

Numerical and Experiment Study on the Effect of SOFA Wind on NOx Distribution in Furnace

Qian Wang^{1,a}, Yongjun Xia^{1,b}, Fasheng Liu^{1,c}, Yongqiang Deng^{1,d}

¹State Grid Jiangxi Electric Power Company Electric Power Research Institute, Nanchang, China
330096

^aqian_0108@126.com, ^bxiay_jun@163.com, ^cShengfaliu@163.com, ^djxncdyq@126.com

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Abstract: In this paper, an experimental study and numerical simulation method was combined to research the impact of a power plant 600MW supercritical four walls tangentially fired boiler furnace OFA wind opening size on the inside furnace NOx concentration distribution and the results coincide. There are four Cases in all. The influencing factors and forming rules of NOx that was produced by pulverized coal furnace during combustion processes were analyzed.

Introduction

The pulverized coal combustion in the furnace is a very complex physical and chemical process. In recent years, many countries have made great progress in the numerical calculation of the combustion process especially in the basic numerical methods, theoretical models, computer programs and software development. It is of great practical significance to study on the numerical stimulation of the boiler furnace and has become one of the important means of boiler operation and design. It's very important to study the application value of this method in engineering.

At present, the NOx concentration emission standards of the coal-fired power plant in China have become more stringent. Therefore the domestic research in the furnace NOx emissions are increasing, low NOx concentration combustion air classification is the most commonly used combustion technology. In this paper, the influence of SOFA wind on the NOx concentration distribution of 600MW supercritical coal - fired boiler was analyzed by experiment and numerical simulation.

Simulate Objects and Methods

Simulation Object

This article's mock object is a # 2 boiler in a power plant and was independently developed by Harbin Boiler Co., Ltd. It is the HG-1964 / 25.4-YM17-type wall-type cutting-fired supercritical boiler. This boiler is a middle reheat, supercritical pressure transformer running with built-in recirculation pump to start the system of the boiler, single furnace, balanced ventilation, solid slagging, open-air layout of the π -type boiler. It uses medium-speed grinding straight-blown powder system and each furnace with 6 HP1003 bowl-type medium-speed coal mill. There are five boilers running and one boiler standby when burning with the design coal. The structure of the diagram shows on Fig.1.

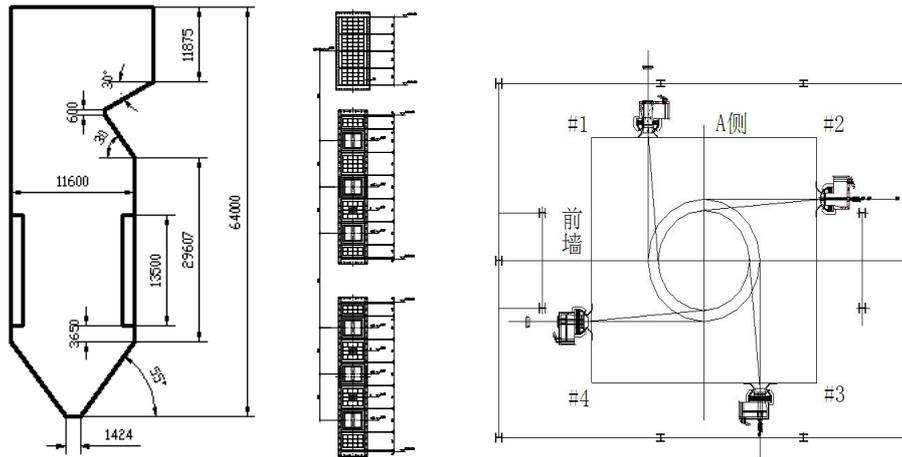


Fig.1 The Structure of the Furnace Burner Size and Layout Diagram (Unit: mm)

Mathematical Model

In this paper, we use non-premixed combustion model. The turbulence transport was simulated by the standard turbulence model, the P-1 radiation model was used to calculate the radiation heat transfer. It uses the double matching rate model to release the volatiles of pulverized coal. The SIMPLE method is used to solve the gas flow field, and the random particle orbital model is used to solve the solid particle phase. It uses the orthogonal non-uniform staggered grid, and the grid element on the control volume method for the differential equation discrete, the general form of the differential equation is:

$$\frac{\partial (rf)}{\partial t} + \frac{\partial (rV_j f)}{\partial X_j} = \frac{\partial}{\partial X_j} \left(\Gamma_f \frac{\partial f}{\partial X_j} \right) + S_f + S_{pf}$$

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.

