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Comparative analysis of the influence of pulverized coal-fired boiler pollutant emission before and after retrofitting on air distribution device

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Abstract. Traditional energy coal is still one of the main power generation units in China, so in order to improve the thermal efficiency of boiler and reduce the emission of nitrogen oxide, this paper takes the 200MW tangent round boiler of a power plant as the research object. On the basis of the original boiler, the simulation analysis of the boiler before and after retrofitting is carried out under the condition of boiler maximum continuous rate (BMCR). The temperature field in boiler center position and the distribution of NO, CO in furnace before and after retrofitting is compared. Comparing with the curve of NO, it can be found that the concentration of NO at the outlet of the retrofitting boiler is lower than that of the former, and the effect of boiler retrofit is obvious.

1. Introduction

Overall, the development of the electric power industry is still highly dependent on coal, and status of coal in energy will not change. Therefore, how to use coal resources efficiently and environmentally is always the direction of the coal producers and researchers. In this paper, according to the actual size of the 200MW unit, modeling, grid division, cold simulation analysis and comparison analysis of boiler pollution emissions before and after retrofit are carried out by CFD software.

2. Boiler description and model construction

This paper takes the DG670/13.7-19 boiler of a thermal power plant as the research object. An introduction to the combustion area before retrofitting is shown in Figure 1. Among them, there are 8 secondary air layers including AA layer, AB layer, BB layer, BC layer, CC layer, CD layer, DE layer and EE layer, one layer of OFA compact exhaust air, and one layer of primary air has four layers of A, B, C, D. Figure 2 is the arrangement of the burner at the four corners of the furnace after retrofitting. The arrangement of the retrofitted burner is that DE secondary air is changed into X-X-1 Lower Tertiary air, EE secondary air is changed into X-X-2 Upper Tertiary air. Three separate exhaust winds were added to the OFA compact burn out wind.



OFA
E-E
D-E
D
C-D
C-C
B-C
B-B
B
A-B
A
A-A

Figure 1. Layout of burner at four corners of boiler before retrofit.

SOFA-3
SOFA-2
SOFA-1
OFA
X-X-2
X-X-1
D
C-D
C-C
B-C
B-B
B
A-B
A
A-A

Figure 2. Layout of burner at four corners of boiler after retrofit.

3D modeling software is used to establish the whole model of boiler before and after retrofitting. The boiler is divided from bottom to top into cold ash bucket region, main combustion area, separate combustion area and flame-angle region. because the reheater and platen superheater of the furnace have little effect on the combustion area, they are omitted. This paper mainly studies the combustion situation of the furnace itself, and does not consider the specific model of the burner, so the model of the burner is also ignored, only considering the position and shape of the burner. The final boiler entity model is shown in Figure 3[1].

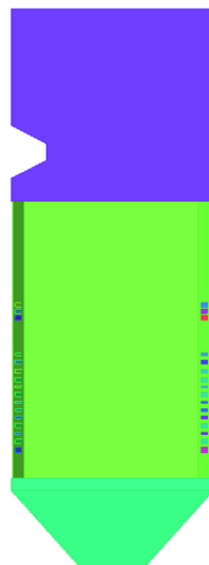


Figure 3. Three dimensional boiler model.

The meshing methods in this paper all adopt the hexahedral structural mesh division. In order to prevent the pseudo-diffusion in the simulated combustion process of the boiler, the Y-shaped mesh is used in the combustion area of the boiler. In order to improve the quality of the grid of whole boiler, the ICEM software is used to divide the grid. Firstly, the model is imported into ICEM to set the specific boundary condition name, then the structure mesh of hexahedron is constructed for several areas of furnace, the number of grids for the cold ash bucket is 170,000, and the number of grids for the flame angle area and the flue gas outlet is 310,000. The number of grids in the combustion area is 1.46 million, the total number of grids in the boiler is 1937468, and the number of grids in the main combustion area is 1.46 million [2]. Figure 4 is the internal mesh generation of the furnace. Figure 5 is the grid cross-section of the combustion zone.

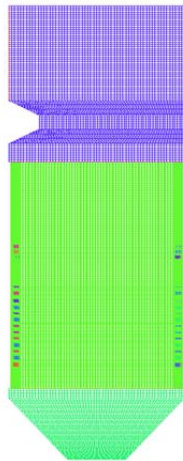


Figure 4. Integral mesh generation.

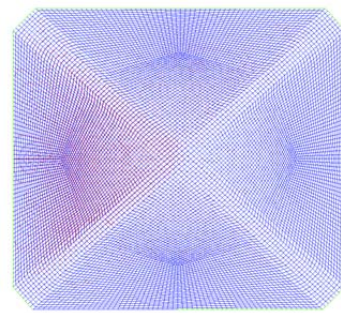


Figure 5. Grid cross-section of combustion zone.

