ANALYSIS OF NUMERICAL SIMULATION AND STRATEGY OVERVIEW OF A 350MW SUPERCRITICAL BOILER AIR DISTRIBUTION REGULATION

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ABSTRACT

There remain the operation lag and inaccuracy judgment in many power plants in the world caused by manually operating the air distribution. Boiler is one of the three main equipment of thermal power plant. Reasonable boiler air distribution can significantly improve the boiler combustion state, effectively reduce the heat loss of exhaust gas, reduce the heat loss of imperfect combustion, and reduce NOx emissions. Combining the three-dimensional simulation with control logic is a technique to cope with the operation lag and inaccuracy in many power plants in the world. In this paper, a 350MW supercritical boiler is used as a model for numerical simulation of combustion, the mathematical model and physical model is established. The air distribution mode, adjustment mode and amplitude of the boiler under each load are determined through the calculation results, and the air distribution adjustment strategy is outlined and the corresponding program is built. The calculation results show that the optimal air distribution mode of the boiler under different loads is different： the positive pagoda is selected for 160MW and 280MW, and the waist reduction is selected for 180MW and 230MW. Under 290-350MW load, the adjustment of the combustion air damper opening has a weak effect on the outlet oxygen, so give priority to the adjustment of the SOFA air damper opening can achieve better results. Overall, the findings confirm the air distribution mode under each load of the boiler, and demonstrate the basis of the damper adjusting range, which can be helpful to achieve automatic adjustment of air distribution and the boiler.

1. THE SELECTION OF THE BEST AIR DISTRIBUTION MODE UNDER TYPICAL WORKING CONDITIONS

1.1 Study on air distribution demand under 350MW working condition

Under 350MW load，Figure 1 shows the trajectory of pulverized coal particles in layers B, D and F. It can be seen from the figure that the pulverized coal particles from the primary damper of layer B flow to the furnace outlet without multi rotation movement driven by the updraft, which is easy to cause more unburned heat loss of fuel. The pulverized coal particles in the primary nozzle of layer D rotate and rise in the burner zone after being ejected, and the residence time in the furnace is longer, which is an ideal condition. After the pulverized coal ejected from the primary damper of Layer F, most of them rise through the swirling flow like the pulverized coal ejected from the middle burner, and a small part of them fall into the dry-bottom under the gravity action. The above law indicates that the opening of the bottom combustion air should be set larger.

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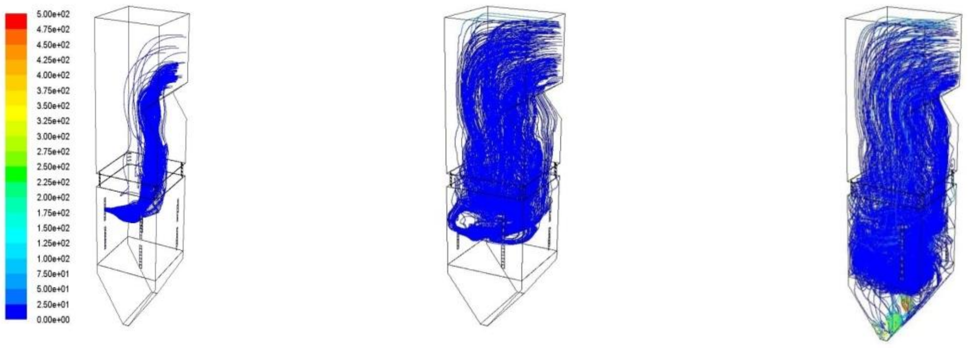
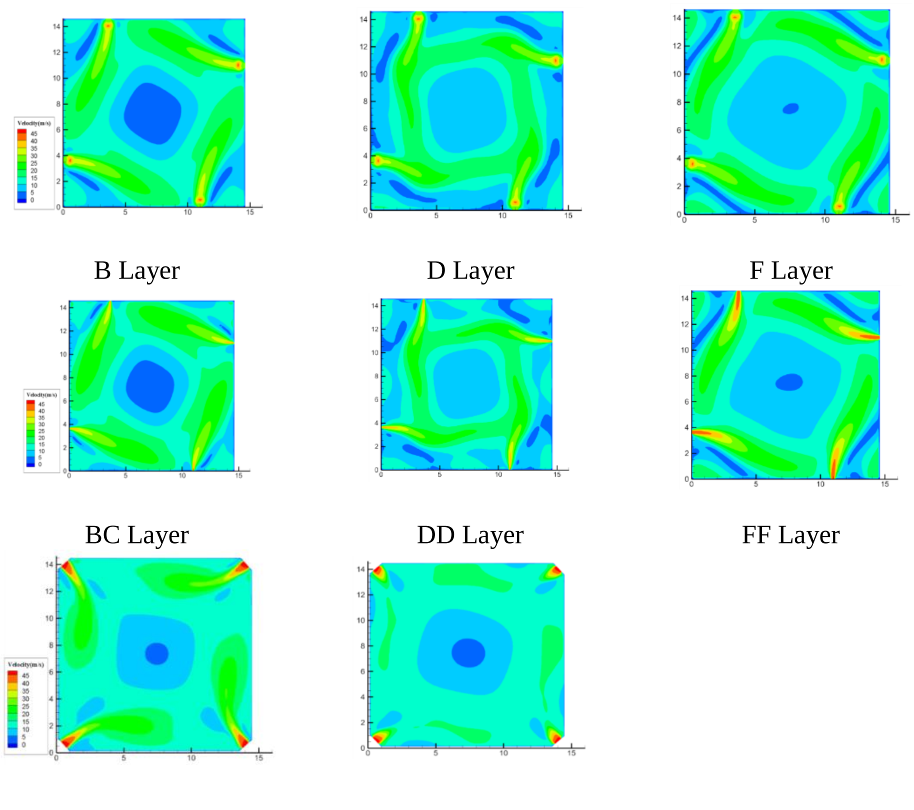


