Research and application on optimization of sealed water return system of feed pump

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Abstract. The importance of sealed water return system of feed pump to the safety and economy of power plant is analyzed. This paper studies the common sealed water supply way of feed pump, and three main sealed water return system way and working principle, and analyzes their respective advantages and disadvantages. The calculation methods of water seal height of single stage and multistage water seal are studied. A design scheme of water tank and water seal is proposed, which enhances the adaptability of water seal device and optimizes the system.

Keywords: Feed pump seals water; recycling; water seal height calculation; coal-fired power plants.

1. Introduction

In order to improve the efficiency of the unit, the sealed water of the feed pump must be recovered as the clean water source. In the usual scheme design, the sealed water is recovered to the condenser [1]. Choose the water pump sealing recovery system, must consider two aspects of the problem[2], on the one hand, need to consider the unobstructed sealing water back water, otherwise, the sealed water will enter through the feed pump journal and connected with the bearing back oil, resulting in water feed pump oil, affect the safe operation of the feed pump; On the other hand, the seal of the water to the condenser pipeline must be firm and reliable, otherwise it will affect the vacuum degree of the condenser[3].

The normal recovery of sealed water from the feed pump is a headache for many power plants[4-7]. Whether the system runs stably or not will affect the normal operation of the feed pump set and the condenser. In order to prevent the failure of the sealed water system of the feed pump, destroy the vacuum of the condenser or affect the water quality of the condenser, many power plants will directly discharge the sealed back water of the feed pump into the circulation puddle when the unit is running, so as to ensure the normal operation of the unit. Although this operation can avoid the sealing water backwater is not smooth and other problems, but a lot of high quality in addition to saline will be wasted. Take a 600 MW unit as an example, the sealed water flow of each steam driven feed pump is 6 t /h, and the annual operation time of each unit is 4 500 h. Then the two steam driven feed pumps will waste 54000 t of debrine every year. So how to design the sealing water system of the feed pump scientifically and reasonably, so that it can recover the sealing water completely without affecting the normal operation of the unit has important practical significance.

2. The feed pump seals the main form of the water back water system

The sealed water of the steam feed pump comes from the master pipe of the condensate pump outlet. A fine filter is arranged in the water injection line near the pump group to ensure the purity of the sealed water. The backwater is divided into two ways: one way through the sealed water back to the jellyfish tube into the trench or through the multistage water seal (three levels of water seal) back to the condenser; The other way to discharge water back to the steam pump front pump inlet electric door front pump inlet pipe. During normal operation of the feed pump, the feed water is discharged separately from the pump inlet and the pump balance chamber along the maze seal. The steam pump unloading water is composed of high-pressure water supply in the pump through the labyrinth seal at both ends of the steam pump to leak out of the water supply and part of the sealed water, the temperature of the unloading water is controlled by the injection of sealed water in the middle of the

shaft sleeve, so the water quality of the sealed water for the steam pump should be kept high cleanliness. During the normal operation of the feed pump, the feed water is discharged from the pump inlet and the balance chamber of the pump along the maze seal. When the steam feed pump is used as a backup pump, the water supply inside the pump is still leaking out from the labyrinth seal. Two steam pump sealed water return water share a U-shaped water seal back to the condenser.

In different operating conditions, the steam pump seal water pressure adjustment valve is used to adjust the steam pump seal water differential pressure to maintain within a suitable differential pressure range. The sealed water differential pressure is the difference between the sealed water supply pressure of the steam pump and the discharged water pressure of the steam pump. The condensed water is injected at a control pressure 100 ~ 130kPa higher than the discharged water. The pressure control valve keeps the pressure difference between the sealed water and the discharged water at about 120kPa. A sealed water differential pressure control actuator must be installed in the sealed water pressure regulating valve. The sealed water differential pressure signal of the sealed water differential pressure control actuator is obtained from the joint of the sealed water supply and the discharge water. The steam pump is labyrinth sealed at both actuated and unactuated ends and is controlled by a pressure regulator.

3. Main ways to seal water back water systems

3.1 Single-stage water seal

The structure of single stage water seal is relatively simple. Its principle is that the negative pressure of the condenser operation, assuming that the running back pressure is 6 kPa (a), about -0. 095 MPa (g), the condenser can cause the siphon water column height is about 9.5 m, theoretically using a single stage water seal, the feed pump seal water return water column height 10 m can ensure that the condenser vacuum will not be destroyed. In actual operation, due to water level fluctuation and other reasons, the height of the water seal needs to be higher, usually the height of the water column is designed to be 12-13 m. But this kind of water seal pipe generally needs to be embedded in the early stage of the project, and the condenser in the power plant is generally arranged in the zero meter layer, the position of the condenser opening can not be arranged at will, this way can be modified after the completion of the design of little room. Because the single-stage water seal occupies a small area, and is simple to make and easy to install, this kind of water seal is the most common in domestic power plants.

