Research on the numerical simulation of secondary air diffusion angle to the swirl burners combustion process

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Abstract. In this paper, the combustion process of swirl burners during 660 MW unit power plant is simulated. The influence of secondary air diffusion angle on the furnace temperature and furnace slagging is studied. In detail the temperature field and the carbon concentration field and velocity field inside the furnace are analysed when the secondary air diffusion angle is set as 30°, 45° and 60° respectively. The simulation results show that when the secondary air diffusion angle is set as 30°, the center temperature of the furnace is highest, and at this time the pulverized coal combustion is sufficient, the carbon concentration near the water wall is the lowest, moreover, it is not easy to slag in the furnace. With the increase of secondary air diffusion angle, the center temperature of boiler burning zone gradually decline, carbon concentration near the water wall increase, it is the more prone to coking inside the furnace. The numerical simulation results not only provide a reference basis for the boiler operation, but also provide an important reference value for exquisite combustion research of the boiler.

1 Introduction
The problem of pulverized coal furnace slagging in thermal power plant is very common, if the degree of slagging is light, it would affect the heat transfer and reduce the efficiency of the boiler, if the degree of slagging is heavy, it would cause serious security issues which is not planned. Slagging is a very complex physical and chemical process, it involves in gas-solid multiphase turbulent transportation, boiler air distribution, the distribution of velocity field, temperature field which all will affect the slagging. Boiler slagging can cause serious consequences which are incalculable, so in order to realize the safe, stable and economic operation of the boiler, it is essential to prevent and reduce boiler slagging. Along with the rapid development of computer technology, computational combustion theory and computational fluid dynamics, calculation of heat transfer and other subjects in computer assisted also obtain fast development. Current research in the boiler furnace combustion process is no longer limited to traditional method, but also can use computer based on computational fluid dynamics method which is used to numerically simulate and calculate combustion process of the boiler furnace. By the method, a lot of effective data in a short period of time can be obtained, and the flow of the air in the boiler, the heat transfer process and combustion process in the furnace also can be simulated, which can provide a powerful reference for boiler operation and modification of manufacturing, and also is very important reference value for engineering application[1-4].

The results to carry out the numerical simulation aimed at the whole boiler will have good warning effect on boiler emissions of pollutants and furnace slagging situation. Hence, in this paper, when the secondary air diffusion angle for swirl burners of 660 MW unit boiler is changed, the influences of the temperature and slagging inside the boiler furnace will be analyzed in numerical simulation below.
2 Combustion equipment
Take the 660 MW unit boiler furnace of front and back wall opposed swirl burners for a numerical simulation object. The boiler is 15456.8 mm in length, 19419.2 mm in width and is 40000.0 mm in height. The structure of boiler furnace is the shape of rectangular, the number of burners is a total of 24, burners are arranged on the front wall and back wall. Each of front wall and back wall which are installed 12 burners respectively are divided into three layers, each layer of the boiler is installed 4 burners. The layout schematic diagram of front wall burners is shown in Figure 1.

![Figure 1: The layout schematic diagram of boiler front wall burners](image)

3 Calculation area and meshing
Calculation area includes the whole furnace, according to the actual structure size of the boiler and burners in the furnace area the computational grid is divided. Considering parameters change of the flow in the burner region and reaction process significantly the density of grid is increased in the furnace of the vicinity of the burner. Above the burner and the following region of the furnace, mesh size will be enlarged gradually in order to achieve a smooth transition of the grid size. The type of grid mainly is the shape of tetrahedral pyramid and wedge.

