Study on Calculation Method of Inlet Steam Flow of External Steam Cooler in Feedwater Heating System

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Abstract. In order to improve the thermal economic performance of coal-fired units in thermal power industry, supercritical units above 600MW generally adopt the method of installing external steam cooler system to improve the utilization of reheat. In view of the difficulties and problems in calculating the three extraction flow of the external steam cooler high pressure heater system by the traditional method, In this paper, a new calculation method of medium flow at the inlet of external steam cooler is proposed based on medium fluid dynamics. This method does not need to install a measuring device, the treatment method is simple and clear, and improves the test efficiency while saving the cost.

1. Introduction

In recent years, with the development of thermal power units to large capacity and high parameters, how to further improve the thermal economy of coal-fired units has become an urgent problem to be solved in the thermal power generation industry, especially the utilization of reheat [1]. For the ultra supercritical reheat unit, the temperature of the exhaust steam of the high-pressure cylinder of the steam turbine after reheating is high, resulting in the increase of the superheat of the extraction steam of the intermediate pressure cylinder of the steam turbine regenerative system. The extraction steam of the intermediate pressure cylinder with high superheat used to preheat the low-temperature boiler feed water will bring irreversible losses and affect the thermal economy of the unit [2, 3]. In order to reduce the superheat of extraction steam and improve the regenerative effect, high-pressure heater (high-pressure heating) system and some low-pressure heater (low-pressure heating) systems are equipped with steam coolers. The installation of external steam cooler system with flexible layout is an effective scheme to reduce the superheat of regenerative extraction steam [4, 5]. The external steam cooler has a large heat exchange area, which can not only reduce the end difference of the heater at this level, but also directly heat the feed water. With higher thermal economy, it is gradually used in supercritical units above 600MW [6].

It is difficult to calculate the three extraction flow of the external steam cooler high-pressure heater system with the traditional method. The three extraction flow can also be calculated directly from the heat balance equation of the external steam cooler. However, this method needs to install a flow orifice to measure the feed water flow of the external steam cooler, which increases the test cost, changes many measuring points and increases the test time. In view of the above problems, a calculation method of inlet steam flow of external steam cooler in feedwater heating system is proposed in this paper. This method does not need to install measuring device, the treatment method is simple and clear, and the test cost and time are saved.

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2. Calculation principle of inlet steam flow of external steam cooler system

The structure of the external steam cooler system studied in this paper is shown in Figure 1.

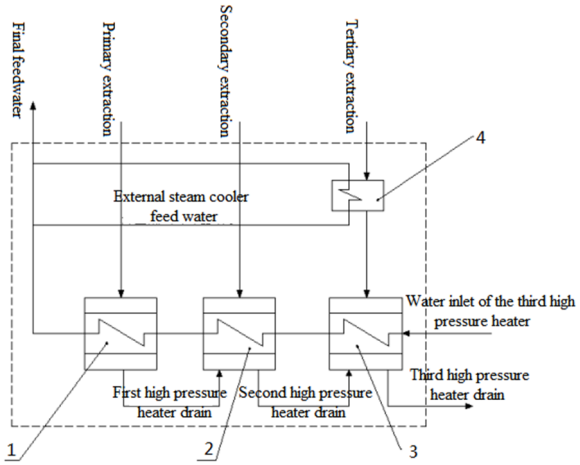

Figure 1. Design heating condition of steam turbine of monitored thermal power unit

Figure 1 shows a single-stage series external steam cooler. The three-stage extraction steam enters the external steam cooler 4 for cooling and heat release, and then enters the third stage high-pressure heater 3 for heat release, which can effectively reduce the steam superheat, reduce the heat exchange temperature difference and heat loss of the third stage high-pressure heater 3, and increase the outlet water temperature of the third stage high-pressure heater 3, The regenerative steam extraction capacity of higher pressure stage is reduced and the heat consumption is reduced. On the other hand, the feed water flow at the outlet of the first stage high-pressure heater 1 is partially through the external steam cooler 4, which increases the final feed water temperature and further reduces the heat consumption. For the thermal test, the three-stage extraction steam flow (three extraction flow), that is, the inlet steam flow of the external steam cooler 4, is used whether the condensate flow is used to calculate the feedwater flow or a kind of correction.

It is difficult to calculate the three extraction flow in the external steam cooler high-pressure heater system by traditional methods. Firstly, the feed water flow into the external steam cooler 4 is uncertain, and the three extraction flow cannot be calculated by the direct heat balance formula of the external steam cooler 4.In addition, since the external steam cooler 4 is provided with a drain pipe to the third stage high-pressure heater 3 for startup and shutdown drainage, if the valve is not tight, the steam inlet volume of the third stage high-pressure heater 3 may not be completely equal to the three extraction flow. Therefore, only the heat balance calculation of the third row of the third stage high-pressure heater cannot obtain the accurate three extraction flow.

In addition, the direct four row heat balance equation of the external steam cooler can also calculate the three extraction flow, but this method has two problems: first, the flow orifice needs to be installed to measure the feed water flow of the external steam cooler 4, which increases the test cost; Second, it is necessary to measure the feed water pressure and temperature at the inlet and outlet of the external steam cooler 4 and the inlet pressure and temperature of the third stage high-pressure heater 3. There are many replacement measuring points, which increases the test time.

