Journal of Applied Science and Engineering Innovation, Vol.2 No.4, pp.126-129
ISSN (Print): 2331-9062
ISSN (Online): 2331-9070

Numerical Simulation of Low NOx Combustion Process of 200MW Boiler

Qingshan Yuan[1], Lei Li [1] and Changjin Wang[1]

[1] *Department of Petroleum and Chemical Engineering, Northeast Petroleum University,Qinhuangdao,Hebei066004, China*

Abstract: Based on the NH3 oxidation rule and domestic and foreign scholars' researches on the power station boiler's low NOx combustion and SNCR denitration technology, the overall reaction model is adopted to run the numerical simulation of air-staged low-nitrogen combustion of a 200MW power station boiler with the help of Fluent software platform. Finally, the furnace temperature and the concentration distribution of O2, CO and NO are obtained respectively through the calculation.

Keywords NOx combustion; Overall reaction; Furnace combustion; Numerical simulation

INTRODUCTION

Currently, the NOx control technologies for coal-fired power station boiler fall into two kinds: low NOx combustion technology and flue gas denitrification technology. The air-staged combustion is the low NOx combustion technology, and SNCR is the flue gas denitrification technology.

The air-staged combustion refers that the air for combustion is injected into the furnace after being divided into two parts along the furnace height direction. First, the air of 80~90% in the total amount is ejected into the primary combustion zone to make the fuel burn in the oxygen-deficient state. As the burning velocity and combustion temperature of the fuel are reduced accordingly, a large amount of CO is generated to form the reducing atmosphere. Meanwhile, N in the fuel is decomposed to generate a large number of intermediate products such as NHi. Under the reducing atmosphere, such substances as NHi lead to the reduction of generated NO, inhibiting the generation of the fuel NOx. The remaining air is sent to the upper portion of main combustion zone of the furnace in the form of over fire air to make the fuel burn completely under the condition of excess air. Although the burning in this zone belongs to the oxygen-enriched combustion, the thermal NOx is not easy to generate because of low combustion temperature [1] .

For the air-staged combustion technology, the investment and operating costs are relatively low, and the denitration efficiency is moderate. In the operation, it is generally affected by some factors, such as coal type, excess air coefficient in the main combustion zone, level of temperature in the main combustion zone, entering location of overfire air and boiler load [2]. In addition, the fume temperature at the furnace exit increases, the loss of incomplete combustion increases, and the phenomena such as high temperature corrosion and slagging appear on the surface of water cooled wall [3]. In view of them, when the air-staged combustion technology is adopted, various factors should be taken into account in order to obtain the desired denitration effect.

MODEL ESTABLISHEMNT

Geometric Model

The HG-670/140-11 boiler is laid out in the Π-type shape, which is characterized by ultra-high pressure, intermediary reheat, natural circulation, single-stage evaporation, large-diameter concentrated down flow pipes and solid slag. It is equipped with the ball mill coal pulverizing system with intermediate storage bunker. It works with two DTM350/700 steel ball mills. It has the furnace with the height of 41.1m and cross section of 11.66m×11.66m, which is shown in Figure 1. The fuel for boiler is the coal blended in the ratio of 1:1 between Hegang's bituminous coal and Dayan NO. 2 Coal Mine's brown coal.

Meshing

Figure 2 is the grid structure encrypted through ICEM, which uses ICEM's Y-type mesh structure to process the gridded zone with lower quality. The result after being processed is shown in Figure 3.The grids reach up to about 720,000 in number after the final division.

Mathematical Model

The pulverized coal combustion process is a two-phase turbulent flow process which is accompanied by a variety of heat transfer phenomena and chemical reactions. In the simulation of the combustion process,

Corresponding Author: Qingshan Yuan, Department of Petroleum and Chemical Engineering, Northeast Petroleum University ,QingHuangDao, Hebei066004, China

it is necessary to establish various simplified models of physical and chemical processes.

(1)The gas phase flow generated by pulverized coal combustion is the strong turbulence, so the achievable k-ε two-equation model can be used as it is easy to use.

(2)For the movement of pulverized coal particles in the flue gas and the coupling calculation with the gas-phase, the stochastic model is used [4], which has one main advantage: simple calculation. When the particles have more complex changes, it can better track the movement of particles and false diffusion cannot generate in the numerical computation. Meanwhile, the impact of fluid turbulent fluctuation on the particles is considered.

(3)The double-step competition reaction model proposed by Kobayashi is used to simulate the pyrolysis process of coal.

(4)For the combustion of coke, the diffusion power control combustion model is used.

(5)For the radiation model, the P-1 radiation model is selected.

(6)In the pulverized coal combustion process, the NOx generation simulation is calculated with the post-processing method. In the calculation, the thermal NOx and fuel-type NOx are considered, ignoring the rapid-type NOx.

