Analysis of Intermittent Vibration and Its Emergency Treatment Measures

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Abstract. Intermittent vibration is a major unstable factor in the safe operation of unit. Based on the working experiences of dealing with the intermittent vibration of steam turbine, this paper is to analyze the reasons for the intermittent vibration and the corresponding measures, which can provide reference for the unit for which such a phenomenon may appear.

Keywords: Steam Turbine, Intermittent Vibration, Rub and Impact, Coking, Oil-Film Whipping

1. Introduction
Steam turbine is an important high-speed rotating core equipment in industrial drag and the stable operation of steam turbine is directly related to the safety and efficiency of the whole production.

In the operation of the steam turbine, the vibration of different degrees, direction, generally within the limited scope of vibration, doing no harm to the equipment, is allowed. However, due to various reasons, abnormal vibration will appear during the unit operation, especially during the trial operation. Although there are many reasons for abnormal vibration, vibration anomalies are mostly caused by the accidental installation and improper operation and maintenance according to the statistics of the field vibration problems. The rotor of the steam turbine is balanced at high speed before leaving the factory, and after passing the test of empty load, it leaves for users. So in addition to the repair, replacement of parts or the existence of permanent bending deformation of the rotor, under normal circumstances, the turbine rotor does not need to be re-calibrated balance[1]. The reasons for abnormal vibration of steam turbine and unit during starting and running are mainly found from installation and maintenance. The vibration spectrum analyzer or other real-time analyzer is used to monitor and analyze the causes and solve them. This paper expounds the intermittent vibration, caused by installation and maintenance, which is easy to cause abnormal shutdown production accident. Through the analysis of the characteristic of typical intermittent vibration, the causes of the intermittent vibration are put forward, and the treatment measures are put forward to provide reference for similar fault units.

2. Related Factors Influencing Vibration and Evaluation Criteria of Vibration
There are many reasons affecting turbine vibration, which can be divided into the following:

2.1 Blade Vibration
Blade vibration should be considered in the design stage. For example, the tensile reinforcement of the turbine's final stage torsional blade commonly used in our gate is to reduce the vibration stress and improve the natural vibration frequency of the blade. Therefore, vibration of blades is not considered in general operation.

2.2 Rotor Vibration

The vibration of rotor is divided into unbalance one and vibration at critical speed.

Dynamic unbalance is the vibration caused by mass eccentricity in the rotor. Critical speed is the speed at which the excitation force generated by mass eccentricity resonates with the same frequency of transverse natural vibration of the rotor. At the critical speed, the vibration of the rotor increases sharply. The critical speed is related to the stiffness, mass, and span of the rotor. Under the circumstances of high stiffness, light mass, small span, the critical speed is high. Conversely, the critical speed is low. In addition, the rotor's critical speed is also affected by the rotor's operating temperature, support stiffness and so on. The higher the working temperature is, the stiffness of the rotor will be reduced, thus reducing the critical speed. The support stiffness decreases and the critical speed decreases [2].

According to work experience, the above two kinds of vibration involved almost have never happened on sites. Therefore, the vibration caused by improper installation, operation and maintenance of the unit is mainly considered [3]. The vibration caused by this kind of phenomenon is analyzed mainly considering the following two factors: forced vibration and self-excited vibration [4].

2.3 Forced Vibration and Self-Excited Vibration

Of forced vibrations are: support systems, which involve stiffness of support, contact area of bearing, clearance of bearing, etc. Guide key system, which is related with dynamic and static touch vibration, caused by main expansion obstruction or too large guide key clearance; the rotor out of alignment, which mainly produces disturbing force to the rotor vibration, making the unit vibrate; rotor bending vibration, especially that the thermal bending of the rotor is caused by insufficient warm-up, excessive load lifting, improper turning and other factors and bending just because of rotor touch with static parts. The self-excited vibration is mainly caused by oil film self-excited and gap self-excited. The vibration caused by the self-excitation of the oil film is the oil film oscillation, which is related to the lubricating oil temperature, the bearing top gap, and the specific pressure of the bearing (the ratio between the bearing load and the vertical projection area (length × diameter) of the bearing). The greater the specific pressure is, the better the bearing stability will be[3, 4, 5, 7]. For the turbine that drives the generator set, the asymmetry of excitation center, the eccentricity of rotor and stator or the short circuit between the turns of the steam turbine and the different center of the rotor and the cylinder, which is caused by the uneven force exerted on the rotor, and the self-excitation vibration is formed repeatedly. Therefore, the elimination of self-excited vibration is mainly to reduce the bearing clearance, increase the bearing side clearance, and improve the viscosity of lubricating oil to enhance the stability of the bearing. Adjust the center of rotor and cylinder to make the flow clearance of steam turbine uniform in hot state to reduce the exciting force [6].

2.4 Criteria for Evaluating Unit Vibration

According to the evaluation guidelines given by IOS 7919 and vibration measurement experience, the vibration of steam turbines with power between 1MW and 50MW have the following requirements [1].

The vibration value required for the new unit

\[ Sp - p \leq \frac{4800}{\sqrt{n}} \mu m \]
Acceptable values for vibration in long run

\[ Sp - p \leq \frac{9000}{\sqrt{n}} \mu m \]

The value of vibration that can run for a short time under certain conditions

\[ Sp - p \leq \frac{13200}{\sqrt{n}} \mu m \]

Unacceptable vibration value serious enough to cause damage

\[ Sp - p \geq \frac{13200}{\sqrt{n}} \mu m \]

\( n = \text{Frequency of Rotor} \times 1000 \text{ rpm} \)

3. **Characteristics of Intermittent Vibration**

The intermittent vibration generally belongs to the forced vibration, also has the part to belong to the self-excited vibration.

