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Experimental Study on NO Emission Concentration of Pulverized Coal in Different Atmosphere

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Abstract.The NO emission of pulverized coal during combustion in the O_2/N_2 atmosphere and O_2/CO_2 atmosphere was studied by using the sedimentation furnace test bed. The effects of CO_2 concentration, temperature and excess air concentration on the NO emission characteristics of single coal and mixed coal The results show that the NO content of the pulverized coal is lower than that of the O_2/N_2 combustion atmosphere, and the decrease of the NO content in the O_2/CO_2 atmosphere is about 30%~35%. When the CO_2 concentration changes from 20% to 50% of the process, the amount of NO produced in the selected coal gradually decreased, the change range is not large; with the pulverized coal combustion temperature continues to rise, the selected coal in the two kinds of atmosphere combustion NO content increased And the NO emission concentration is more obvious in the O_2/N_2 atmosphere. When the temperature reaches 1200°C and 1500°C, the slope of the NO emission curve can be found to vary greatly. With the increase of the excess air coefficient α Increase, in these two atmosphere NO production also showed a rising trend.

1. Introduction

Pulverized coal emissions of CO_2, NO and other pollutants on the global greenhouse effect of a great impact, threatening the Earth's ecological environment. In order to effectively reduce CO_2 emissions during coal combustion. Many domestic and abroad research institutions will focus on the O_2/CO_2 atmosphere of coal combustion technology research. The technology can effectively capture the CO_2 produced during coal combustion, which has a positive effect on clean coal combustion[1-3]. However, due to the combustion technology used in the atmosphere is different from the conventional combustion, and thus in the actual pulverized coal combustion NO and NO conversion process there are significant differences.

Kimura et al.[4]found that the combustion of pulverized coal in the O_2/CO_2 atmosphere contributes to the reduction of NO emissions, which decreases by about 1/3 of the pulverized coal combustion in the conventional atmosphere.You Zhuo et al.[5]compared the anthracite and bituminous coal in O_2/CO_2combustion atmosphere and O_2/N_2 combustion atmosphere, respectively. The results show that compared with the air combustion atmosphere, The NO content generated by combustion in the O_2/CO_2 atmosphere is greatly reduced, and the NO reduction reaction effectively reduces the NO production. Liu et al.[6]used Fluent numerical simulation software to simulate the combustion and NO emission concentration characteristics of pulverized coal under O_2/CO_2 atmosphere. The results show that the NO emission concentration depends largely on the peak temperature and The axial distribution is similar to the temperature change trend. Yu Yan et al.[7]studied the NO emission characteristics of

Shenhua coal and Yangquan anthracite under two combustion atmospheres by gas-bearing furnace. The results show that NO in the flue gas during the combustion temperature from 1100℃ to 1300℃ The amount of production increased first and then decreased, and the NO production reached a peak at 1200°C.

At present due to the limitations of experimental equipment, at home and abroad on the O_2/CO_2 The NO emission characteristics of pulverized coal combustion in the atmosphere are mainly concentrated below 1300℃, and the NO emission law at high temperature of 1200℃ and 1500℃ is less studied, and the NO emission law of coal mixed coal in different proportion atmosphere Little research. In order to solve the above problems, the NO emission characteristics of pulverized coal combustion were studied by means of the sedimentation furnace test bed. The combustion atmosphere, CO_2 concentration and excess air coefficient were compared and analyzed for the influence of combustion of NO and coal.

2. experimental part

The experimental system is shown in Fig.1, which consists of furnace part, temperature control system, powder supply system, gas distribution system, water cooling system and sample collection system. The temperature control system has high precision and the error is maintained at 2°C, The temperature controllable temperature of 800~1800℃, the combustion of the flue gas first processed by the filter into the German MRU VARIO PLUS-type flue gas analyzer, the O_2, CO and NO for testing. In this experiment, the amount of powder is 1g/min and the combustion atmosphere is O_2/N_2 and O_2/CO_2. The theoretical air intake is calculated according to the amount of powder, the theoretical oxygen consumption, the excess air coefficient and the CO_2 ratio,the total amount of airflow is 10L/min, when less than 10L, with He to add, so you can keep the furnace a good air flow, the experimental process set the automatic flue gas tester flow rate is 10L/min, so that the furnace become a micro negative pressure. In the experiment, the automatic flue gas tester was started and the micro-powder was started. The experiment was carried out with Datong bituminous coal and Indonesian lignite. The coal powder was taken over 100 mesh sieve and fineness<150μm. The coal quality analysis results are shown in the table 1.