Simulated Cases and boundary Cases

All nozzles use the first type of boundary Cases, with given the speed and temperature. The boundary of the export boundary is the boundary Case of the pressure outlet. The solid wall is treated by the wall function method. The temperature boundary is given temperature,

The primary air's temperature is 80 °C, secondary air's temperature is 332 °C. It mainly simulates the effect of SOFA wind opening size on the distribution of NOx concentration in the furnace. The test of the furnace temperature field under various Cases is carried out under the full load of the unit. There are four simulated cases, in total and the cases of the parameters are shown in Table 2 below. The industrial analysis and elemental analysis of coal are shown in Table 1 below.

Table 1 Analysis of coal quality and industrial analysis

Elemental analysis (%)					Industry Analysis (%)			
C _{ar}	H _{ar}	O _{ar}	N _{ar}	S _{ar}	Q _{net.ar} (kJ/kg)	M _{ar}	A _{ar}	V _{ar}
52.33	3.36	5.12	0.86	0.59	21150	7.3	30.38	34.67

Table 2 Adjust the calculated operating Case parameter table

Project Case	Once wind rate (%)	Once wind speed (m/s)	Secondary air rate (%)	Secondary wind speed (m/s)	SOFA windshield opening (%)
Case 1	20	27	80	48	0
Case 2	20	27	75	45	30
Case 3	20	27	72	42	60
Case 4	20	27	70	40	100

Comparisons of Calculation Results and Test Results

Cross section temperature field analysis

Fig.2 shows the temperature field and the NOx concentration field profile for the lowest cross section of working Cases 1, 2, 3 and 4. From the temperature field and the NOx concentration field distribution of each working Case, the highest concentration of NO corresponds to the highest temperature on the flame jet, and the four Cases are basically the same. This is mainly because the pulverized coal enters the furnace to produce high-temperature heat generation type NO and fuel type NO, since a large amount of O₂ is consumed at this time, and a large amount of CO is generated, so the outside area of the flame center is a reducing atmosphere, part of the NO will be reduced to N₂.

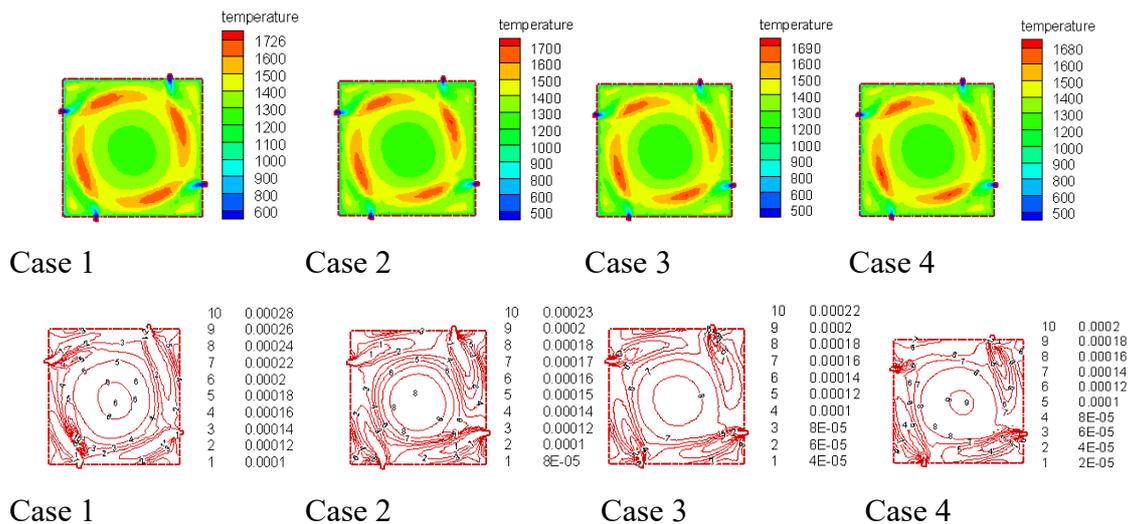


Fig.2 The temperature field and the NOx concentration field of the same cross section (y = 19.69m) under different operating Cases (unit: K/10⁶×ppm)