4 Mathematical model
The combustion of pulverized coal in the boiler is an extremely complex physical and chemical process, the whole process of which contains a variety of physical and chemical phenomena, so a simplified model of a lot of physical and chemical process needs to be established when the numerical calculation is done for the whole furnace including the gas-solid phase flow model of turbulent gas phase flow model, the radiation heat transfer model and so on. The process of the second blast with a wind entrainment of pulverized coal air flow through the movement of the burner into the furnace is a turbulent gas flow, there are many kinds of fluid motion state, the turbulence is one of them. This article uses realizable k-ε model to simulate the process of boiler in the gas phase turbulent, random trajectory model is applied to the orbit-tracking of pulverized coal, P1 radiation model is used for radiation heat transfer model, which can well describe the radiation heat transfer between coal particles and gas. SIMPLEC algorithm is used during calculation process. In the process of simulation, only the gas-solid two-phase flow is considered. The way of pulverized coal particles entering the boiler from the primary air duct is surface, the speed is the primary wind speed, and the particle size distribution of pulverized coal particles satisfies the Rosin-Rammler formula.

5 Numerical simulation results
In the swirl burner, the air out of the secondary air tuyere is rotary jet flow, under the full load operation of the boiler, the primary air wind speed of numerical simulation is set as 25 m/s, secondary
air wind speed is set as 35 m/s, when the secondary air diffusion angle is set as 30 °, 45 ° and 60 ° respectively, how the temperature distribution, carbon concentration distribution and velocity of the first column boiler burner longitudinal section are distributed. The temperature distribution of the first column boiler burners longitudinal section is showed from left to right in Figure 2 as the secondary air diffusion angle of 30 °, 45 °, 60 °. The carbon concentration distribution of the first column boiler burner longitudinal section is showed from left to right in Figure 3 as the secondary air diffusion angle of 30 °, 45 °, 60 °. The velocity distribution of the first column boiler burners longitudinal section is showed from left to right in Figure 4 as the secondary air diffusion angle of 30 °, 45 °, 60 °.

Figure 2: The temperature distribution of the first column boiler burners longitudinal section as the secondary air diffusion angle of 30 °, 45 °, 60 °

According to Figure 2 that illustrates the temperature distribution of the first column boiler burners longitudinal section, the primary air wind outlet of the burner exists a partial low temperature zone that is called the black dragon area begins in a wind vents, and then gradually disappears inside the furnace. The temperature field inside the furnace is an axially symmetric distribution, the temperature of the top burner in the center of the furnace is highest. When secondary air diffusion angle is set as 30 °, 45 ° and 60 °, the upper center temperature of furnace respectively is 2160 K, 2080 K and 2080 K. It is showed that with the increase of secondary air diffusion angle, the center temperature of the furnace at the top layer burners reduces, the efficiency of pulverized coal combustion in the furnace declines.

Figure 3: The carbon concentration distribution of the first column boiler burners longitudinal section as the secondary air diffusion angle of 30 °, 45 °, 60 °
Figure 4: The velocity distribution of the first column boiler burners longitudinal section as the secondary air diffusion angle of 30°, 45°, 60°

According to Figure 3 and Figure 4, imperfect combustion of pulverized coal exists around the burners and vents and near the water wall, which makes clear that pulverized coal are mixed with ash. The collision of the secondary air between burner outlet and adjacent burner outlet leads to the convergence of the location of the secondary air in the middle of the adjacent burner and the movement of the secondary air toward the furnace center, the phenomenon that airflow beats the furnace wall happens. With the increase of secondary air diffusion angle, aggravate the phenomenon that the airflow strikes the furnace wall, and increase the risk of furnace slagging.

6 Conclusion
Through the numerical simulation of the 660 MW unit boiler furnace of front and back wall opposed swirl burners, the effect of changing the size of secondary air diffusion angle on the temperature field distribution and furnace slagging is studied. The conclusion is that: with the increase of secondary air diffusion angle, the temperature of the central combustion zone of the boiler decreases gradually, and the carbon concentration near the water wall increases gradually, and the bigger the diffusion angle is, the more easily the slagging is. When the secondary air diffusion angle is between 30° and 45°, the combustion of pulverized coal in the furnace is sufficient, the carbon content near the water wall is lower, and the slagging is lighter. When the secondary air diffusion angle reaches 60°, the slagging quantity of water wall increases gradually, and the combustion efficiency of pulverized coal decreases. The numerical simulation results not only provide a reference basis for the boiler operation, but also provide an important reference value for exquisite combustion research of the boiler.

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