(a) (b) (c)

Figure 2: Trajectory of pulverized coal particles. (a) B layer; (b) D layer and (c)F layer.

Figure 2 shows the cross-section velocity contours of partial primary air, combustion air and SOFA air. It can be seen from the figure that the rigidity of the primary air and combustion supporting air gradually decreases after entering the furnace, and the primary air needs the assistance of the peripheral air to maintain the rigidity. The bottom airflow (D, F, DD, FF) has good circular shape and the airflow is not adherent to the wall. The "W" turbulence intensity in the furnace center increases and the tangential diameter of the upper airflow (B, BC) increases with the furnace height increasing, so the inlet air velocity should be controlled and the influence of airflow scouring on water wall should be paid attention to. The SOFA damper is arranged in four corners to increase turbulence effect, it can be seen that the airflow deflects and expands outward after being ejected from the damper, and the velocity difference in the cross section decreases, which is conducive to the further combustion of pulverized coal.



B Layer D Layer F Layer

BC Layer DD Layer FF Layer

S2 Layer S4 Layer

Figure 2: Velocity contours of damper cross-section (m/s).

In this paper, numerical calculations are carried out for 6 typical load conditions, among which the 350MW (full load) and 320MW (rated load condition) load air distribution modes are fixed. According to the design parameters of the power plant, when the boiler is running under 350MW and 320MW, the opening degree of combustion-supporting air doors is 35% and 30% except the FF layer, respectively. And the opening degree of the FF layer combustion air is 40% under both 320MW and 350MW. The other load conditions are set as positive pagoda, waist reduction and inverted pagoda. The optimal conditions are selected through the calculation results. This paper takes 180MW load conditions as an example.

1.2 Numerical calculation of 180MW working condition

The air distribution mode of 180MW working condition is shown in Table 1. By comparing the outlet temperature, oxygen content and NOx emission of the three air distribution modes under the same load, as well as the temperature distribution of the water-cooled wall in the combustion zone, the better air distribution mode have been selected.

Table 1. 180MW combustion-supporting air distribution mode (%)

Air damper	Positive pagoda	Waist reduction	Inverted pagoda
AA	15	20	20
AB	15	20	20
BC	15	15	20
CC	15	15	15
DD	20	15	15
DE	20	15	15
EF	20	15	15
FF	20	20	20

Figure 3 shows the variation curve of average cross-section temperature with furnace height under three air distribution modes in 180MW working condition. The section with furnace height of 13-58.3m is captured (the dry-bottom is ignored).

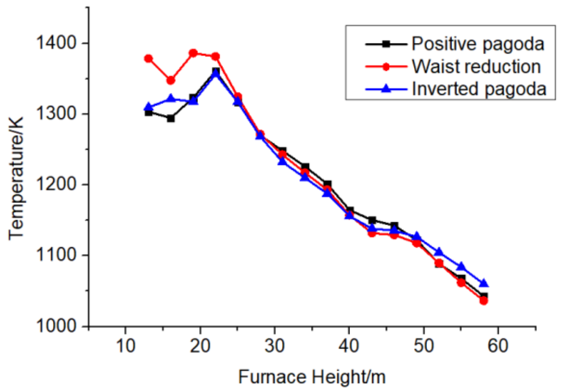


Figure 3: 180MW temperature curve with height.

