Study on Calculation of Inlet Steam and Inlet Water Flow of Drain Pump of Low Pressure Heater

Lingkai Zhu [1], Wei Zheng [1], Qian Wang [1], Ziwei Zhong [1], Zhiqiang Gong [1]

[1] State Grid Shandong Electric Power Research Institute, Jinan, China

Abstract. In the traditional drainage system of low pressure heater of thermal power unit, the measuring point of drain pump is usually added to directly measure the water and steam flow of low pressure heater of drain pump with instruments. This method is time-consuming and labor-intensive, and the measurement results are affected by many environmental factors. In order to solve this problem, this paper proposes an automatic calculation method based on the principle of heat balance.

1. Introduction

In recent years, with the development of thermal power units to large capacity and high parameters, the influence of regenerative system on thermal economy of units has gradually increased[1]. The drainage system of the low pressure heater of the traditional thermal power unit is mainly of the self draining type. The drainage of the low pressure heater flows automatically from high to low and finally discharges to the condenser. The drainage water flows automatically step by step[2,3]. On the one hand, the drainage water releases heat from the lower level to drain the lower level steam inlet, reducing the effect of regenerative steam inlet; on the other hand, the drainage water is discharged to the condenser, increasing the cold source loss. Therefore, in a large capacity thermal power unit, a drainage pump is set in a certain stage or several stages of low-pressure heater system to drain the water at this stage to the outlet of the heater at this stage, improving the outlet water temperature of the heater, and squeezing the steam inlet of a higher stage of low-pressure heater, Meanwhile, the loss of cold source is reduced.

The traditional measurement method usually uses the instrument to measure directly[4,5]. When adding drain pump measuring points in the heat recovery system, appropriate flow meters should be selected according to its performance requirements, fluid characteristics, installation requirements, environmental conditions and cost factors. After adding this measuring point, there will be a certain impact on the flow, and it needs to spend manpower and material resources to maintain it. Therefore, it is time-consuming and labor-intensive to directly solve the problem of drain pump flow from the hardware, and there are many inconveniences.

In view of the shortcomings of the prior art, a clear and convenient method for calculating the water and steam inlet flow of the low-pressure heater with drain pump is provided. This method is based on the heat balance method and uses the cycle iteration function of excel to calculate the water inlet and steam inlet flow of the low-pressure heater with drain pump conveniently and simultaneously.

2. Low pressure heater system with drain pump

In order to improve the regenerative effect of the heater, at present, drain pump is usually set for the heater. Figure 1 shows a low-pressure heater system with drain pump. The drain water from #5 and #6 low-pressure heaters flows automatically to #7 low-pressure heater stage by stage. The drain pump of #7 low-pressure heater pumps the drain water from #5, #6 and #7 three-stage low-pressure heaters to the outlet of #7 low-pressure heater. Therefore, after the drain pump is added, the condensate flow in and out of the heater is no longer the same. The outlet flow of #7 low-pressure heater is equal to the main condensate flow at the inlet of the deaerator. The water inlet flow and steam inlet flow of the #7 low-pressure heater are unknown.

* Corresponding author: zhulingkai@woyoxin.com

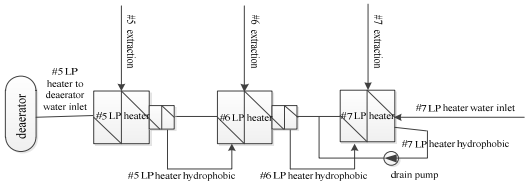

Figure 1. Overall strategy system of security protection.

3. Calculation Method for Inlet Steam and Inlet Water Flow of Drain Pump of Low Pressure Heater

There are n-stage low-pressure heaters in series. The outlet of the first stage low-pressure heater is connected to the deaerator. The n-stage low-pressure heater is equipped with a drain pump. The drain water of the n-stage low-pressure heater is mixed with the feed water at the outlet of the n-stage low-pressure heater by using the drain pump. The drain water of other low-pressure heaters flows automatically step by step. Its characteristics are: the heat balance equation is established for the 1st, 2nd ... and n-1 low-pressure heaters, and the extraction flow of the 1st, 2nd ... and n-1 low-pressure heaters is calculated. Wherein, according to the extraction pressure, extraction temperature, inlet water temperature, outlet water temperature and drain water temperature of the first stage low-pressure heater and the main condensate flow from the first stage low-pressure heater to the deaerator, the heat balance equation of the first stage low-pressure heater is established; According to the steam extraction pressure, steam extraction temperature, inlet water temperature, outlet water temperature and drain water temperature of the 2nd ... and n-1 stage low-pressure heaters and the main condensate flow from the 1st stage low-pressure heater to the deaerator, the heat balance equation of the 2nd ... and n-1 stage low-pressure heaters is established.