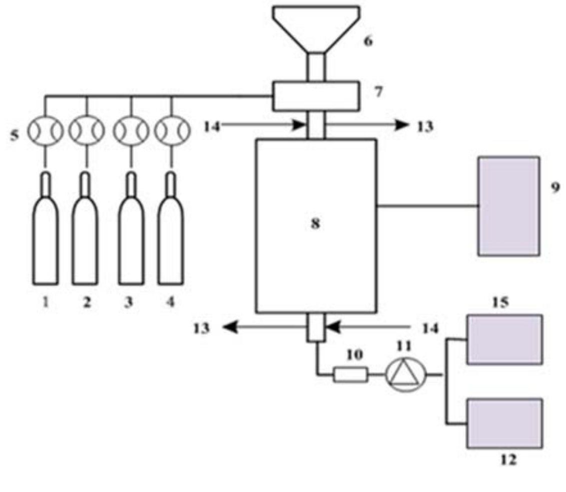


Fig 1. Schematic diagram of the test system

1-O_2 cylinder 2-CO_2 cylinder 3-N_2 cylinder 4-He cylinder 5-flow controller 6-micro-powder 7-Air Mixer 8-Furnace 9-Temperature Control System 10-Filter 11-Suction Pump 12-Flue Gas Analyzer 13-cooling water outlet 14-cooling water inlet 15-automatic flue gas tester

Table 1. Analysis and Industrial Analysis of Coal Samples

Coal	Elemental analysis/%					Industry Analysis/%			
	Cad/%	Had/%	Oad/%	Nad/%	Sad/%	Aad/	Vad/	FCad/	Mad/%

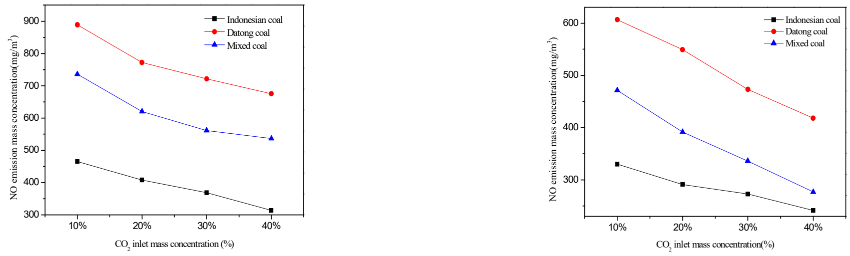
						%	%	%	
Datong bituminous coal	64.83	4.47	5.24	1.04	0.6	22.58	26.34	49.84	1.24
Indonesian lignite	54.13	4.56	17.65	0.68	0.12	5.20	41.48	35.66	17.66
Mixed coal（Datong 60% + Indonesia 40%）	58.69	4.5	6.25	0.90	0.48	18.35	30.80	40.02	10.83

3. Experimental results and analysis

3.1 Effect of CO_2 concentration on NO production

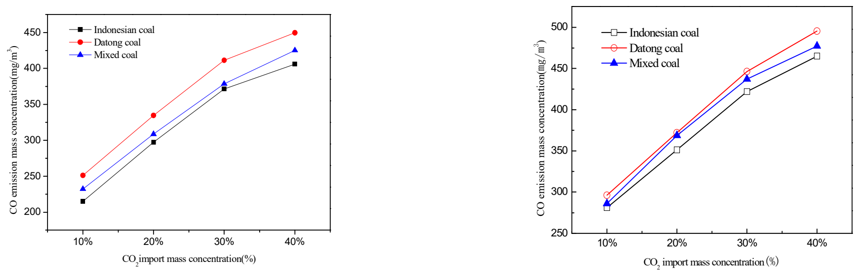
During the experiment, the theoretical oxygen volume of T=1200°C and T=1500°C, O_2/CO_2 atmosphere and excess air coefficient of 1.2 was selected. The CO_2 intake rate was adjusted by flow controller to study the effect of CO_2 concentration on NO production influences. Fig2 and Fig3 show the results of the formation of NO and CO in flue gas at four different CO_2 concentrations in the O_2/CO_2 atmosphere at 1200°C and 1500°C respectively. As can be seen from Fig.2 at both combustion temperatures.With the increase of CO_2 concentration from 10% to 40%, the NO emission concentration of the three kinds of coal decreased gradually, which was mainly due to the high concentration of CO_2, resulting in a large amount of CO and NO generated by the reduction reaction generated N_2. In addition, the NO emission concentration curve in Fig.2 is slow, because the increase of CO production is reduced with the increase of CO_2 concentration, the reduction reaction of NO is weakened, and the O_2 and CO_2 intermediate products HCN and NH_3 oxidation reaction to generate NO, and CO_2 possess high density, large specific heat of the physical properties, making the pulverized coal combustion rate decreased, burnout characteristics decreased, thereby promoting the fuel N element converse to NO, the combined effect of two aspects led to NO production concentration become slow down.

