Numerical Simulation and Experimental Study on Blending Lignite from Bituminous Coal Boiler

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Abstract. In this paper, the turbulent flow between gas-solid two-phase is used to calculate the turbulence model of RNG k-ε model. The trajectory field of pulverized coal particles is based on Lagrangian random particle orbit method. Radiation heat transfer was calculated by discrete propagation method; double parallel reaction model was adopted for the release of pulverized coal volatiles; gas phase mixed combustion was described by mixed fraction model; diffusion kinetic model was used for coke combustion; Lagrangian method was used for calculation of particle phase.

1. Introduction
The Regarding coke agglomeration of the furnace which exists in one unit of HG-2080/17.5-YM12 boiler of some Power Generating Plant in Liaoning, in this article, through overall test major root cause of coke agglomeration of the Pulverized coal fired boiler furnace is located, and reconstruction solution is proposed; regarding description of floating, heat conduction and burning process of coal power inside boiler body, model theory and numerical simulation method have been introduced in broad outline, analyzed and summarized; The reasons of coke agglomeration of the furnace have been found; boiler combustion adjustment after reconstruction has been succeeded to solve the problem.

2. Simulated object and conditions
2.1. Simulation Object
This paper simulates power plant manufactured by the Harbin Boiler Production HG-2080/17.5-YM12 sub-critic, a reheat, single-chamber-type arrangement and controlled circulation boiler. Combustion chamber is straight for the positive pressure blowing tangentially, and burner spout can swing and Scraper slag machine is adopted. Section size is 20052m × 20193m and furnace volume is 25228 m³. Furnace Square arranges swing burners, which arrange the high wind burn-OFA above them to ensure that the value of NOx emissions. The boiler structure diagram is shown in Fig 1.
2.2. Simulation cases

This paper simulate three kinds of conditions. The condition of the coal and ash characteristics is shown in Table 1 and Table 2.

Table 1. The condition element analysis and industry analysis of coal

| Project | C<sub>ar</sub> | H<sub>ar</sub> | O<sub>ar</sub> | N<sub>ar</sub> | S<sub>ar</sub> | Q<sub>net.ar</sub> | M<sub>ar</sub> | A<sub>ar</sub> | V<sub>def</sub> |
|---------|--------------|---------------|---------------|--------------|---------------|----------------|--------------|--------------|--------------|
| Case 1  | 51.18        | 3.35          | 7.32          | 0.82         | 0.39          | 20151          | 5.34         | 31.6         | 41.35        |
| Case 2  | 44.55        | 2.95          | 7.82          | 0.73         | 0.35          | 17202          | 11.56        | 32.1         | 43.16        |
| Case 3  | 41.24        | 2.76          | 8.07          | 0.69         | 0.34          | 15727          | 14.7         | 32.4         | 44.06        |

Table 2. Characteristics of coal ash

| Project | Unit | Case 1 | Case 2 | Case 3 |
|---------|------|--------|--------|--------|
| DT      | ℃    | 1405   | 1295   | 1250   |
| ST      | ℃    | 1445   | 1355   | 1355   |
| FT      | ℃    | >1500  | 1355   | 1355   |
| SiO<sub>2</sub> | %   | 63.35  | 63.16  | 56.57  |
| Al<sub>2</sub>O<sub>3</sub> | %   | 22.11  | 18.68  | 18.21  |
| Fe<sub>2</sub>O<sub>3</sub> | %   | 3.4    | 6.06   | 8.54   |
| CaO     | %    | 7.78   | 1.58   | 3.74   |
| MgO     | %    | 0.77   | 1.85   | 2.16   |
| SO<sub>3</sub> | %   | 0.78   | 1.13   | 2.43   |
| TiO<sub>2</sub> | %   | 0.78   | -      | -      |
| P<sub>2</sub>O<sub>5</sub> | %   | 0.42   | -      | -      |
| K<sub>2</sub>O | %   | 1.4    | 3.21   | 2.7    |
| Na<sub>2</sub>O | %   | 0.5    | 1.41   | 1.05   |

In the formula, φ is the variable to be solved (eg u, v, etc.). The left side is the non-stationary term and the convective term, the right is the diffusion term, the source term, the gas-solid interaction.

There are three kinds of NO generation mechanism: thermal type NO, fuel type NO and rapid type NO. In the combustion of coal-fired boiler, the rapid concentration of NO is relatively low and can be omitted. This article only consider the heat type NO and fuel type NO.

3. Mathematical model
The turbulent flow between gas-solid two-phase is used to calculate the turbulence model of RNG $k-\varepsilon$ model. The trajectory field of pulverized coal particles is based on Lagrangian random particle orbit method. Radiation heat transfer was calculated by discrete propagation method; double parallel reaction model was adopted for the release of pulverized coal volatiles; gas phase mixed combustion was described by mixed fraction model; diffusion kinetic model was used for coke combustion; Lagrangian method was used for calculation of particle phase.

Differential equation of general form is:

$$\frac{\partial (\rho \phi)}{\partial t} + \frac{\partial (\rho V_j \phi)}{\partial X_j} = \frac{\partial}{\partial X_j} (\Gamma \frac{\partial \phi}{\partial X_j}) + S_\phi + S_{\rho\phi}$$

Here are unsteady term and convection terms on the left, and particles of the interaction by diffusion term, source item, and gas-solid flowing on the right.