3. Innovative calculation method of inlet steam flow of external steam cooler

In order to solve the above problems, this paper proposes a technical scheme, which regards all the heaters and external steam coolers in the feedwater heating system as a whole module, lists the heat balance equation for the heat in and out of the whole module, and obtains the inlet steam flow of the external steam cooler. The specific steps are as follows:

(1) Measure the following parameters: pressure and temperature of primary extraction, pressure and temperature of secondary extraction, pressure and temperature of tertiary extraction, inlet water temperature of primary high-pressure heater 1, secondary high-pressure heater 2 and tertiary high-pressure heater 3, outlet water temperature of primary high-pressure heater 1, primary high-pressure heater 1 Drain temperature, final feedwater temperature, final feedwater pressure and feedwater flow of the second stage high pressure heater 2 and the third stage high pressure heater 3. Among them, replace the pressure transmitter at the pressure measuring point to measure the pressure, replace the temperature sensor at the temperature measuring point to measure the temperature, and use the orifice flowmeter to measure the differential pressure at the flow measuring point.

(2) According to the pressure and temperature measured in step (1), the first stage extraction enthalpy, second stage extraction enthalpy, third stage extraction enthalpy, inlet enthalpy and drain enthalpy of the first stage high pressure heater 1, the second stage high pressure heater 2 and the third stage high pressure heater 3, outlet enthalpy and final feed enthalpy of the first stage high pressure heater 1 are calculated by using IFC-97 industrial water and steam thermal property model loaded in Excel. According to the feedwater flow differential pressure measured in step (1), the feedwater flow is calculated by using the orifice flow calculation model loaded in Excel.

IFC-97 thermodynamic property model of industrial water and steam and orifice flow calculation model are the existing calculation software in the industry. Through the calculation model to calculate and generate results, it can greatly save manpower, improve efficiency and accuracy. After loading the calculation model into excel and inputting corresponding parameter values, it can quickly generate results, which is simple and clear.

(3) Calculate the first stage extraction steam flow for the first column of heat balance equation of the first stage high-pressure heater. For the first stage high-pressure heater, column 1 heat balance equation is as follows:

$$G_1 h_1 + G_{gs} h_{1j} = G_1 h_{1s} + G_{gs} h_{1c} \quad (1)$$

Wheres: G_1 -primary extraction flow, G_{gs} -feedwater flow, h_1 -primary extraction enthalpy, h_{1j} -inlet enthalpy of the first stage high pressure heater 1, h_{1s} -first stage high pressure heater 1 drain enthalpy, h_{1c} -Outlet enthalpy of first stage high pressure heater 1.

According to the heat balance equation of the first stage high pressure heater 1, the first stage extraction steam flow is obtained as follows:

$$G_1 = \frac{G_{gs}(h_{1c} - h_{1j})}{h_1 - h_{1s}} \quad (2)$$

(4) The second stage extraction steam flow is calculated for the two rows of heat balance equations of the second stage high-pressure heater. For the second stage high-pressure heater, the heat balance equation of column 2 is as follows:

$$G_2 h_2 + G_1 h_{1s} + G_{gs} h_{2j} = (G_1 + G_2) h_{2s} + G_{gs} h_{1j} \quad (3)$$

Wheres: G_2 -secondary extraction flow, h_2 -secondary extraction enthalpy, h_{2j} -inlet enthalpy of the second stage high pressure heater 2, h_{2s} -second stage high pressure heater 2 drain enthalpy.

According to the heat balance equation of the second stage high pressure heater 2, the second stage extraction steam flow is obtained as follows:

$$G_2 = \frac{G_{gs}(h_{1j} - h_{2j}) + G_1(h_{1s} - h_{2s})}{h_2 - h_{2s}} \quad (4)$$

(5) The first stage high-pressure heater 1, the second stage high-pressure heater 2, the third stage high-pressure heater 3 and the external steam cooler 4 are regarded as a closed integral module, and the heat entering the integral module is the first stage steam extraction heat, the second stage steam extraction heat, the third stage steam extraction heat and the water inlet heat of the third stage high-pressure heater 3, The heat flowing out of the overall module is the drainage heat and final feed water heat of the third stage high-pressure heater 3. For the overall module, formulate a heat balance equation and calculate the third stage extraction steam flow, that is, obtain the inlet steam flow of the external steam cooler.

For the overall module train, the heat balance equation is as follows:

$$(G_1 + G_2 + G_3) h_{3s} + G_{gs} h_{gs} = G_1 h_1 + G_2 h_2 + G_3 h_3 + G_{gs} h_{3j} \quad (5)$$

Wheres: G_3 -tertiary extraction flow, h_3 -tertiary extraction enthalpy, h_{3j}-inlet enthalpy of the third stage high pressure heater 3, h_{3s} -third stage high pressure heater 3 drain enthalpy, h_{gs} -final feedwater enthalpy.

According to the heat balance equation of the whole module, the third stage extraction steam flow, i.e. the extraction steam flow of external steam cooler 4, is obtained as follows:

$$G_3 = \frac{G_{gs}(h_{gs} - h_{3j}) + G_1(h_{3s} - h_1) + G_2(h_{3s} - h_2)}{h_3 - h_{3s}} \quad (6)$$

4. Conclusion

In this paper, a new calculation method of steam inlet flow of external steam cooler in feedwater heating system is proposed. When used in high-pressure heating system with only two-stage high-pressure heaters, the steam inlet flow of external steam cooler can be calculated after calculating the first stage extraction flow. In the low-pressure heating system with external steam cooler, the low-pressure heaters at all levels and external steam cooler are regarded as an integral module, and the heat balance equation is listed for the integral module. The parameters to be measured in this method are the measuring points to be replaced in the conventional steam turbine thermal test, and there is no need to add a new feed water flow orifice of the external steam cooler and measure the feed water pressure and temperature at the inlet and outlet of the external steam cooler and the inlet pressure and temperature of the high-pressure heater connected with the external steam cooler, which saves the test cost and time.

Acknowledgements

This work is supported by the science and technology project of Shandong Electric Power Research Institute (ZY 2020-05), which studies the calculation method and platform application of minimum operation mode of thermal power plant based on power grid peak shaving dispatching

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