It can be seen from Fig2, the CO_2 concentration from 10% to 20%, the amount of NO production changes significantly higher than the CO_2 concentration from 30% to 40% when the change in the range of NO, reflecting the simple increase in the intake of CO_2 Concentration, NO emission reduction effect is not very satisfactory, while increasing the CO_2 concentration, should be reasonable control of the intake of O_2 concentration, which Can effectively reduce the amount of NO emissions. Compared with Fig 2, it is found that the NO emission of pulverized coal at 1500°C is obviously higher than 1200°C, which indicates that the high temperature environment can increase the burning degree of pulverized coal and promote the transformation of element N into NO in fuel. In addition, in the case of constant CO_2 concentration, the NO concentration produced by combustion with coal is much larger than that of Indonesian coal, mainly due to the different volatiles, nitrogen content and carbon content of coal and Indonesian coal. And the rate of change from the NO production amount at different temperatures, the concentration of NO produced by the combustion of Indonesian coal is not significant, while the difference between Datong coal and Indonesia coal is very different. The specific rate of NO production at 1500°C is obviously lower than 1200°C. This is mainly because with the increase of temperature, the gasification reaction rate is accelerated, resulting in the production of CO increased, the reduction of NO enhanced, thus a certain extent inhibited the formation of NO. It can be seen from the figure, in the O_2/CO_2 combustion atmosphere, high temperature and high oxygen case, the curve of coal generate NO shows the same as the single coal combustion when the same discharge law, basically maintained in two single coal burning alone NO emission concentration of the average.



（a）1200℃ （b）1500℃

Fig 2. three kinds of pulverized coal concentration of NO emissions at different CO_2 concentrations



（a）1200℃ （b）1500℃

Fig 3. three kinds of pulverized coal concentration of CO emissions at different CO_2 concentrations

3.2 The effect of temperature on NO emission

Fig 4,5 shows the O_2/N_2 atmosphere and O_2/CO_2 atmosphere at different temperatures (900°C, 1200°C, 1500°C) three kinds of coal powder NO precipitation curve. In the experiment, the combustion conditions were obtained with excess air coefficient=1.2, V (O_2)/V (CO_2/N_2)=2:8. The results show that the NO emission in the two combustion atmospheres increases with the increase of the temperature in the furnace. The NO emission in the O_2/N_2 atmosphere is higher than that in the O_2/CO_2 atmosphere. This is mainly because the O_2/CO_2 atmosphere does not exist in the molecular nitrogen, it can only produce fuel NO, and O_2/N_2 atmosphere of thermal NO and rapid type of NO with the temperature increases rapidly increase the conversion of N elements. At the same time, it was found that in the case of T=900°C, the NO emission from pulverized coal in the two combustion atmospheres in the order of is Indonesian coal, mixed coal and Da tong coal, which is because the volatilization of NO in Indonesia is much larger than Da tong coal. As the temperature continues to rise, NO emissions from coal pulverized coal are gradually higher than that of Indonesian coal in the two atmospheres, mainly due to the increase of the amount of pulverized coal and the increase of NO production due to the increase of temperature. When T=1200°C, CO_2 and Char began to gasification reaction, and promote the CO on the reduction of NO and intermediates. This is the reason why the slope of the NO emission curve decreases in the O_2/CO_2 atmosphere after 1200°C.

