Analysis and Treatment of Turbine’s Increasing Shaft Displacement and Thrust Bearing’s Burning Loss

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Abstract. In this paper, the writer is to analyze the causes of axial displacement and thrust bearing temperature according to the relevant factors affecting the axial force of turbine and provides treatments. It can be used for reference for units with this phenomenon or axial force increasing.

Keywords: Turbine, Thrust Bearing, Axial Translation, Temperature

Introduction
The thrust bearing of steam turbine is used to bear the axial force of steam and coupling acting on the rotor to locate the rotor position and ensure the axial clearance within the safe range. The greater the thrust, the greater the shaft displacement and the higher the thrust bearing temperature. Therefore, in addition to temperature, it is necessary to monitor the axial displacement for thrust bearing. The temperature and displacement of thrust bearing are the key monitoring objects in the safe operation of turbine. During the operation of the unit, if the temperature or axial displacement is abnormal, it should be analyzed and excluded in time to ensure the safe operation of the equipment.

The 50 thousand ASU turbine of a chemical plant is EHNKS50/80/16 high temperature and high-pressure steam extraction condensing unit. About 10 months after the unit was put into operation, axial displacement and thrust bearing temperature gradually increased: the axial displacement increased by about 0.01mm/5 days; when the temperature rose from 56°C to 72°C, the axial displacement rose faster. About 6 months later, a thrust bearing was burned out. When the tile was burned, the thrust bearing temperature did not exceed the alarm value of 105°C. At the meantime, the large shaft displacement caused to the jump. Before the axial displacement began to increase gradually, there were vibration anomalies -- occasional spurts of vibration. After about 2 months of operation, the temperature and shaft displacement of the new thrust bearing replaced gradually increased.

1. The Balance of Axial Force of Turbine Rotor and Its Rough Calculation
The axial force of turbine rotor is mainly composed of four parts.

The thrust caused by the pressure difference between the rotor blades and the rotor blades [1]:

\[ F_a = (P_1 - P_2d) \times \Delta S, \quad \Delta S = \pi D \rho. \]  

In the formula, \( \rho \) is the degree of reaction at average diameter D.
Thrust caused by static pressure difference between front and rear guide blade [2]:

\[ F_d = (P_1 - P_2) \times \Delta F = (P_1 - P_2d) \times \rho \times \Delta F \quad \Delta F = \pi Dd \rho d \] (2)

Axial forces caused by differences in hub diameters between stages (including balance force) [2]:

\[ F_g = P_1 \times \Delta S_g \] (3)

\[ \Delta S_g \] is the area difference caused by hub diameter differences.

The force acting on the rotor by the coupling \( F_o \). We can find it from the drawing of coupling.

Total axial thrust:

\[ F_{total} = \sum F_a + \sum F_d + \sum F_g + \sum F_o \] (4)

Figure 1. Guide blade and moving blade [4]

2. Factors Influencing Axial Force

The axial force varies with the variation of the working condition. The axial force is usually proportional to the steam flow, except for the back-pressure turbine. The relationship between the pressure and flow of the back-pressure unit is nonlinear [1, 2]. According to the calculation formula of rotor axial force, it can be gotten the factors that affect the axial force: throttle flow, pressure difference, reaction degree, area difference, external axial force applying to the turbine rotor.

2.1 The Influence Factors of Steam Flow

The intake of steam is related to the load. The greater the load, the greater the intake of steam [5]. The axial force is calculated according to the maximum power and the maximum steam intake. Therefore, the fluctuation of the load should be checked if the sudden change of the axial displacement of the unit in operation appears. The greater the load is, the greater the steam intake is and the greater the axial force is [6].

2.2 The Influence Factors of Pressure Difference

When the load increases, the steam intake increases, and the pressure difference between different levels increases, the unit axial force increases. If salt of soft water exceeds the standard, it is easy to cause leaf scaling [7]. Thus, the pressure difference between the front and rear of the corresponding blade and guide impeller increases, which leads to the axial force increasing. After scaling, the friction between steam flow and blade increases, and static electricity accumulates. Wear of Inner packing gland causes to the pressure difference between stages increasing, which also reduces the balancing
ability of the balance face of the balance plate and increases the axial force. In general, the better the vacuum is, the greater the pressure difference is and the greater the axial force is. Only if \( F_g \) is negative, the better the vacuum is, the less the axial force is.

2.3 The Influence Factors of Reaction Degree
The axial force of the unit increases with the decrease of steam inlet parameters and the increase of reaction degree at all levels. The low inlet steam parameter causes to the phenomenon that the last few stages of steam contain water and the axial force increases sharply. After the steam contains water, the wet steam generates more static electricity due to the friction with the blade in the work process of the latter several stages. Since the rotor is insulated during operation, the static electricity on the rotor cannot be released, so the static electricity will accumulate more and more, and the voltage will be higher and higher [3, 5]. When it reaches a certain degree, the voltage will break through the oil film in the weakest place, release the voltage, form the current, cause the electric corrosion, and then cause the burning tile. Therefore, it is very important to ensure the admission parameters complying with the design.

2.4 The Influence Factors of Area Difference
Hub scaling at some stages results in larger hub diameter, larger area difference, roughened blade surface, and increased axial force. Severe scaling will block the steam passage between the blades, which will not only cause the pressure difference between the stages to increase, but also cause the area difference between the hubs to change greatly.