Pulverized coal is injected into the burner and burns to release a large amount of heat. In the initial stage of combustion, oxygen is relatively sufficient, and the mixing of combustion air reduces the temperature of flue gas. Then the oxygen is replenished in the SOFA area and the temperature rises. With the increase of the height of the furnace, the flue gas temperature decrease. The flue gas temperature at the furnace outlet of the three modes is 1090K for the positive pagoda, 1085K for the waist reduction, and 1131K for the inverted pagoda, respectively. In addition, the furnace outlet average oxygen of the three modes is 5.09% of the positive pagoda, 4.89% of the waist reduction and 4.91% of the inverted pagoda. Compared with the outlet oxygen content design value 5%, the deviation of the waist reduction air distribution mode is relatively large. The outlet average temperature design value is 1096K, and the deviation of the inverted pagoda air distribution method is relatively large.

The curve of NO concentration with furnace height under three air distribution modes under 180MW load is shown in Figure 4. The furnace outlet NO concentration of positive pagoda, waist reduction and inverted pagoda is 437.4mg/m^3, 457.1mg/m^3 and 462.0mg/m^3, respectively, and the NOx emission of waist reduction is relatively low.

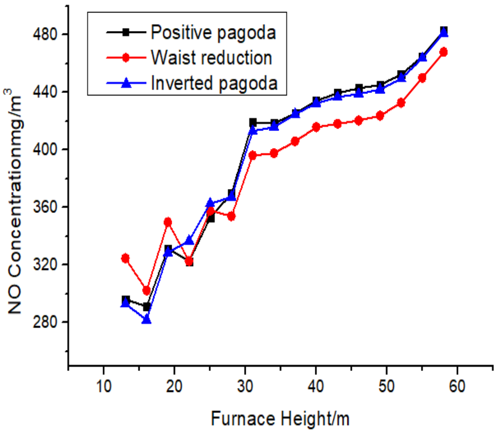
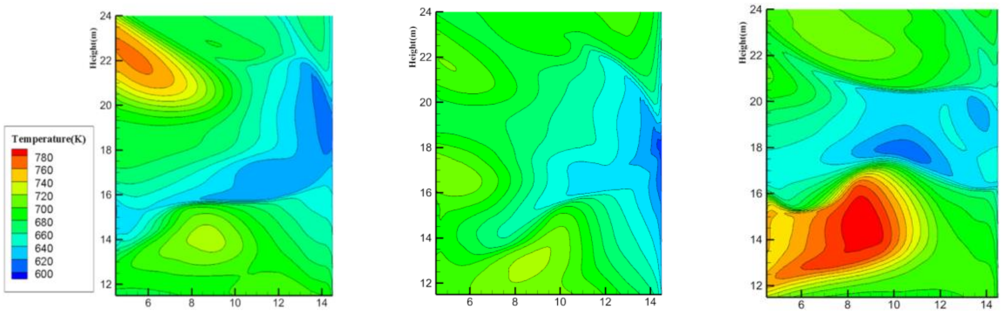


Figure 4: The variation curve of 180MW NO concentration with furnace height (mg/m^3).

Figure 5 shows the wall surface temperature distribution diagram of the burner zone under three air distribution modes of 280MW working conditions. The intercept area is 4.5-14.5m in the Y-axis direction (the burner part is ignored). Compared with each working condition, there are low-temperature areas in the lower right side of each figure. Among the three contours diagram, there is local high temperature in the upper part of the positive pagoda, and the local high temperature in the lower part of the inverted pagoda, while the wall temperature of the waist reduction is more uniform and the temperature range is 600-700k which is obviously better than the other two air distribution modes. In summary, waist reduction air distribution mode is selected as the combustion air distribution mode under 180MW load.



(a) (b) (c)

Figure 5: 180MW Surface temperature distribution of water-cooled wall. (a) Positive pagoda; (b) Waist reduction and (c)Inverted pagoda.