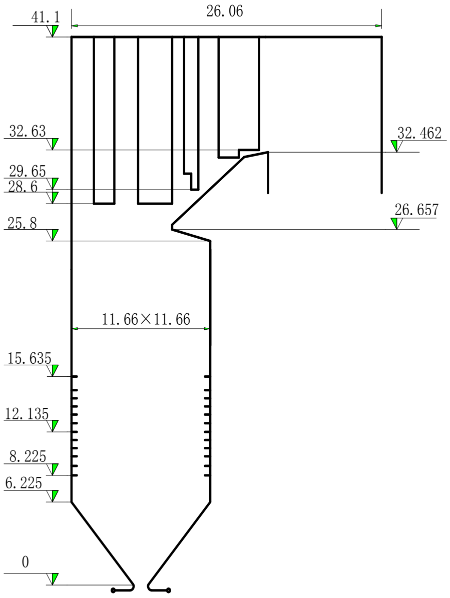

Figure 1. Furnace Structure Diagram

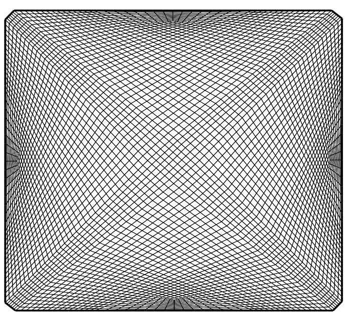

Figure 2. Grids after ICEM Processing

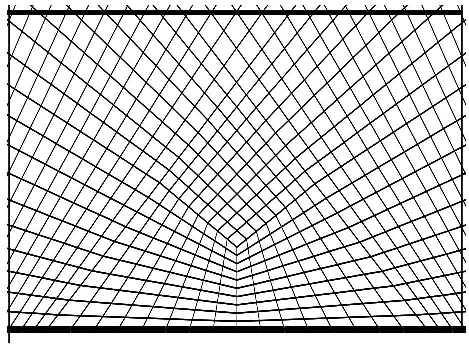

Figure 3. Amplified Schematic Diagram of Grids in the Adherence Zone

Boundary Conditions

(1)Inlet boundary conditions. The velocity inlet boundary conditions are used at each nozzle: the velocity direction is perpendicular to the nozzle plane; the temperature is the same as air temperature; the hydraulic diameter and turbulence intensity are set.

(2)Outlet boundary conditions. The pressure outlet boundary conditions are used at the rear of boiler. But for the pressure outlet boundary conditions, the static pressure must be specified at the outlet boundary, which is only used for pressure of sonic flow. In the calculation, the outlet static pressure is -50Pa.

(3)Wall boundary conditions. For solid walls, the speed-free slip and mass-free penetration conditions are used, that is, $\Phi = 0$.

NUMERICAL ANALYSIS

Combustion Process Simulation

The cold-state flow field in the furnace is calculated. Figure 4 is a cloud chart of speed for the horizontal section of secondary air nozzle center. Figure 5 is a locally amplified schematic diagram of flow field at the No. 1 corner.

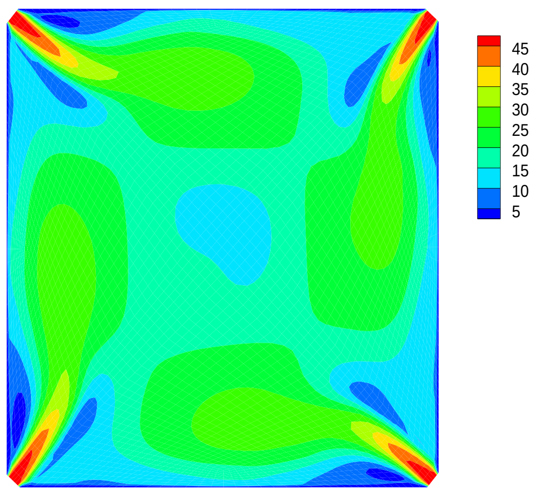

Figure 4. Cloud Chart of ICEM Grid Speed

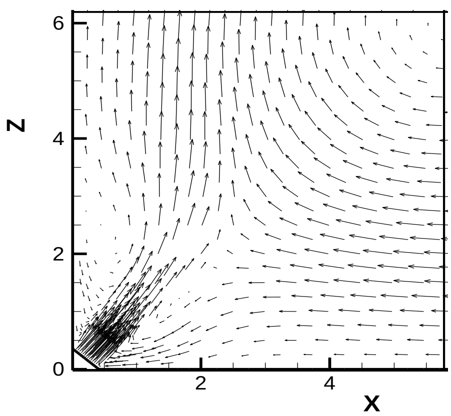

Figure 5. A Locally Amplified Schematic Diagram of Flow Field at the No. 1 Corner

Furnace Temperature Distribution

Figure 6(a) shows the general change rule of furnace temperatures: the furnace temperature rises along the furnace height direction first and then falls gradually. The burner zone in the furnace has the highest temperature. Due to the continuous injection of pulverized coal stream, the heat released in the pulverized coal combustion is more than that absorbed by the furnace wall, which leads to continuous rise in the furnace temperature and even the locally highest temperature of up to 1900K. After that, with the continuous burning of pulverized coal, the temperature begins to drop. When the flue gas reaches over the furnace arch throat, not only the furnace wall absorbs the heat, but also there are strong heat convection and heat radiation between the heating sides of superheater and flue gas. So, the rate of decline in the flue gas temperature increases.