2.5 The External Influence Factors
The force acting on the rotor of the coupling is related to the pretension of the coupling [8]. If the pretension of the steam inlet coupling is too small, or if the pretension of the steam outlet coupling is too large, it will increase the positive axial force of the rotor. On the contrary, the axial force of the rotor will be reduced. The turbine pulling the generator may also be subjected to axial forces caused by the generator excitation center which is not installed in place. For the bearing seat with the steam inlet end expanding displacement along the cylinder, the coaxiality of the coupling cover on its side seriously fails to meet the requirements, which causes the deflection force of the bearing seat in the expansion process. As a result, it also causes the reduction of the bearing area of the thrust bearing, and further reduces the bearing capacity of the thrust bearing.

3. Analysis of Axial Displacement and Thrust Pad Temperature Rising Gradually
According to the above influencing factors which can influence axial force, the steam turbine was inspected comprehensively on site. What can be found: the seal teeth in the steam turbine are almost completely off (the gland seal off is the cause of the occasional vibration jump of the unit), which reduces the balancing capacity of the balancing piston disc and increases the axial force. The right positioning nut of the thrust rod of the bearing house is loose, which reduces the bearing area and bearing capacity of the thrust bearing. The steam turbine pipe pulls the steam turbine to the right, which makes the cylinder move 0.55mm relative to the rotor to the right (front seal clearance 0.45mm), causing the static and static friction of the steam seal. The designed operating parameters of the steam turbine are 8.9mpa /525℃, and the actual operating parameters are 8.8mpa /470℃. The reduction of inlet steam parameter increases the reaction degree of rotor blade and increases the axial force. Moreover, due to the low steam parameters, all the steam in the last five stages of the turbine impeller included water, which caused a sharp increase in the axial force of the turbine, and the increase was related to the steam flow rate and water content. The bearing surface of the thrust bearing surface is dark gray and rough and there are also some irregular pits, which are the appearances of electrostatic corrosion.[3] Too low steam parameter may be inclined to cause static accumulation. See figure 2. The design value of pretension of the nose end coupling is less than the actual value. As a result, the coupling is under pressure when running, which increases the positive axial force of the turbine rotor.
According to the above problems, it can be concluded that the axial force of the turbine has been greatly improved, resulting in the increase of axial position. With the increase of axial force, the oil film of thrust bearing is the weakest and it is also the most vulnerable to electrostatic breakdown [9]. With the constant heating of the thrust bearing current, the temperature of the thrust bearing keeps increasing and the shaft displacement becomes larger and larger. With the expansion of the electric etch surface on the thrust bearing, the bearing oil film on the thrust bearing becomes more and more unstable, and the thrust bearing burns out sooner or later. Electrostatic corrosion is shown on the right.

![Figure 2. Thrust bearing pad with electric corrosion](image)

4. Accident Treatment and Effect

The rotor and the holding ring were returned to the factory, and the steam seal plate was embedded again. The bearing pedestal was readjusted on site to make the contact area between thrust bearing and thrust disk reach more than 90%. The minimum pass area of the balance hole was rechecked to determine the balance capacity. The stress imposed on the steam turbine inlet pipe is limited. Meanwhile, the design institute replaced the support and hanger of the steam intake pipeline. In order to ensure that static electricity is no longer harmful, the turbine rotor was installed with a brush (brush fixed on the oil seal ring -- non-explosion-proof) to eliminate the corrosion of thrust bearing caused by static electricity. See the Figure 3.

In addition, the steam intake parameter (8.8Mpa/505℃) was improved to reduce the ability of generating static electricity. Soften water as far as possible to avoid adding more agents or less agents, in order to reduce leaf scaling. If there are more agents, phosphate is easy to exceed the standard, resulting in phosphate adhesion on the leaf accumulation of static electricity.

The steam turbine has been in operation for about 11 months since December 2019. The problem has been solved just because the turbine shaft displacement is always between 0.21-- 0.26mm, and the temperature is between 57-- 63℃. Unit load fully meets the production requirements, to ensure the benefits of customers.

5. Preventive Measures

For users and the company, that there is no problem with steam turbine is the best and most ideal state, so precautions are particularly significant to make the turbine work in normal operation. What should be done as follows: pay close attention to thrust bearing temperature and shaft displacement; Always look at long-term historical trends and be sensitive to abrupt jumps and trends in historical trend curves [10]; ensure that steam parameters are within a reasonable range; Communicate with
professionals in a timely manner to ensure the safe operation of equipment if you find something abnormal. Especially for users, do the above measures can ensure the normal operation of the steam turbine and ensure their own benefits.

![Static electrical carbon brush](image)

**Figure 3.** Static electrical carbon brush

### 6. Conclusion

The case in this paper is ostensibly caused by static electricity, but it is essentially caused by a factor affecting the axial force —— unqualified steam parameters. The increase of axial force causes the oil film between the thrust plate and the thrust bearing to be weak, thus forming static electricity to be released from the thrust bearing. Therefore, to be familiar with and master the relevant factors affecting the axial force, and to understand the associated influence caused by the relevant factors can help us analyze the problem and quickly find the direction to solve the problem. This case is a typical case of the influence of comprehensive factors and it has extensive reference significance.

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