3. Analysis and simulation of BMCR Conditions before and after retrofitting

In order to compare the combustion conditions before and after retrofit of boiler, the boiler was simulated and analyzed. Including the temperature field analysis of the boiler, the distribution analysis of CO at the secondary air position and the center position of the furnace, and finally, the concentration of nitrogen oxide in the center section of the furnace is analyzed.

3.1. Temperature field analysis

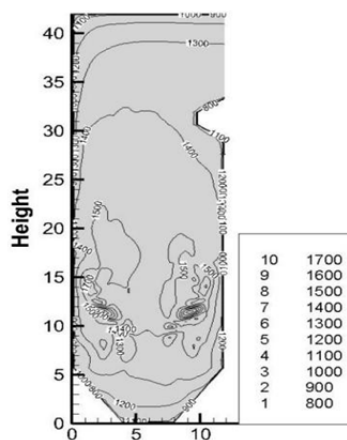


Figure 6. Temperature field of furnace central section before retrofit .

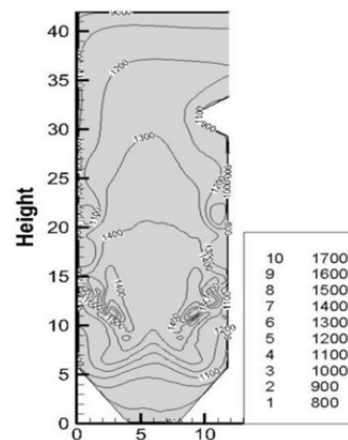


Figure 7. Temperature field of furnace central section after retrofit.

Figure 6 and Figure 7 are a comparison diagram of the temperature of the central section before and after the retrofit of the boiler air distribution device. It can be seen from the diagram that the temperature of the before retrofitted and after retrofitted boilers are distributed between 800K and 1700K, after the pulverized coal leaves the nozzle, the temperature increases rapidly and the maximum is about 1700k. The pulverized coal forms a symmetrical combustion in the boiler, which is consistent with the actual combustion process [3].

Figure 8 shows the variation curve of average temperature as a function of furnace height. It is concluded that the position of the third air nozzle of the modified boiler is between 15 and 20 meters. It contains small amount of pulverized coal, has high wind speed and a strong mixing effect on the combustion process of coal powder, and supplements the oxygen needed in the burnout stage. Due to its low wind temperature of about 350 K and much water vapor, the temperature in the furnace has dropped sharply from 15 meters to 20 meters. The change of flue gas temperature from 20 meters to 42 meters is relatively gentle. A small amount of pulverized coal and fuel gas in the combustion zone and tertiary air position is mixed and burned here.

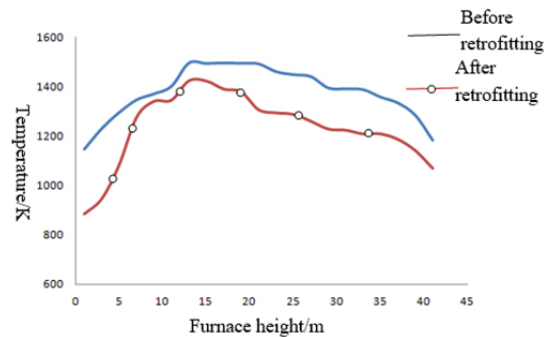


Figure 8. Average temperature variation curve in the direction of furnace height before and after retrofitting.

3.2. Analysis of CO distribution before and after retrofit at the location of exhausted wind and outlet

Figure 9, Figure 10, Figure 11 and Figure 12 show the mass distribution diagram of CO at the second floor of the boiler burnout air ($Z=SOFA3$) and the outlet section before and after the retrofit. The maximum mass fraction of CO is 0.0014 kg/m³ and the mass fraction of CO after retrofitting is 0.0025kg/m³. This is because the retrofitted boiler has added two layers of tertiary air on the original basis, and there will be a small amount of pulverized coal burning in the burnout area which leads to insufficient combustion and further oxygenation to CO₂ under the action of burnout wind. From the CO mass fraction distribution at the outlet, it can be seen from the cloud diagram that the distribution of CO mainly concentrated in the lower part of the outlet, close to the flame-angle position.

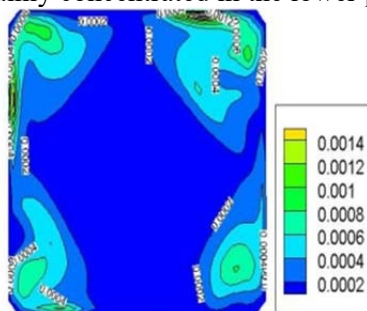


Figure 9. CO Distribution Diagram at $Z=SOFA3$ before retrofitting

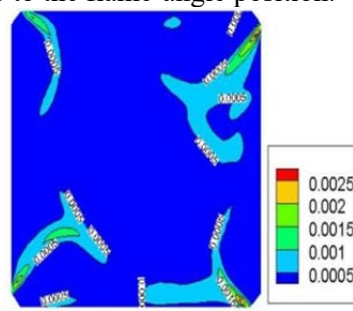


Figure 10. CO Distribution Diagram at $Z=SOFA3$ after retrofitting

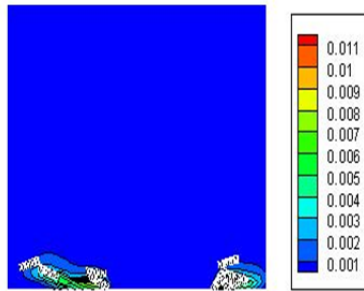


Figure 11. CO Distribution Diagram of exit Section of Furnace before retrofitting.