3.2 Multistage water seal

The principle of multistage water seal is equivalent to the superposition of single stage water seal, generally 3 levels. The total pressure difference between inlet and outlet is maintained at about 12 m, which can meet the requirements of condenser vacuum. The key to multi-stage water seal is the maintenance of water seal, which requires that each level of water seal cannot be destroyed. Before the water seal is started, water must be injected first and the gas inside the water seal must be emptied; And the multistage water seal in the production to ensure the sealing of the internal parts of the water seal. The structure of multistage water seal is compact, but its production and operation are complicated, and there are high requirements for operation control.

The multistage water seal device is to use the water column in the water seal cylinder to achieve the isolation of the condenser and the outside world, to realize the tightness of the vacuum, and to use the water column height and along the resistance balance between the feed pump seal water return pipe and the pressure difference between the condenser. Compared with the single-stage water seal, the multi-stage water seal reduces the height of the water seal cylinder and the buried height.

Before the multistage water seal cylinder is put into operation, first of all, water injection and exhaust should be carried out to completely discharge the air. The air door should be lined with water, close the emptying door, stop water injection, and make preparations before the water seal cylinder is put into operation. When the vacuum of the condenser is established normally, the feed water pump

can be recovered to seal the water return water, close the sealed water return drainage trench door, open the sealed water return water to the water seal cylinder door, open the water seal cylinder to connect the condenser return water door, and monitor the vacuum of the condenser during operation.

3.3 Seal water tank

The water tank type sealed water backwater design has also been applied in power plants, its principle is to put the backwater of the sealed water of the feed pump into the water tank cache first, and after the water level in the water tank reaches a certain height, the negative pressure of the condenser is used to inhale the condenser hot well. The key of the system is to control the water level of the water tank, commonly used floating ball type control structure, through the height of the water level to decide whether to put the water in the water tank into the hot well, and through the height of the water level control valve opening. It is necessary not only to ensure the smooth return water but also to ensure that it does not affect the vacuum of the condenser and the normal operation of the unit. The water tank sealing water return structure is simple and easy to operate, but the reliability is not strong. If the floating ball control system fails or misoperates, it will cause the decline of condenser vacuum and affect the safety of unit operation.

4. Water seal height calculation

4.1 Single stage water seal height calculation

The calculation of water seal device generally includes the calculation of water seal flow capacity and water seal pressure efficiency, that is, the calculation of water seal pipe diameter dn and water seal height H.

The inner diameter of water sealing pipe is calculated by the following formula:

$$d = 594.5\sqrt{\frac{G}{W \cdot \rho}} \tag{1}$$

Where, d is inner diameter of water sealing pipe (mm); G is hydrophobic mass flow rate (t/h); ρ is hydrophobic density (kg/m^3); W is velocity: 0.3 to 2m/s is recommended.

The momenta flowing through the control surface must satisfy the Bertrand equation:

$$\frac{P_1}{g\rho_1} + \frac{W_1^2}{2g} + Z_1 = \frac{P_2}{g\rho_2} + \frac{W_2^2}{2g} + Z_2 + h_W \tag{2}$$

Where, P_1, P_2 is water seal inlet and outlet static pressure (Pa); ρ_1, ρ_2 is water sealing inlet and outlet density (kg/m3); W_1, W_2 is water sealing inlet and outlet speed (m/s); Z_1, Z_2 is water seal inlet and outlet potential energy (m); h_W is total resistance loss (m).

Since $Z_2 - Z_1$ is the height of water seal H, the above formula can be obtained by finishing:

$$H = \frac{1}{g}\left(\frac{P_1}{\rho_1} - \frac{P_2}{\rho_2}\right) + \frac{1}{2g}\left(W_1^2 - W_2^2\right) - h_W \tag{3}$$

After the example verification, the value of dynamic pressure energy of $\frac{1}{2g}\left(W_1^2 - W_2^2\right)$ is small and can be ignored, then:

$$H = \frac{1}{g}\left(\frac{P_1}{\rho_1} - \frac{P_2}{\rho_2}\right) - h_W \tag{4}$$

4.2 Multistage water seal height calculation

Select four-stage water seal, inlet pressure 0.1MPa, outlet pressure 0.003MPa. The working process of A water seal is as follows: close the inlet and outlet valves of the water seal pipe, open the

water injection and discharge valves, close the discharge valves and the water injection valves after filling with water, and open the water level control valve. When no water flows out, close the water level control valve, then open the outlet valve of the water seal pipe, and slowly open the inlet valve to put into operation. At this time, air is above the liquid column in the water seal pipe. When working, the water head is generated by the change of liquid level. The sum of the effective water heads of all levels of water seal is the total water head of the water seal.