According to the steam extraction flow of the 1st, 2nd ... and n-1 stage low-pressure heaters and the main condensate flow from the 1st stage low-pressure heater to the deaerator, the heat balance equation and flow balance equation are established for the nth stage low-pressure heater at the same time. Based on the iterative method, the steam extraction flow and water inlet flow of the nth stage low-pressure heater are calculated, that is, the steam inlet flow and water inlet flow of the drain pump of the low-pressure heater are respectively.

The specific method for calculating the extraction steam flow of the 1st, 2nd ... and n-1 low-pressure heaters is as follows:

Obtain the extraction pressure, extraction temperature, inlet water temperature, outlet water temperature and drain water temperature of the first stage low-pressure heater, and calculate the extraction enthalpy, inlet water enthalpy, outlet water enthalpy and drain water enthalpy of the first stage low-pressure heater using the thermodynamic property model of water and steam. Obtain the main condensate flow from the first stage low-pressure heater to the deaerator. According to the above parameters, establish a heat balance equation for the first stage low-pressure heater, and calculate the extraction steam flow of the first stage low-pressure heater.

Obtain the extraction pressure, extraction temperature, inlet water temperature and drain water temperature of the 2nd ... and n-1 low-pressure heaters, and calculate the extraction enthalpy, inlet water enthalpy and drain water enthalpy of the 2nd ... and n-1 low-pressure heaters using the thermodynamic property model of water and steam. According to the main condensate flow from the first stage low-pressure heater to the deaerator, the extraction enthalpy, inlet enthalpy and drain enthalpy of the 2nd ... and n-1 low-pressure heaters, the heat balance equation is established for the 2nd ... and n-1 low-pressure heaters, and the extraction flow of the 2nd ... and n-1 low-pressure heaters is calculated.

Obtain the extraction steam pressure, extraction steam temperature and inlet water temperature of the nth stage low-pressure heater, and calculate the extraction steam enthalpy and inlet water enthalpy of the nth stage low-pressure heater using the thermodynamic property model of water and steam. Assumed water inlet flow of the nth stage low-pressure heater is set, and the heat balance equation of the nth stage low-pressure heater is established by combining the extraction flow of the 1st, 2nd ... and n-1 stage low-pressure heaters, the drain enthalpy of the n-1 stage low-pressure heater, the inlet enthalpy of the n-1 stage low-pressure heater, the main condensate flow from the first stage low-pressure heater to the deaerator, the extraction enthalpy of the n-stage low-pressure heater, and the inlet enthalpy of the n-stage low-pressure heater. The extraction steam flow of the nth stage low-pressure heater is calculated on the premise of the assumed inlet water flow of the nth stage low-pressure heater, which is the inlet steam flow of the drain pump of the low-pressure heater

The flow balance equation is established for the nth stage low-pressure heater according to the steam extraction flow of the 1st, 2nd ... and nth stage low-pressure heaters and the main condensate flow from the first stage low-pressure heater to the deaerator, and the arithmetic water inlet flow of the nth stage low-pressure heater is obtained through reverse calculation, so that the assumed water inlet flow of the nth stage low-pressure heater is equal to the arithmetic water inlet flow of the nth stage low-pressure heater, which is calculated based on the iterative method, The final iteration value is taken as the water inlet flow of the nth stage low-pressure heater, that is, the water inlet flow of the drain pump of the low-pressure heater.

Excel is used for automatic calculation based on iterative method. IFC-97 industrial water and steam thermodynamic property model in Excel is used for calculation.

The main condensate flow from the first stage low-pressure heater to the deaerator is measured by measuring the flow differential pressure from the first stage low-pressure heater to the main condensate of the deaerator. The flow differential pressure from the first stage low-pressure heater to the main condensate of the deaerator is measured by ASME flow nozzle, and then the main condensate flow from the first stage low-pressure heater to the deaerator is calculated by using the ASME nozzle flow calculation model in Excel.

The extraction steam pressure of the 1st, 2nd ... and n-stage low-pressure heaters is measured by pressure transmitter.

The steam extraction temperature, water inlet temperature, water outlet temperature and drain water temperature of the first stage low pressure heater, the steam extraction temperature, water inlet temperature and drain water temperature of the 2nd ... and n-1 stage low pressure heaters, and the steam extraction temperature and water inlet temperature of the n-stage low pressure heater are measured by temperature elements.