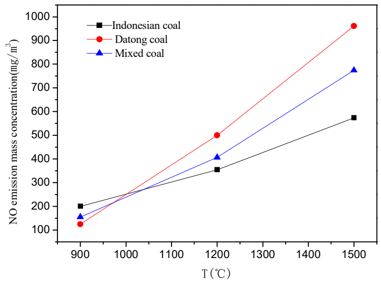


Fig 4. different temperatures NO emissions under O_2/N_2 atmosphere

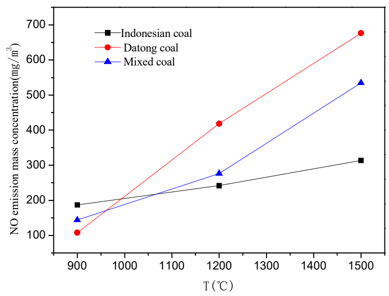


Fig 5. different temperatures NO emissions under O_2/CO_2 atmosphere

The slope of the three kinds of pulverized coal NO emission curves increases from 1200°C to 1500°C In Fig.4, which is mainly due to the large amount of NO generation in the high temperature environment. In Fig.5, it is not difficult to find between 1200°C and 1500°C. The slope of the NOx emission curve in Indonesia is significantly lower than that of coal and coal, due to the fact that the nitrides contained in the Indonesian coal are lower than those of the same coal, The formation of fuel-type NO is suppressed in the environment. Comparing the two graphs, it can be seen that as the temperature increases from 1200°C to 1500°C, the change of NO emissions in the O_2/CO_2 atmosphere varies slowly with temperature in the O_2/N_2 atmosphere under the same combustion conditions, indicating that the temperature Of the pyrolysis of coal to promote the formation of high concentrations of CO in the coal surface of the reduction reaction to a certain extent, inhibit the formation of NO.

3.3 Excess air volume on the impact of NO emissions

The most important factor in determining whether the pulverized coal combustion is in a reducing atmosphere or an oxidizing atmosphere is the excess air coefficient. Fig6, Fig7, Fig8 shows the Datong bituminous coal, Indonesian lignite and its mixed coal in the two combustion temperatures(1200°C, 1500°C), two atmospheres(O_2/CO_2,O_2/N_2)NO and CO with the excess air coefficient α (0.8,1.0,1.2,1.4) changes in the precipitation curve. In the experiment, the combustion conditions of $V(O_2)/V(CO_2/N_2)=2:8$ were taken. The results show that the emission of CO in O_2/N_2 atmosphere is less than that of O_2/CO_2 in the range of excess air coefficient, and the most obvious is the effect of α=0.8. This is mainly because the reaction (1) is carried out in the environment of high temperature and high CO_2 concentration during the initial combustion stage. The emission of NO in the O_2/N_2 atmosphere is higher than that of O_2/CO_2 (a) and (b) of the three types of pulverized coal were observed in the presence of a large amount of thermodynamically NO in the high temperature and O_2/N_2 atmosphere, and NO was found in the O_2/N_2 atmosphere at 1500°C Amplitude is much higher than 1200°C, which shows that the temperature can promote the formation of thermodynamic NO. Comparison of Fig6, Fig7, it is not difficult to find that the two kinds of coal in the same conditions of burning, with the coal NO emissions far greater than the Indonesian coal, showing that the same nitrogen content in coal is much higher than Indonesia coal, Combined with Fig8, it can be found that the NO emissions of mixed coal are between Datong coal and Indonesian coal, indicating that coal combustion can reduce NO emissions to a certain extent.

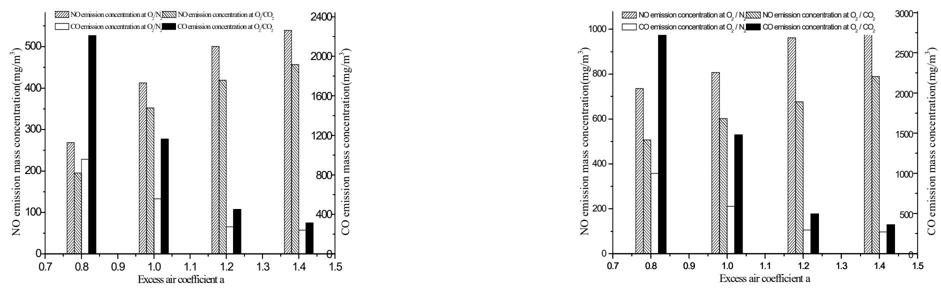
It can be seen from Fig. 6, Fig. 7 and Fig. 8 that the concentration of CO in the O_2/N_2 and O_2/CO_2 atmospheres decreases with the increase of the excess air α, while the NO concentration tends to increase. This is due to the increase in the amount of air to promote the combustion of coal, so that the resulting CO in the O_2 concentration increases in the case of reaction (2) to generate large amounts of CO_2, and CO reduction inhibited the heterogeneous reaction (3) And homogeneous reaction (4), the increase of 0_2 concentration also promoted the formation of pulverized fuel NO, which reduced the conversion of NO to N_2 under the premise that fuel type NO was continuously generated. When the excess air coefficient α is from 0.8 to1.2, both the oxidizing atmosphere and the reducing atmosphere, the NO generation rate and the CO reduction rate are greater than the excess air coefficient from 1.2 to1.4 changes more. This shows that the air classification combustion helps to control the O_2 concentration, and it is positive for reduce the NO emission.