1.3 Air distribution strategy

The secondary air distribution strategy of the boiler is shown in Figure 6 and as follows:

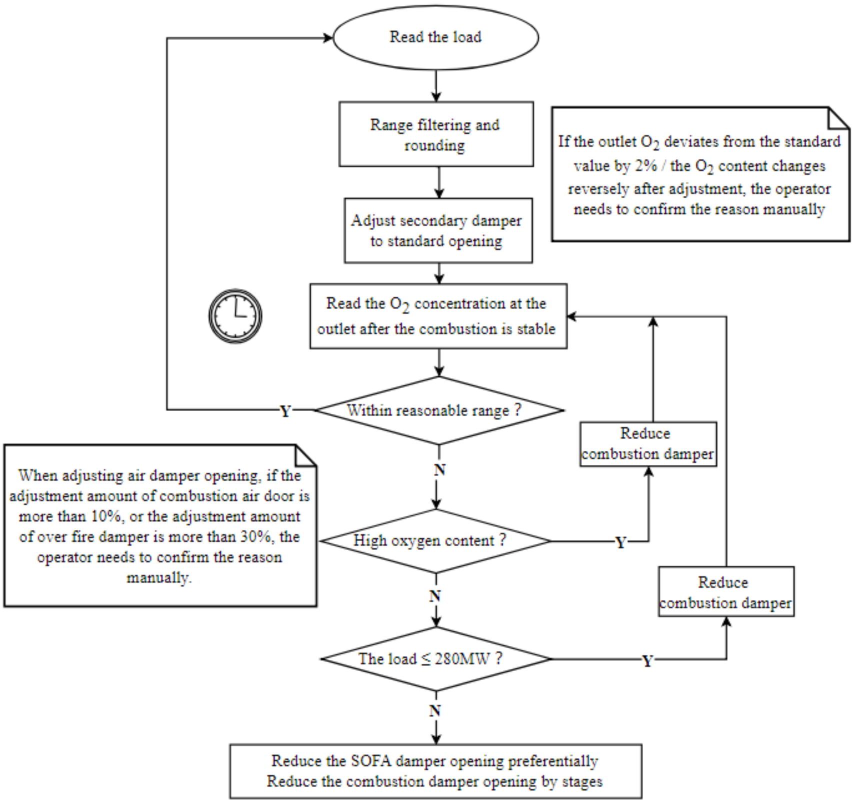


Figure 6: Flow chart of air distribution control strategy.

（1）The boiler load is read intermittently. The first read load is set as Q_1, and the second read load is Q_2 and so on. When the difference between $Q_1$and $Q_n$is less than 10MW, it is defined as a small load change, which is ignored by the program. When the difference between Q_1 and $Q_n$is larger than 10MW, the program runs again from the reading load, and redefine Q_1.

（2）Adjust the parameters of primary air, pulverized coal, surrounding air, etc. according to the load, and adjust the combustion air and SOFA air to the standard opening degree according to the linear interpolation calculation in Table 1.

（3）When the combustion state in the furnace is stable, the furnace outlet sensor oxygen content can be read. If the oxygen content is within a reasonable range, the existing air damper opening degree can be kept unchanged until the load changes or the oxygen content at the outlet is abnormal.

（4）If the oxygen content is not within a reasonable range, adjust the secondary air damper opening degree according to Figure 6. When the oxygen content is relatively high, it can be adjusted by reducing the combustion air damper opening degree. When the oxygen level is relatively low and the load is no more than 280MW, the combustion air damper opening degree can be adjusted by increasing.

When the oxygen content is relatively low and the load is greater than 280MW, the priority is to increase the SOFA damper opening degree. If the demand cannot be met, then the combustion air damper opening degree can be increased step by step on this basis.

（5）When the primary and secondary air damper adjustment still cannot meet the demand, multiple adjustments will be made, and the adjustment range based on the influence of the above outlet oxygen adjustment. When the adjustment is excessive, for example, the oxygen content changes from below the reasonable range to above the reasonable range after one adjustment, reverse linear adjustment shall be used according to the effect of the above outlet oxygen adjustment.

CONCLUSIONS

Through numerical calculation, positive pagoda air distribution is selected as the combustion air distribution mode under 280MW and 160MW loads, and the waist reduction air distribution mode is selected as the combustion air distribution mode under 230MW and 180MW loads. The optimal air damper opening degree of combustion air under typical loads is summarized in Table 2.

Table 2: The best distribution method for combustion air (%)

Load/MW	160	180	230	280	320	350
AA	10	20	20	20	30	35
AB	10	20	20	20	30	35
BC	15	15	20	20	30	35
CC	15	15	15	20	30	35
DD	15	15	15	30	30	35
DE	15	15	20	30	30	35
EF	20	20	20	30	30	35
FF	20	20	30	30	40	40

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