Numerical Simulation of High Temperature Air Combustion Boiler

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Abstract

In order to study the influencing factors of NOx emission from tail flue gas of high temperature air combustion boiler, the NOx emission from biomass gasification combustible gas in different combustion conditions was compared. The numerical simulation results show that the high temperature air combustion technology has an obvious effect on the suppression of NOx emission. The emission of NOx in high temperature air combustion boilers increases with the increase of preheating temperature of combustion-supporting air. The reduction of O2 concentration in combustion-supporting air can effectively reduce the emission of NOx in the boiler, and because too low O2 concentration will not lead to a greater reduction of NOx emission, and will also make the flame combustion in the furnace unstable, so the selection of O2 concentration in combustion-supporting air is not the smaller the better.

Keywords

Biomass boiler; NOx emissions; high temperature air combustion.

1. Introduction

Energy plays an important role in economic development and social progress. If any country wants to achieve sustainable development, it must have enough energy to support it. However, the use of energy will inevitably lead to environmental pollution, which is a problem that economic development and social progress have to face[1,2]. High temperature air combustion technology refers to the combustion mode in which the exhaust heat of flue gas is ultimately recovered by regenerator, and the temperature of combustion-supporting air is heated to more than 800℃, so that the temperature of combustion-supporting air is higher than the ignition temperature of fuel, and the temperature difference of temperature field in boiler is lower than the preheating temperature. The advantages of high temperature air combustion technology lie in the diversity of fuels, which is in line with the trend of energy structure adjustment in China[3,4]. High temperature air combustion technology can not only utilize traditional fossil fuels with high calorific value, but also utilize low calorific value combustible gas produced by biomass or garbage gasification efficiently. When air is used as fuel gas, regenerative combustion system can raise the air temperature to the ignition temperature of gas combustion, and then stabilize the combustion condition of low calorific value gas[5,6]. Because of the small temperature difference of the temperature field in the boiler and the absence of high temperature zone in the furnace, the generation of thermodynamic NOx is restrained. In this paper, biomass gasification combustible gas is used as fuel to simulate high temperature air combustion.

2. Effect of Preheating Temperature of Combustion-supporting Air on NOx

Fig.1 shows the curve of NOx produced in the furnace when the preheating temperature of combustion-supporting air rises from 800℃ to 1200℃.

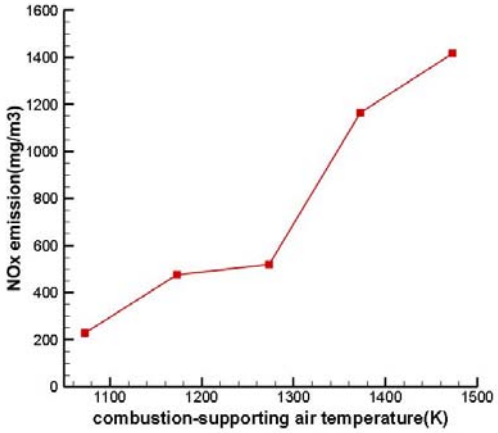

Fig 1. NOx Emission Curve of Combustion-supporting Air at Different Preheating Temperatures

It can be seen from Fig.1 that the emission of NOx in high temperature air-fired boilers increases with the increase of preheating temperature of combustion-supporting air. This is mainly due to the increase of preheating temperature of combustion-supporting air, which leads to the increase of temperature field in the furnace of high temperature air-fired boilers, and the increase of production of thermodynamic NOx leads to the increase of NOx emission. Moreover, when the preheating temperature of combustion-supporting air rises from 800℃ to 1000℃, the increase of NOx emission is relatively slow; when the preheating temperature of combustion-supporting air rises from 1000℃ to 1100℃, the NOx emission increases sharply; and when the preheating temperature of combustion-supporting air rises from 1100℃ to 1200℃, the increase of NOx emission becomes slower again. The main reason is that the generation of NOx in the furnace of high temperature air combustion boiler is mainly thermodynamic NOx, while the generation of thermodynamic NOx has a critical temperature. When the preheating temperature of combustion-supporting air is below 1000℃, only a small part of the high temperature zone in the high temperature air combustion boiler reaches the critical temperature, so the production of thermodynamic NOx is low and the emission of NOx is low. The quantity increases slowly with the increase of preheating temperature of combustion-supporting air. When the preheating temperature of combustion-supporting air reaches above 1100℃, most of the temperature fields in the furnace reach the critical temperature. At this time, the production of thermodynamic NOx rises sharply, which leads to a sharp increase in the emission of NOx in the temperature range of 1000℃~1100℃.