$$CO_2 + C \rightarrow 2CO \quad (1)$$

$$2CO + O_2 \rightarrow 2CO_2 \quad (2)$$

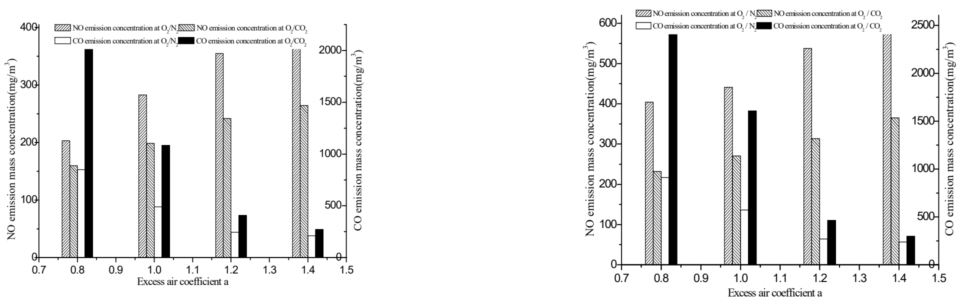
$$Char + NO \xrightarrow{CO} \frac{1}{2} N_2 + \cdots \quad (3)$$

$$CO + NO \xrightarrow{Char} \frac{1}{2} N_2 + CO_2 \quad (4)$$



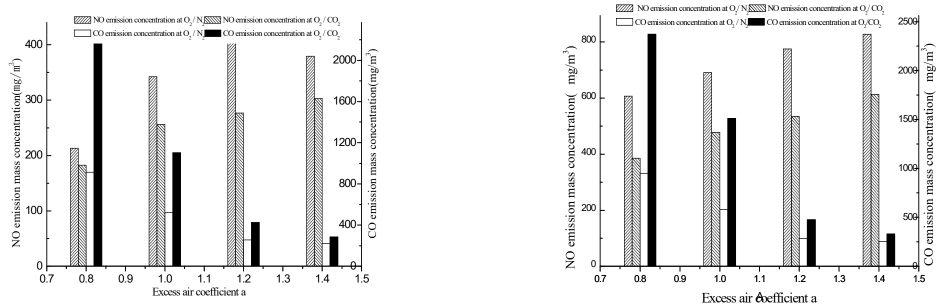
（a）1200℃ （b）1500℃

Fig 6. Datong bituminous coal in different atmospheres NO, CO emission concentration



（a）1200℃ （b）1500℃

Fig 7. Indonesia coal in different atmospheres NO, CO emission concentration



（a）1200°C （b）1500°C

Fig 8. mixed coal in different atmospheres NO, CO emission concentration

4. Conclusion

(1) At 1200°C and 1500°C, with the increase of CO_2 concentration, the NO emission of the three kinds of pulverized coal in the laboratory was gradually decreased, the CO emission increased gradually, and the fluctuation degree of the two was smaller. When the CO_2 concentration increased from 10% to 20%, the change range of NO and CO was significantly higher than that of CO_2 and the change of NO and CO from 30% to 40%, indicating that the reasonable control of CO_2 concentration was helpful The amount of NO generated.

(2) In the O_2/N_2 and O_2/CO_2 atmosphere, the amount of NO produced and the conversion rate of the pulverized coal increased with the increase of the temperature in the temperature range selected by the laboratory. Under the same conditions, NO emissions in the O_2/N_2 atmosphere are higher than O_2/CO_2 atmosphere, and the temperature increases from 1200°C to 1500°C. The change of NO emission in O_2/CO_2 atmosphere is smaller than that in O_2/N_2 atmosphere, which indicates that the increase of temperature can promote coal pyrolysis, generate high concentrations of CO can effectively decrease NO emissions.

(3) In the two atmospheres, with the increase of the excess air coefficient, the CO emission of the selected coal in the laboratory showed a decreasing trend, and the NO emission showed an upward trend, and the excess air coefficient increased from 0.8-1.2, NO emission rate and CO reduction rate are larger. At the same temperature, the same atmosphere and the same excess air ratio, NO emissions in O_2/N_2 atmosphere are always larger than O_2/CO_2 atmosphere, the emission of CO is always greater than the O_2/N_2 atmosphere in the O_2/CO_2 atmosphere.

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