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Numerical study of rice husk and coal co-combustion characteristics in a circulating fluidized bed

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Abstract. This paper discussed the rationality of coal and rice husk co-combustion. Using ICEM software, a two-dimensional model of the riser has been established for circulating fluidized bed experimental table. Using Fluent software, numerical simulation has been made for the combustion reaction of different proportions of rice husk mixed with coal. The results show that, with the increase of rice husk ratio, both the combustion temperature and the amount of nitrogen oxides decrease and the effect is gradually reduced. In this simulation, the rice husks occupying about 30% is a reasonable proportion.

1. Introduction

Coal is a kind of high polluting energy source. The use of coal shall be reduced in response to pollution and climatic issues. However, in many developing countries, including China, coal will keep the position as the most important energy source for quite a long time. China, for example, has been developing other energy sources instead of coal in order to reduce pollution. According to China's 13th Five-Year Coal Industry Development Plan[1], during the 12th Five-Year Plan period in China, coal consumption proportion declined significantly and maintained a downward trend. Coal energy consumption accounted for 72% of the total energy consumption in 2010 and 64% in 2015, decreasing by 8% in five years, and the trend will remain. However, by analyzing the data provided by the 13th Five-Year Plan, it can be found that the proportion of coal consumption continued to decline during the 12th Five-Year Plan period, but the absolute amount of coal consumption increased. China's coal consumption was 3.49 billion tons in 2010 and increased to 3.96 billion tons in 2015. Therefore, currently, the clean utilization of coal is still very important.

To address climatic change and pollution, in China's 13th Five-Year Plan for Energy Development, it has proposed that the proportion of non-fossil fuels will reach 15% by 2020[2]. Increasing the proportion of biomass fuels in total consumption is a feasible way to achieve this goal. However, as the most important utilization technology of green renewable energy, the utilization of biomass fuel lags behind relatively and its application needs to be further improved. The 12th Five-Year Plan required that all types of biomass should generate 13 million kilowatts power by 2015, but it actually reached just 10.3 million kilowatts, much lower than the 12th Five-Year Plan goal[3]. Additionally, other types of biomass utilization other than electricity generation also failed to reach the target. The main reason for low biomass utilization is it has low energy density. Long-distance transport is not economical. If there is an appropriate application direction and relative economic reasonable application technology, this situation will be improved greatly.

Rice husk is a kind of important biomass. Co-combustion of coal and rice husks is a way to compensate for the above two shortcomings. Co-combustion of rice husk with coal has been widely studied in circulating fluidized-bed combustor because it has a good fuel adaptability and the combustion pollution is low. However, most studies are experimental ones[4-6], and there are fewer numerical simulation studies.

2. Models

2.1. Control equations
Mass balance equation, momentum balance equation and energy balance equation were used.

2.2. Turbulence model
Standard K-ε turbulence model was used.

2.3. Models of Combustion reaction
Gungor's models [7, 8] were used to simulate chemical reactions.

2.4. Physical model
Because the geometry is very simple, the physical model was established with the ICEM of ANSYS software package. This is shown in Figure 1. The simulated riser is 3 meters in height and 0.1 meters in diameter. The primary air is fed to the riser burner through distributor (Air distributor), 0.2 m^3 per minute. The secondary air is 1.0m above the air distributor of the riser, 0.1m^3 per minute at room temperature.

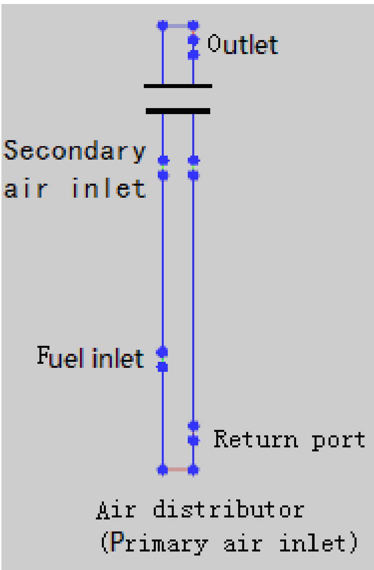

Figure 1. Physical model.

3. Numerical simulation

3.1. Assumptions
Because the model can't completely match the real condition, some assumptions or simplifications are as follows:

1. Primary air is assumed to be uniformly entered into the air distributer, and the flying particles are separated and returned to the riser through the return port.
2. Solid particles, such as bed materials, coal and husk, are all treated as spheres with the same diameter.

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3. The shrinkage and porous structure of husk particles are not considered..
4. It is assumed that the composition of fuel is stable.

3.2. Fuel analyses
Fuel characteristics are shown in Table 1 and Table 2.

Table 1. Proximate analyses of coal and rice husk.

	Weight %			
	Fixed carbon	Volatile	Moisture	Ash
Coal	38.66	35.84	17.11	8.39
Rice husk	18.21	57.48	8.18	16.13

Table 2. Ultimate analyses of coal and rice husk.

	Weight %				
	C	H	O	N	S
Coal	52.22	4.97	40.80	1.33	0.68
Rice husk	48.05	7.27	4405	001	0

3.3. Simulation results

3.3.1. Temperature profile along the riser. The temperature profile along the riser of the three cases has been simulated. The temperature profile is shown in figure 2. The bottom zone is the main fuel pyrolysis and reaction zone, so the bottom temperature is higher. The secondary air has a great effect on the temperature of the riser. In general, The temperature gradually decreases with the increase of husk content in the mixture, which is consistent with the low calorific value of rice husk.

