion, then the rotor rotate, and the generator can generate electric energy. After the gas expands, the water vapor is discharged to the condenser through the exhaust valve, and it can be recycled after being condensed into liquid water.

4. Maintenance Necessity of Steam Turbine
Thermal power generation is the main form of power generation, and its stability largely determines the stable supply of electricity and shoulders the mission of ensuring the normal development of the national economy. The stability of the steam turbine is directly related to the safe power generation of the power plant, once the fault occurs, it will not only cause trouble to people's daily life, but also cause damage to large-scale equipment. Therefore, the maintenance and repair of steam turbines is a major issue in the maintenance department of power plants, improves the operation and maintenance of steam turbines from theoretical and empirical aspects, and introduces maintenance personnel with excellent theoretical quality and rich maintenance experience, it is of great significance to ensure the safe and stable operation of the steam turbine.

5. Fault Classification of Steam Turbine
The environment in which the steam turbine is in normal operation is complicated, under the influence of environmental temperature, humidity, the manufacturing process of the steam turbine and the limited life, it will cause various problems. The most common fault of steam turbine is abnormal vibration, which mainly includes three kinds: normal vibration, abnormal forced vibration and self-excited vibration. There are many reasons for these three kinds of abnormal vibrations, as shown in Table.1.

In addition, steam turbines may also have problems such as low condenser vacuum, oscillating speed control system, speed control motor failure, deviation of water content, and permanent bending of the rotor.
Table 1. Types and causes of abnormal vibration of steam turbine

| abnormal vibration type | abnormal vibration cause |
|-------------------------|--------------------------|
| ordinary forced vibration | the mass unbalance of the steam turbine brings the vibration balance; the binding surface of steam turbine is different from the vibration; when the speed is a certain value, it resonates with the bearing seat; the connection point between the rotor and the bearing is inconsistent |
| abnormal forced vibration | the cylinder is inflated and not smooth; the bolt of the coupling is loose; the rotor has crack; the local friction of the rotor is severely heated; the excitation current of the generator is too large; the center hole is oiled; the main shaft and the bearing are statically rubbed |
| self-excited vibration | the cylinder head expansion or expansion difference is abnormal; the steam turbine load is too high, and the high-pressure rotor generates air flow excitation |

6. Fault Analysis of Abnormal Vibration

6.1. Fault cause of abnormal vibration
Abnormal vibration of steam turbine is one of the common faults of steam turbine; however, due to the complex structure of steam turbine, many factors may lead to this result, abnormal vibration of steam turbine becomes a major problem in maintenance. In order to prevent the abnormal vibration of steam turbine to cause threat, once the abnormal vibration problems appear, it is mostly improved by reducing the load on the steam turbine, however, the effect of this method is not obvious, and it is necessary to solve the problem fundamentally. The gas excitation is one of the common causes of abnormal vibration of the steam turbine. When the machine is running, the blade will be excited by the unbalanced gas, and the steam flow will be generated, the final stage of the large unit is long, and the gas excitation may occur at the end of the expansion of the blade. Another cause of abnormal vibration is thermal deformation of the rotor. After the unit start, the rotor temperature increases gradually with the load stage, and the stress release in the material causes the rotor to bend and deform, when the steam turbine is running, the friction at each point is different, cause the temperature in the radial direction of the rotor to be uneven, localized heating causes the rotor to bend thermally. The bending of the rotor generates an unbalanced force, which causes the steam turbine to vibrate abnormal during operation.

6.2. Methods for solving abnormal vibration
There are many reasons for the abnormal vibration of the steam turbine, it is necessary to consider the analysis from various aspects to find a solution; fault analysis is also a difficult problem. After discovering the abnormal vibration of the steam turbine, it is necessary to observe the state when abnormal vibration of steam turbine is recorded, and mark the machine load at that time, chart of working state of steam turbine under different loads are made. The flow excitation is eliminated by changing the characteristics of the high-pressure speed control valve of different steam turbines. In short, the abnormal vibration of steam turbine is due to the steam flow, after observing the chart, when the steam turbine is used, the load of the steam flow is avoided, thus eliminating the flow excitation. Another cause of abnormal vibration of steam turbine is thermal deformation of the rotor. The thermal deformation of the rotor is a situation that often occurs under the long-term operation of the steam turbine, due to the long working time of the steam turbine, the high pressure, high temperature and high strength of the working environment, the result of thermal deformation is difficult to avoid. Usually unit vibration caused by this situation is solved by the rotor tempering straight axis. In addition, attention should be paid to the maintenance of the rotor, during the operation of the steam turbine, although it is a high temperature environment, it is necessary to pay attention to the temperature of the rotor, reduce the probability of thermal deformation of the rotor, and reduce the frequency of repairing the rotor later, thereby reducing the cost.