It is assumed that the amount of gas in each level of the water seal is constant when working. By solving the following equations step by step from the outlet to the inlet, the height hj of the effective head of water seal at each level can be obtained.

$$\begin{aligned} P_i &= P_{i-1} + \sum_{j=1}^{i} \gamma h_j \\ P_i V_i &= P_i' \cdot V' \\ V_i &= \theta(\mathrm{h_i}) \end{aligned} \tag{5}$$

Where, P', P' is respectively the pressure before and after expansion of the gas in the i water seal, Pa; V_i', V_i is the volume of the gas in the i water seal before and after expansion, respectively, m3; γ is Water severity, N/m3; θ is V_i as a function of $\mathrm{h_i}$, determined by the structure of the water seal.

5. Improved sealed water return control valve

5.1 Add electric control valve

While selecting a valve regulating valve with high precision, increase the control precision of the seal water, ensure the multistage dynamic adjustment of water seal, reduced the repeatedly cast operators refund security risks brought by the multistage water seal, at the same time reduce the overflow of the multistage water seal and other anomalies occur, the valve in the control logic into automatic state and track level adjustment, and set up the opening, Avoid this door large opening and closing, the system reliability and economy greatly increased.

5.2 Install electric isolation valve

If there are any improper control, or electric control valve fault is wide open, leading to water damage and destruction of the condenser vacuum, under the condition of the effective judgment, therefore, can rapidly at a distance will increase the new electric door closed, steam will automatically from the overflow pipe, through the pump seal water, greatly reducing the operation personnel processing time, reduce the vacuum reduction amount, reducing the possibility of a unit shutdown.

5.3 Add liquid level gauge

In the original system design, the water seal level gauge is not considered. In most cases, it depends on the operator to inspect or adjust through the parameter change, so the system reliability is not high. In order to further reduce the flow capacity and ensure the water seal not to undermine, increase the first-level level shows that at the same time convenient for on-site inspection and compare the distance level, increase in the first level of the multistage water seal magnetic flap water level gauge (with remote transmission function) to realize real-time monitoring for water seal water level and the overflow of the increase of electric regulator tracking the level adjustment, That is to ensure that the level of the first water seal exists and will not flow out of the overflow port.

5.4 Replace globe valve with gate valve

As the shaft end of the steam pump adopts the labyrinth seal type, the high-pressure side return water (unloading water) is returned to the inlet pipeline of the front pump. The access point is

equipped with DN50 and PN2.5MPa gate valves at the 15.5m layer pipeline behind the electric door of the front pump inlet and in front of the inlet filter screen. However, the unloading water manual door is installed as a stop valve, and the resistance is large. On the premise of excluding the large gap of the labyrinth seal, the analysis shows that the resistance of the unloading water stop valve is large, which causes the high pressure return water is not smooth and the multi-stage water seal inlet pipeline is connected, which is another reason for the abnormal operation of the steam pump sealing water system. Therefore, the high-pressure side return water (discharge water) back to the front pump inlet line stop valve replaced with a gate valve.

5.5 Optimized control of water seal return water temperature

In order to further ensure the flexibility of steam pump seal water regulation, the steam pump seal water backwater temperature is changed from 65 ℃ to 50 ℃, the possibility of steam pump seal water backwater vaporization is further reduced, reduce the repeated casting and withdrawal of multistage water seal, and further improve the reliability of the system.

6. Conclusion

This project analyzes the importance of the sealed water return system of the feed pump to the safety and economy of the power plant, and realizes that it is of great practical significance to design the sealed water system of the feed pump scientifically and reasonably so that it can recover the sealed water completely without affecting the normal operation of the unit. This paper studies the common sealed water supply way of feed pump, and three main sealed water return system way and working principle, and analyzes their respective advantages and disadvantages. This project studies the calculation methods of water seal height of single-stage and multi-stage seals, especially for multi-stage seals, gives different calculation ideas and methods under static and dynamic analysis, and finally puts forward a set of complete water seal height calculation formula. At the same time, the project improved the control valve of sealed water return by installing electric control valve, electric isolation valve, liquid level gauge, and replacing the cut-off valve with gate valve, and improved the reliability of sealed water return system.

Feed water pump seal water system operation there are many related factors, seal type selection, seal of the pipe diameter, pipe layout and the change of the unit operation condition, can affect the sealing water system normal operation, the project put forward the design scheme of the water tank and water sealing, enhance the adaptability to water seal device, optimize the system. The first part of this design is set up a water tank to solve the patency of the backwater, and the second part is set up a water seal to solve the vacuum problem of the condenser, which provides a new choice for the design of the water seal system of the feed pump. For power plants with single-stage water seal or multistage water seal, the main equipment to be added by using this project scheme is a simple water tank, which is simple to make, has no special processing requirements, low cost and will not increase too much investment budget, so it is more suitable for power plant transformation.

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