The heat balance equation is established for the first stage low-pressure heater, and the extraction steam flow of the first stage low-pressure heater is calculated.

$$G_1 h_1 + G_{ns} h_{1i} = G_1 h_{1h} + G_{ns} h_{1o} \quad (1)$$

Wheres:G_1-steam extraction flow of the first stage low-pressure heater, G_{ns}-main condensate flow from the 1st stage low-pressure heater to deaerator, h_1-enthalpy value of stage 1 steam extraction, h_{1i}-enthalpy value of inlet water of the first stage low-pressure heater, h_{1h}-drain enthalpy of the 1st stage low-pressure heater, h_{1o}-enthalpy value of outlet water of the first stage low-pressure heater.

According to the heat balance equation, the steam extraction flow of the first stage low-pressure heater is obtained as follows:

$$G_1 = \frac{G_{ns}(h_{1o} - h_{1i})}{h_1 - h_{1h}} \quad (2)$$

Establish the heat balance equation for the 2nd ... and n-1 low-pressure heaters, and calculate the extraction steam flow of the 2nd ... and n-1 low-pressure heaters.

$$G_{n-1} h_{n-1} + G_{n-2} h_{n-2h} + G_{ns} h_{n-1i} = （G_{n-2} + G_{n-1}） h_{n-1h} + G_{ns} h_{n-2i} \quad (3)$$

Wheres:G_{n-1}-steam inlet flow of stage n-1 low-pressure heater, h_{n-1}-enthalpy value of steam inlet of stage n-1 low-pressure heater, h_{n-1i}-enthalpy value of water inlet of n-1 low-pressure heater, h_{n-1h}-drain enthalpy of stage n-1 low-pressure heater.

According to the heat balance equation, the steam inlet flow of n-1 low-pressure heater is obtained as follows:

$$G_{n-1} = \frac{G_{ns}(h_{n-2i} - h_{n-1i}) + G_{n-2}（h_{n-1h} - h_{n-2h}）}{h_{n-1} - h_{n-1h}} \quad (4)$$

The heat balance equation of the nth stage low-pressure heater is as follows:

$$(G_{n-2} + G_{n-1}) h_{n-1h} + G_{ni} h_{ni} + G_n h_n = G_{ns} h_{n-1i} \quad (5)$$

Wheres:G_n-steam inlet flow of the nth stage low-pressure heater, G_{ni}-assumed inlet water flow of the n-stage low-pressure heater, h_n-enthalpy value of steam inlet of the nth stage low-pressure heater, h_{ni}-enthalpy value of inlet water of the nth stage low-pressure heater.

According to the heat balance equation, the steam inlet flow of the nth stage low-pressure heater is obtained as follows:

$$G_n = \frac{G_{ns} h_{n-1i} - G_{ni} h_{ni} - (G_{n-2} + G_{n-1})\, h_{n-1h}}{h_n} \quad (6)$$

The flow balance equation of the nth stage low-pressure heater row is as follows:

$$G_{ni}' = G_{ns} - G_1 - G_2 - 、 、 - G_{n-1} - G_n \quad (7)$$

Wheres:$\mathbf{G_{ni}}'$-arithmetic water inlet flow of the nth stage low-pressure heater.

4. Conclusion

The calculation method of inlet steam and inlet water flow of drain pump of low-pressure heater proposed in this paper is based on the heat and flow balance of the heater. The formula for calculating the inlet steam and inlet water flow is input into the excel table. The automatic iteration function of excel is used for automatic calculation, and the inlet steam and inlet water flow can be calculated at the same time. It is simple, intuitive and accurate, especially suitable for the thermal test practitioners of power plants to conduct thermal calculation

References

1. Xiaolong Guo. Optimization of steam turbine regenerative system in coal power plant[J]. Mechanical management development, 2022,(2):169-170.
2. Lujiang Li, Jian Wang. Improvement and economic analysis of drainage system of low-pressure heater [J]. Thermal power generation, 2008, 37 (12): 60-64.
3. Qindao Li. Economic Analysis of Drainage System of Low Pressure Heater of Domestic 300 MW Unit [J]. China Power, 1993, (3): 41-45.
4. Yingchun Zhao, Chaofan Zhang, Qi Duan. Optimization of regulation and control strategy for low pressure heater drain pump system [J]. Electric power survey and design, 2021, (11): 41-44
5. Guo Zheng. Application of Frequency Conversion Speed Regulation Technology in Drainage System of Low Pressure Heater [J]. Auxiliary equipment of power station, 2002, (02): 3-6.