4. Boundary conditions

All vents are using the first boundary condition, which are given the speed and temperature. Outlet boundary is selected pressure outlet boundary condition. Solid wall treatment uses the wall function method. The temperature boundary is given the temperature.

5. Numerical simulation results compared with the experimental results

5.1. Temperature field

Burning lignite furnace temperature field in the unit is under full load. From the analysis of Table 3, after burning lignite, the temperature field of the lower burner of the furnace significantly increases, and upper furnace flue gas temperature decreases slightly. Blending with 30% of the lignite, in the main burner zone the temperature of flue gas rise an average of 25~46°C from the elevation of 15m (the lower part of the burner) to elevation 23.5m (D, E layer burner middle); Temperature of gas falls by an average of 33~42°C for the furnace from top elevation 34.4 m (burn-out of the top outlet) to 39m (the lower part of furnace arch).

| Elevation | Case | Unit | #1  | #2  | #3  | #4  | Average |
|-----------|------|------|-----|-----|-----|-----|---------|
| 49m       | 0%   | °C   | 1194| 1194| 1195| 1195| 1195    |
| 30%       |      | °C   | 1158| 1158| 1160| 1144| 1152    |
| 50%       |      | °C   | 1160| 1160| 1163| 1128| 1146    |
| 0%        |      | °C   | 1195| 1195| 1190| 1180| 1185    |
| 37.2m     | 30%  | °C   | 1126| 1128| 1127| 1124| 1126    |
| 37.2m     | 50%  | °C   | 1145| 1146| 1149| 1150| 1150    |
| 0%        |      | °C   | 1265| 1370| 1355| 1430| 1380    |
| 26.5m     | 30%  | °C   | 1435| 1454| 1460| 1474| 1456    |
| 50%       |      | °C   | 1441| 1465| 1431| 1467| 1451    |
| 0%        |      | °C   | 1290| 1250| 1390| 1320| 1313    |
| 23.5m     | 30%  | °C   | 1434| 1298| 1376| 1328| 1359    |
| 0%        |      | °C   | 1421| 1394| 1350| 1302| 1367    |
| 15m       | 0%   | °C   | 1300| 1265| 1255| 1255| 1265    |
As can be seen from the figure, the cross-section temperature of the burner is symmetrically distributed, and the temperature is highest at the center of the cross-section of each layer, and the center can reach 2000K, which is because the central region is the main combustion zone. The temperature at the inlet is low, but due to the swirling flow, the flue gas is returned, coupled with the high pulverized coal concentration and oxygen concentration and their uniform mixing, the pulverized coal is quickly mixed with the secondary air after being ejected from the primary air jet. Therefore, the volatile coke is rapidly ignited and burned, the temperature gradient is large, the temperature rises rapidly, and the temperature quickly rises above 1000K. It is much higher than the ignition temperature of pulverized coal. This also reflects a feature of the hedge boiler, which is fast. In the burner zone, the temperature gradually increases from the lower burner to the middle to the upper burner. The temperature distribution is uniform along the width of the furnace. Because the front and rear wall outlet airflow collided and washed the side wall, the side wall temperature was higher, and some reached 1490K, exceeding the melting point temperature of coal ash 1323K. It is easy to cause wall coking and high temperature corrosion. This is caused by the velocity field distribution and the oxygen field distribution. The front and rear walls are fine because the axial velocity of the exit airflow is not so large that it flushes the opposite wall. The temperature of the side wall is higher than the front and rear walls, and it is necessary to pay attention to the possibility of slagging on the left and right walls and high temperature corrosion.

5.2. CO and O2 concentration furnace

Figure 4 shows the oxygen field distribution of the cross-section of the lower burner and the cross-section of the middle burner. It can be seen from the figure that the oxygen is symmetrically distributed.
distributed, the oxygen gradient at the outlet is large, and the oxygen concentration in the center is lower than the wall surface. This is because the center is the main combustion zone. As the fuel burns, oxygen is consumed in large quantities. When it reaches the middle, most of the oxygen is consumed and the oxygen concentration is basically zero. The oxygen concentration near the left and right walls is low, showing a reducing atmosphere, which tends to lower the ash melting point. Therefore, there is a high possibility of slagging and high temperature corrosion. This is verified in the latter temperature field distribution. Figure 4 is a diagram showing the longitudinal section oxygen content of the furnace. The hurricane section is burned in the height direction side, and the average oxygen concentration is the lowest, and then the oxygen concentration is increased due to the addition of excess air by the smoldering wind.

6. Conclusions

- The overall temperature will decline after burning with lignite and will be difficult to produce large area of slagging. The simulation results coincide with the experimental results.
- As the lignite has high volatile, the burning time of carbon will be shortened when blended with lignite, coming into being high temperature area near the spout, and it can easily lead to slag.
- After burning with lignite, due to its high volatile, the burning time of the powdered coal will move up, causing the temperature of main burner area quickly going up, and the furnace exit flue gas temperature decreases.

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