The opening size of the burning wind in casel1 is zero. At that time, the temperature of the cross-sectional level and the NOx concentration distribution are the highest among the four cases. It shows that the pulverized coal in the working Case 1 is mainly concentrated in the burner area and the oxygen is concentrated in the combustion zone. Cases 2, 3, 4 were added 30%, 60%, 100% of the burnout points respectively. We can see that both the lower section of the temperature field and

NOx concentration field have a certain impact. In particular, the difference between the working Case 1 and the working Case4 is larger, the maximum temperature difference is about 50°C, and the maximum difference of NOx concentration is 80 mg/m³. Therefore, it can be seen that the furnace temperature level and the level of NOx concentration are contradictory objects, to maintain a certain level of the furnace temperature is an important guarantee to ensure the efficiency of the boiler. So the size of the wind opening is the key to solve this problem, from the four operating Cases, the burning wind control in 20% to 50% is the ideal state. We should adjust the burning wind's opening size according to the different coal.

Analysis of longitudinal section temperature field

Furnace parameters of the test are carried out under the full load of the unit, We measured the temperature at each hole by using an infrared thermometer, the simulated value of the temperature and the measured value of the fire hole are about ± 4%, Which shows that the simulation results of the mathematical model have good accuracy and reliability.

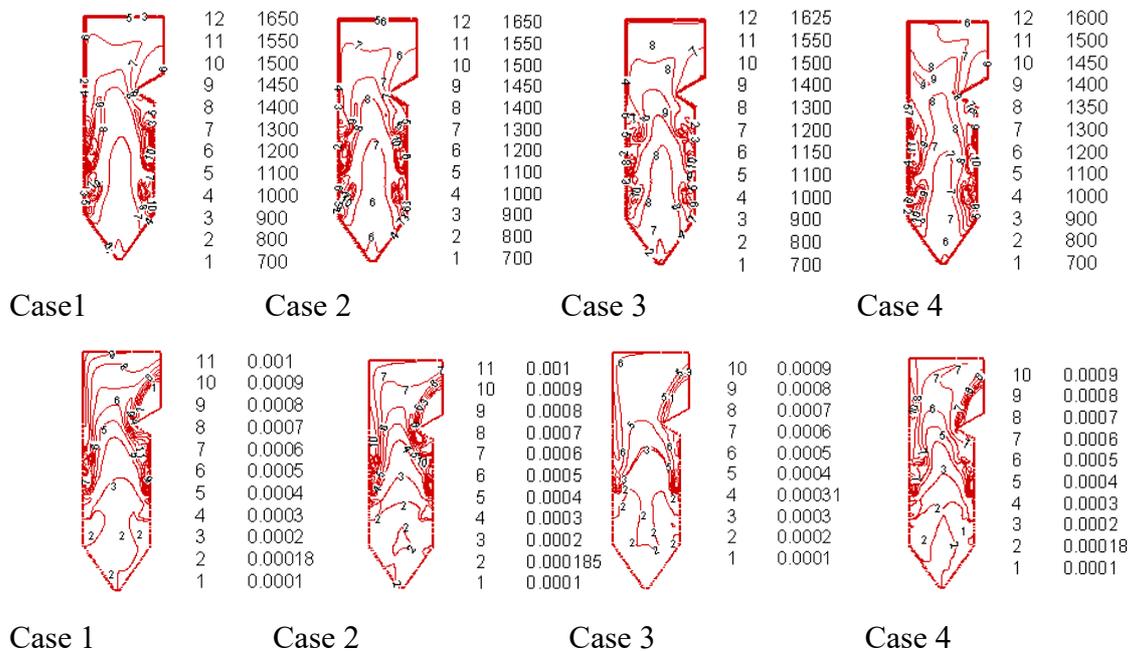


Fig.3 Temperature field and NOx concentration field of vertical center cross section of furnace (unit: K/10⁶×ppm)