7. Fault Analysis of Steam Turbine Shaft
The steam turbine generator set after long-term operation, due to uneven foundation settlement, damage of the sliding pin system, wear of bearing alloys in the lower bearing and release of internal stress of the
equipment, etc., all will cause the central value of the steam turbine shaft to change. Sometimes the change of the center value of the coupling makes the end face difference and the circumference difference exceed the design value range, which affects the stable operation of the unit. Therefore, during the maintenance work of the steam turbine, it is necessary to conduct the centering work on the coupling of the shaft, and make appropriate adjustment according to the standard, so that the center value deviation is within the design value range. There are three main cases in which the rotor coupling is deflected.

As shown in Fig. 2, the centerline of the rotor is not in a straight line, but the center of the two back wheels just coincide. 3#, 4# movement of bearing:

\[ X_{3v} = b_{h1} \times \frac{L_3}{D_{23}}, \quad X_{4v} = b_{h1} \times \frac{(L_3 + L_4)}{D_{23}} \]

As shown in Fig. 3, the end faces of the coupling of the two rotors are parallel to each other, but the centers do not coincide.

\[ X_{3v} = -b_{v1}, \quad X_{4v} = -b_{v1} \]

Fig. 2 schematic diagram of the rotor coupling in deflection state 1

Fig. 3 schematic diagram of the rotor coupling in deflection state 2

8. Conclusion
The stability and reliability of power generation in thermal power plants are directly related to the normal operation of steam turbine, once the faults occur in the operation of steam turbine, it will affect the stability of power generation. Therefore, the operation and maintenance management of the steam turbine unit needs to be an important task for power plants. In the daily work, the maintenance of the steam turbine need to be increased, then the fault rate is effectively reduced, and the steam turbine is maintained in a good operating state, which not only helps to improve the power generation efficiency, but also can effectively reduce the maintenance cost. In addition, the power plant should pay attention to the training of steam turbine maintenance personnel, so as to effectively ensure the reliability and stability of the operation of the steam turbine unit, and provide a reliable power supply for the development of society.
References

[1] Wang Lei. Common Fault Analysis and Maintenance Methods For Steam Turbine of Power Plant [J]. Architectural Engineering Technology and Design, 2017, (11): 3444-3144.

[2] Liang Kaifeng. Discussion on Operation Fault and Maintenance of Steam Turbine in Power Plant[J]. Technology Innovation and Application, 2013, (7): 95.

[3] Fang Mingcheng. Discussion On Common Faults And Treatment Countermeasures Of Power Plant Steam Turbines Under The Background Of Modernization [J]. Science and Informatization, 2017, (30): 65-66.

[4] Lu Zijing. Research on Common Faults and Maintenance Methods of Steam Turbine Auxiliary Equipment in Thermal Power Plants [J]. Mechanical and Electrical Information, 2011, (36), 104-105.

[5] Liu Yalong. Analysis of Quality Assurance Measures in Operation Process of Steam Turbine of Power Plant [J]. Architectural Engineering Technology and Design, 2017, (24): 2558-2558.

[6] Jiang Litao, Chen Zhiqiang. Cause Analysis on Speed Control System Fluctuation of Baby Turbine of Thermal Power Plant [J]. Hebei Electric Power, 2007, (4):43-45.

[7] Tian Yong, Quan Dongsheng. Research on Fault Diagnosis of Power Plant Turbine and Its Application [J]. Science and Technology Prospect, 2017, (21): 127.

[8] Ye Ming. Cause Analysis and Countermeasure of Vacuum Reduction of 350 MW Steam Turbine [J]. Energy Conservation, 2008, (10).