O2 Concentration Distribution in the Furnace

As can be seen from Figure 6(b), the concentration of O_2 at the secondary air nozzle is the highest, and the concentration of O_2 decreases gradually with the shortening of distance from the furnace center. As the pulverized coal jet flow at the center of furnace forms the tangential firing, in the rotating mixture and combustion process of pulverized coal and O_2, the mixed gas flow is difficult to reach the center of furnace; that is, the main zone of pulverized coal combustion is not the center of furnace. Therefore, the concentration of O_2 at the center of the furnace is relatively lower.

CO Concentration Distribution in the Furnace

As can be seen from Figure 6(c), CO is mainly centralized in the burner zone. In this zone, as the effect of mixing with air is not good, the reducing atmosphere is easily formed, which leads to the generation of CO. As the pulverized coal burns while rotating, it is difficult to reach the center of the furnace; so, there is less CO in the center of furnace. With the increase in the furnace height and gradual decrease in the concentration of CO, the concentration of CO at the furnace arch throat has tended to zero. As the temperature over the burner zone is still high, CO in the flue gas reacts with O_2, generating CO_2.

NO Concentration Distribution in the Furnace.

As can be seen from Figure 6 (d) are, NO is generated mainly in the burner zone, and NO concentration in the local zone can reach up to 450ppm.Due to the rotational movement of pulverized coal flow, the pulverized coal burned in the furnace center is relatively little, so the NOx concentration nearby the furnace center is lower compared to that close to the burner nozzle. With the increase in the furnace height, the turbulent diffusion of flue gas tends to be uniform, and the concentration of NO becomes stable gradually. From the screen area, the concentration of NO is basically stable.

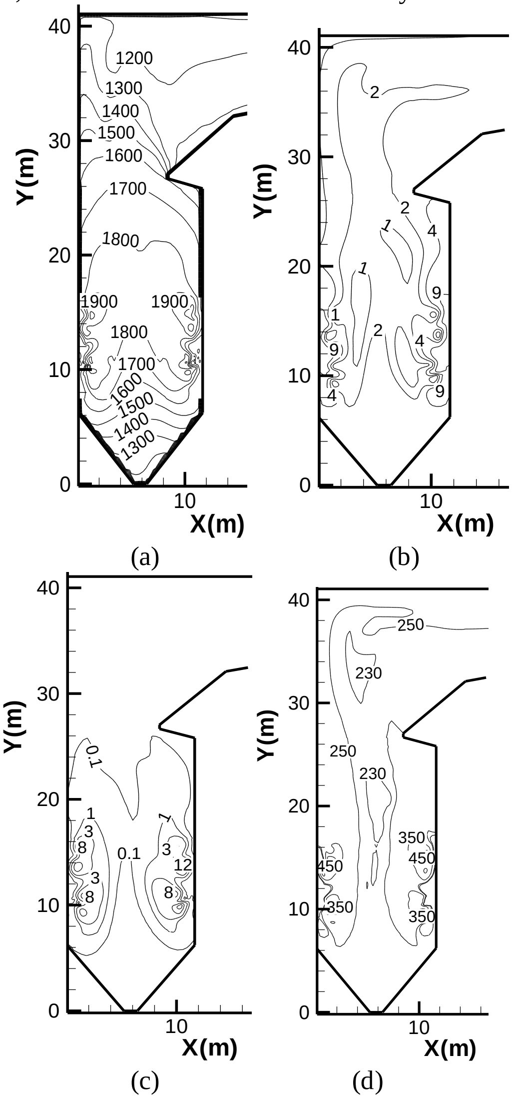

Figure 6. Furnace Parameters Distribution

a. Furnace Temperature Distribution
b. O_2 Concentration Distribution in the Furnace
c. CO Concentration Distribution in the Furnace
d. NO Concentration Distribution in the Furnace

CONCLUSION

With the help of fluent software, the numerical simulation of low NOx combustion process of a 200MW Tangentially Fired boiler is performed based on the proper selection of mathematical model and exact grids. Finally, the furnace temperature and the concentration distribution of O2, CO and NO are obtained respectively through calculation.

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