For the clearance vibration, it belongs to the forced vibration caused by light external force. Its characteristics are that vibration is unpredictable, intermittent, irregular; vibration frequency is more and more frequent; vibration amplitude is larger and larger; vibration interval is shorter and shorter and there is a backward schedule (it only occurs when vibration increases). Not only does it have the 1X, but it has the 1/2 frequency component and the other higher-frequency components, which is mainly based on 1X frequency, and peak clipping occurs in the vibration waveform. In addition, when the intermittent vibration just occurs, the vibration period interval is longer, the vibration duration is shorter and the amplitude is smaller; as time goes on, the vibrations will become more frequent, they will last longer and they will have larger and larger amplitudes.

For the vibration and load related intermittent vibration, this belongs to the self-excited vibration caused by the intermittent vibration. Its characteristic is that the vibration is closely related to the load and changes with the load; when the load is stable, vibration stability is step by step under low load vibration stability [8]; the amplitude of vibration sloshing is larger; intermittent vibration usually occurs in new units or units after maintenance, and the intermittent vibration caused by foundation settlement during operation cannot be excluded. The common characteristic of all intermittent vibration is its abruptness on the historical trend curve of vibration. See Figure 1.

![Figure 1. Trend of vibration](image_url)
For the forced intermittent vibration, it is generally caused by dynamic and static touch, poor drainage and so on. One of the most common factors is the intermittent vibration produced by oil seal carbon deposition which is closely related to the operating environment. Nowadays, the steam turbine oil station is mostly equipped with oil mist machine. Inside the oil tank and bearing seat is micro negative pressure. If the external environment is dusty or insulation material is easy to fall off, it will be sucked into the oil seal teeth [9,10]. With the gradual accumulation of time, it would be mixed with lampblack. Because the bearing pedestal and the cylinder are relatively compact, the heat of the cylinder block at the steam seal of the cylinder will continue to heat the oil seal, thus making it coking, and finally the rotor dynamic and static collision and grinding. After the collision, the protruding part will be transferred by the rotor to the low concave place, and the vibration will be reduced. Over time, the coking continues to grow and the vibrations occur again. Such repetitions create an intermittent vibration. Most of the steam turbines with oil seal carbon deposition have a bad operating environment. For example, the steam turbine plant is too close to the coal yard, or it is often dusty weather, or heat preservation is blocking the heat outflow channels of steam seal and oil seal, etc. To solve the problem of intermittent vibration caused by coking, it is necessary to solve the coking problem. If conditions permit, add dry sealing gas to the oil seal to ensure that the dirty air cannot enter the oil seal ring. In the absence of conditions to add sealed gas, surface hardening treatment technology can be done for the insulation surface of the steam turbine at the front and rear steam seals, ensuring that the insulation material does not drop, the air passage between the seal oil seal cannot be blocked, to ensure the flow of air, that cold and hot air can be exchanged, reduce the steam seal cylinder on the oil seal heating temperature. See Figure 2.
and then shut down and open again. It usually takes three months or so to make the vibration in normal situation in the starting-shutting down process. For such kind of intermittent vibration, the positive pressure needs to be solved.

As for the intermittent vibration of self-excited vibration type, it is the vibration caused by self-excited steam flow or oil film oscillation finally. Self-excitation of steam flow is generally related to installation, which can be eliminated only by ensuring uniform clearance in hot state. Oil film oscillation is not only related to installation, but also related to oil quality, oil temperature, bearing and so on. In general, the viscosity of the lubricating oil can be increased by lowering the lubricating oil temperature to reduce the oil film oscillation (for a unit with a low oil inlet temperature, lowering the oil inlet temperature does not reduce the oil film oscillation; on the contrary, it may increase the oil film oscillation). Or reduce the bearing clearance to increase the relative eccentricity of the bearing to improve the stability of the bearing (increasing the clearance on both sides of the bearing can also increase the relative eccentricity). In order to improve the bearing specific pressure, it is involved in the bearing selection problem, which is not expressed here.

In addition, the external force of clearance disturbance can make the rotor float larger, causing intermittent vibration. For example, for a generator set with a gearbox, since the pinion is supported by the top of the bearing in operation, if the steam turbine and the gearbox are not suitable for the middle under the hot state -- the steam turbine is lower than the gearbox, the turbine rotor will be pulled up by the gearbox pinion shaft, causing oil film instability [8]. This causes the oil film to vibrate.

The following emergency measures can be taken for the units that cannot be shut down immediately due to intermittent vibration. For the vibration caused by oil seal coking, ensure the environmental sanitation, open up the upper and lower air circulation channel between the oil seal and oil seal, make a heat insulation plate between the oil seal and oil seal to reduce the temperature of oil seal, and prevent the insulation material or dust from entering the oil seal. At the same time, a temporary seal gas is installed online or compressed air is supplied from bottom to top between the steam seal and oil seal to reduce the temperature and thus the coking speed. Schedule your time quickly.

5. Conclusion
Based on the types of vibration, this paper analyzes the types of intermittent vibration and the main factors. Moreover, this paper analyzes the relevant influencing factors of the intermittent vibration, and analyzes the characteristics of the intermittent vibration caused by different reasons based on work experience, and gives the common solutions and emergency measures to cause the intermittent vibration, which can provide reference for the relevant symptoms of the unit.

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