3. Effect of O2 concentration in combustion-supporting air on NOx

Fig.2 shows the curve of NOx produced in the furnace when the concentration of O2 in combustion-supporting air decreases from 21% to 9%.

It can be seen from the figure that the emission of NOx in high temperature air-fired boilers decreases with the decrease of O2 concentration in combustion-supporting air. There are two main reasons. Firstly, the decrease of O2 concentration in combustion-supporting air can significantly reduce the average temperature in the furnace of high temperature air-fired boilers, thus inhibiting the generation of thermodynamic NOx in the furnace; secondly, the decrease of O2 concentration in combustion-supporting air. The low temperature causes the

flame of combustion in the furnace to diffuse into the whole furnace, which makes the temperature field in the furnace more uniform, restrains the temperature of the high temperature combustion zone in the furnace, reduces the temperature difference in the furnace, and makes the temperature field in the furnace mostly lower than the critical temperature of the thermodynamic NOx, thus reducing the production of the thermodynamic NOx in the furnace. Moreover, with the decrease of O2 concentration in combustion-supporting air, the change of NOx emission in furnace decreases in inverse proportion to the O2 concentration in combustion-supporting air. When the O2 concentration in combustion-supporting air decreases from 21% to 18%, the reduction of NOx emission is the greatest. When the O2 concentration continues to decrease from 18% to 15%, the reduction of NOx emission is relatively smaller. Finally, when the concentration of O2 decreases from 12% to 9%, the emission of NOx decreases even less. Therefore, the reduction of O2 concentration in combustion-supporting air can effectively reduce the emission of NOx in the boiler, and because too low O2 concentration will not lead to a greater reduction of NOx emission, and will also make the flame combustion in the furnace unstable, so the selection of O2 concentration in combustion-supporting air is not the smaller the better.

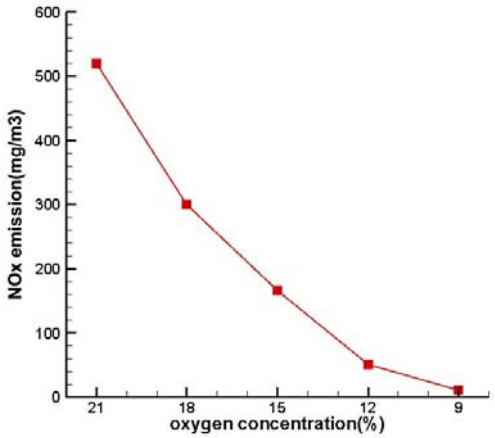

Fig 2. Emission Curve of NOx in Combustion-supporting Air with Different O2 Concentration

4. Conclusion

In this chapter, the numerical simulation of high temperature air combustion technology is carried out by means of numerical simulation. The effects of combustion-supporting air temperature and O2 concentration on the distribution and concentration of NOx in the furnace are analyzed. The following conclusions are drawn:

The emission of NOx in high temperature air combustion boilers increases with the increase of preheating temperature of combustion-supporting air. The reduction of O2 concentration in combustion-supporting air can effectively reduce the emission of NOx in the boiler, and because too low O2 concentration will not lead to a greater reduction of NOx emission, and will also make the flame combustion in the furnace unstable, so the selection of O2 concentration in combustion-supporting air is not the smaller the better.

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