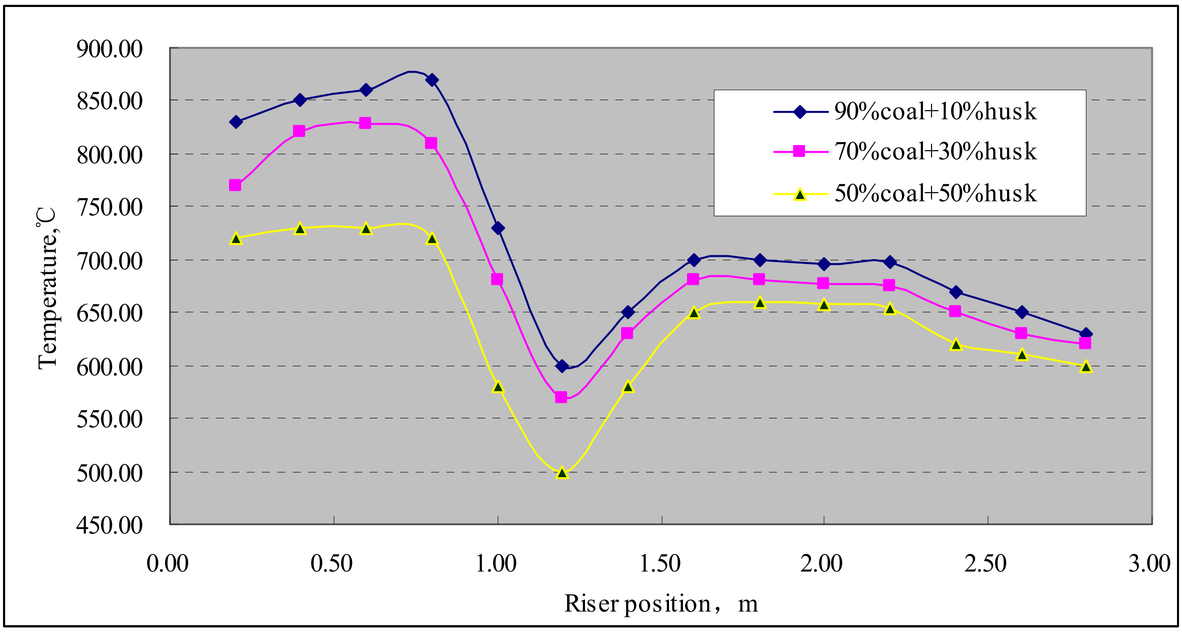

Figure 2. Temperature profile along the riser.

3.3.2. NOx production. The final NOx generation in the three cases is shown in Figure 3. The concentration of NOx gradually decreases with the increase of husk content in the mixture. When the rice husk proportion is 10%, the amount of NO produced is 2 times higher than that of 30% rice husk. When the rice husk proportion is increased to 50%, the effect of NO reduction was not as obvious as that of the former. The generation of N_2O is similar to that of NO.

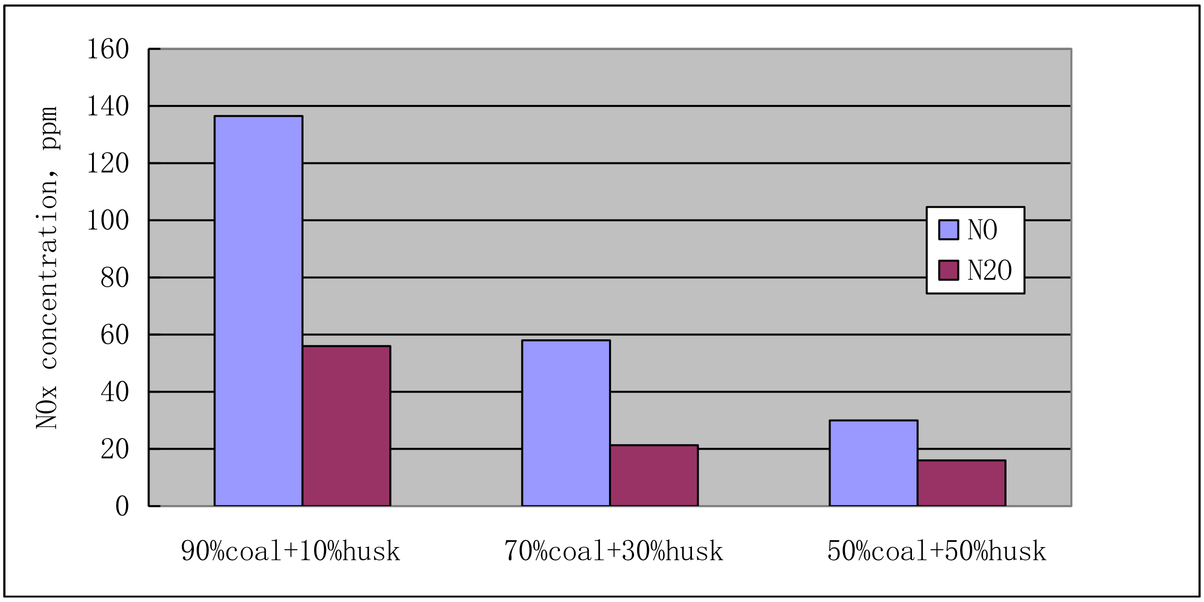

Figure 3. Comparison of NO and N_2O production in different proportions of coal and rice husk.

4. Conclusion

In consideration of the pollution and the economic factors of combustion, too high proportion of rice husks is not better. In this simulation, rice husks accounting for 30% is better than 10% and 50%, which is both economical and environmentally friendly.

Rice husks contain a lot of elements such as silicon, ferrum, calcium, phosphorus and kalium, and the composition of coal is more complex. Some of these elements and oxides have a strong catalytic effect, and due to unclear mathematical model, no catalytic effect was simulated, which needs further research.

Acknowledgement

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