Fig.3 shows the temperature field and the NOx concentration field distribution for the vertical center cross section of the furnace with four operating conditions. From the four operating conditions, the maximum temperature of the furnace is mainly distributed in the main burner area near the wall position, which is consistent with our test results. In this case, the corresponding NOx concentration field is also concentrated in this region. The temperature level of case1 is concentrated in the 1620K, NOx concentration concentrated in the 480 mg/m³ (the following are converted into 6% O², mg / Nm³). It indicates that case1 is mainly generating fuel type NOx and thermal type of NOx. The main burner area is filled with an oxidizing atmosphere and it is not conducive to the reduction of NO.

The temperature levels of case 2 and case 3 are mainly concentrated at about 1550K, and the concentration of NOx is concentrated at 430 mg/m³. These two conditions are mainly fuel-based NO. Because the temperature is below 1600K, so the heat generated NO is relatively low and can

be ignored. When the coerced air is added, the total air volume of the secondary air will be reduced in the main combustion area, resulting in a large amount of CO in this area, forming a reducing atmosphere, inhibiting and reducing the generation of NO. The temperature level is mainly concentrated at 1450K and the concentration of NO_x is concentrated at 410 mg/m³. It can be seen from the analysis of working case 4 that the NO_x concentration is maintained at a low level, but the temperature field is also maintained at a low level. It will affect the boiler furnace heat efficiency, so the wind should not open to the maximum wind.

From the analysis of the four operating cases, it can be seen that the NO concentration in the main combustion zone determines the final NO furnace outlet emission concentration. Case1 in the main combustion zone provides sufficient oxygen to support combustion of pulverized coal, the furnace temperature level is higher than the other three conditions. As it is in an oxidizing atmosphere, the thermal type NO and fuel type NO are more than the other three conditions. It indicates that the cases of 2,3,4 put into the exhaust air can effectively controlled the NO emissions. But it also affected the main combustion zone of the secondary wind speed and momentum, resulting in deterioration of the combustion state, affecting the boiler thermal efficiency.

Distribution Characteristics of NO_x in Furnace

Table3 shows the distribution characteristics of NO_x in the furnace outlet at four operating conditions. In the field test, we compare the measured data of the working condition with the numerical simulation data can be proved that their numerical simulation results are close, the deviation range is nearly 30 mg/m³ or so, which fully shows the numerical simulation results can be reliability and accuracy.

Table 3 NO_x and NO_x concentration deviation at the furnace outlet (unit: mg/ m³)

project	Case 1		Case 2		Case 3		Case 4	
A side	Dial data	Analog value						
	490	450	410	380	390	375	360	355
B side	Dial data	Analog value						
	460	415	440	400	385	360	380	350
deviation	Dial difference	Analog difference						
	30	25	30	20	5	15	20	5

Conclusion

1)Through the comparison and analysis of the four working conditions, it can be seen that the NO_x concentration distribution in the measured furnace is less than 10% of the simulated value, and the region with high NO_x concentration corresponds to the high temperature region, conforms to the NO_x generation mechanism, and the mathematical model simulation results have a certain degree of accuracy and reliability. It will guide the boiler operate safely and economically.

2)From the analysis of the above four conditions, we can see that with the increase of the opening degree of SOFA wind baffle, the emission of NO_x is curve. When the opening degree is 30%, the NO_x emission from the furnace outlet is relatively low. It is conducive to the burning of coal. With the high temperature in the furnace

when the opening degree of 70%, the furnace outlet NO_x concentration emissions is the lowest, but the furnace temperature level is relatively low, and it also partly affected the boiler thermal efficiency.

3) The effect of SOFA wind and secondary air volume on NO_x generation is very obvious from four working conditions. It can be seen that reasonable SOFA wind opening and reasonable secondary air ratio are very effective for reducing NO_x emissions.

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