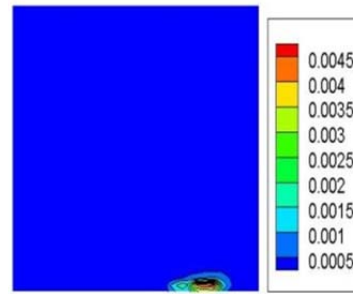


Figure 12. CO Distribution Diagram of exit Section of Furnace after retrofitting.

3.3. NO distribution of center section before and after retrofit

There are mainly two ways to generate NO_x in the combustion process of coal-fired boilers. One is the thermal type, the other is the fuel type. Fuel type NO_x accounts for more than 95% of total production, while thermal NO_x accounts for little. Fuel-type NO_x production is mainly due to the thermal decomposition of nitrogen-containing compounds and then being oxidized during process of combustion. It is decomposed mainly with intermediate volatile components such as HCN , NH_3 and CN . It is further oxidized to NO , which accounts for more than 80% of total nitrogen oxides. Therefore, this simulation mainly considers the distribution of NO [4].

Figure 13 is a broken line diagram of NO mass fraction of the central section of the furnace before and after transformation. After retrofitting, three layers of burnout air are added to the original furnace, which reduces the amount of distributed air in the main combustion zone, and produces a large amount of CO to restrain the formation of nitrogen oxides effectively in the incomplete combustion of the main combustion zone. With the increase of furnace height, the mass fraction of nitrogen oxide increases, the CO produced by combustion is insufficient and the amount of reduced nitrogen oxides is low, which results in the increase of NO mass fraction at outlet. The input of tertiary air above the furnace height is 17 meters, which brings a lot of water and reduces the average temperature of the furnace, and the ambient temperature of nitrogen oxides is reduced, and reduces the nitrogen oxides by reduced carbon produced by ultra-fine pulverized coal combustion [5].

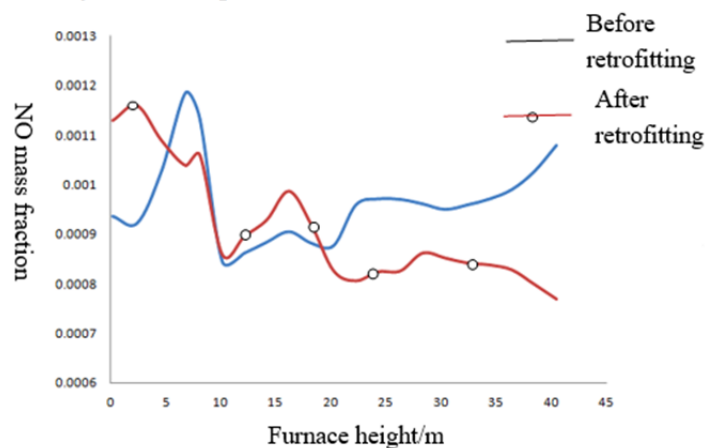


Figure 13. Mass fraction of NO in furnace central section before and after retrofitting.

4. Conclusions

On the basis of the original 200MW tangent round boiler, the position of the secondary air in the DE and EE layers has been changed to the tertiary air, and the three-layer separate exhaust air has been added to the upper part of the compact burning air. The BMCR simulation analysis of the boiler before and after retrofit was made. Comparing the temperature field at the center of the furnace, it can be seen that the pre-retrofitted boiler has a severe partial combustion phenomenon, the combustion temperature distribution in the furnace is uneven, and the outlet temperature of the furnace is higher. The temperature field distribution of the boiler after retrofitting is symmetrical. Comparing the CO concentration distribution of the burnout wind and the center section of the furnace, the comparative analysis shows that the maximum CO concentration after retrofitting is 0.0045, which is significantly lower than the concentration before the retrofitting. By comparing the mass fraction of NO in the furnace before and after retrofit, it can be known that the concentration of NO at the outlet of the retrofitted boiler is lower than that before the retrofit, and the effect of boiler retrofit is obvious.

The purpose of this study is to understand and master the process and its regularity of the retrofitted four-corner tangentially pulverized coal boiler, which provides a useful reference for improving boiler design, operation and retrofitting level.

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