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Characteristics of sodium compounds on NO reduction at high temperature in NOx control technologies

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ABSTRACT

Characteristics of sodium compounds additives on NO reduction at high temperature were investigated in a tube stove and a drop tube furnace. Sodium carbonate, sodium hydroxide and sodium acetate were chosen as Na additives to research the effect on NO reduction. It was found that sodium compounds could reduce NO emission and promoted NO reduction efficiency during pulverized coal combustion, coal reburning and urea-SNCR process. Adding sodium carbonate into crude coal gained 3.2%–34.8% of NO reduction efficiency on different combustion conditions during the coal combustion process. NO reduction efficiency was affected by sodium content and coal rank. Na additive performed NO reduction effect in whole Shenhua coal combustion process and in char rear combustion of Gelingping coal. Adding sodium hydroxide into the reburning coal increased NO reduction efficiency of the reburning technology. NO reduction efficiency was increased to 82.7% from 50.0% when the weight ratio sodium to the reburning coal was 3% and the ratio of the supplied air to the theoretical air of reburning fuel was 0.6. Sodium carbonate, sodium hydroxide and sodium acetate performed the promotion of NO reduction efficiency in urea-SNCR. Sodium acetate promoted NO reduction efficiency best while sodium hydroxide promoted worst at 800 °C. Sodium additives as SNCR promoter performed much better at lower temperature than at higher temperature, and they promoted NO reduction weakly in urea-SNCR when the temperature was greater than 900 °C.

1. Introduction

The emission of NOx (NO, NO_2 etc.) from coal combustion has been of great concern because it produces photochemical smog, acid rain, low visibility and fine particulates, and it is also a health hazard. A number of NOx control technologies have been applied in thermal power plants and industry furnaces to reduce NOx emission, and the technologies that are most widely used include low NOx burners, fuel reburning, selective catalytic reduction, and selective non-catalytic reduction (SNCR) [1–5]. It is known that some metal compounds in coal ash have promotion effects on coal combustion characteristics such as ignition, combustion rate, and burnt-out performance [6–8]. Recently the researchers have found that some metal compounds also can promote NO reduction in coal combustion process and other NO reduction process [9,10]. Levels of NOx reduction comparable to advanced reburning can be achieved by injection of iron compounds without injecting a NO reducing agent [11]. Lissianski et al. [12] have studied the effect of metal-containing compounds on NOx reduction using natural gas as the main fuel and reburning fuel. Their work demonstrated that small addition rates of Na-, K- and Ca-containing compounds increased the efficiency of NOx reduction in combustion and reburning process. Zamansky et al. [13] found that about 80–90% NOx reduction was achieved by

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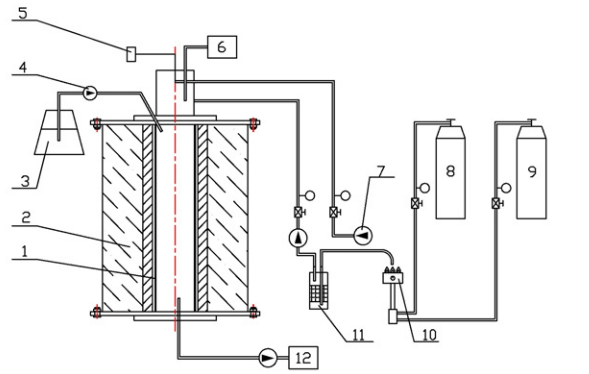
10–20% natural gas reburning in the presence of ammonia or urea and sodium carbonate in comparison with 45–65% NOx reduction by 10–20% reburning only. It was shown by experiments [14,15] that the effective temperature window of SNCR can be broadened and the efficiency of NO reduction can be enhanced by adding parts per million levels of sodium compounds. Seungmoon et al. [16] found that the increase of NO reduction efficiency was observed in presence of alkaline additives in NOxOUT process and the maximum efficiency was increased more than 30%. Recent kinetic efforts have focused on predicting the effect of alkali metals on NOx control technologies such as SNCR and reburning [14,15,17], and it is suggested that alkali compounds increase the radical pool via the chain reactions and the radicals enhance the SNCR performance of N-agents by increasing the production rate of NH_2 radicals. The kinetic mechanism of metal compounds with NOx and coal nitrogen in high temperature also is hungering for more experimental data to support. This work researched on characteristics of reducing NO using sodium compounds additives at high temperature in coal combustion and coal reburning and SNCR process by the experiments.

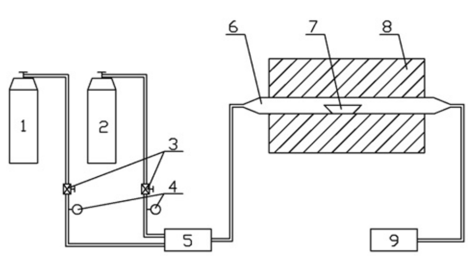


1-corundum tube, 2-furnace, 3-urea solution, 4- peristalsis pump, 5-screw feeder, 6-Testo gas analyzer, 7-fan, 8-liquefied gas bottle, 9- ammonia bottle, 10-gas burner, 11- desiccator, 12- NGA 2000

Fig. 2 – Schematic diagram of the drop tube furnace.

2. Experimental

The experiment system shown in Fig. 1 was used to investigate the effects of sodium compounds on NO emission during the coal combustion process. It was an electric-heated tube stove controlled by an automatic temperature controller. A 77 mm long porcelain vessel was put in the center of a quartz tube whose diameter was 18 mm, and the pulverized coal sample was put into the vessel. Argon was chosen as a carry gas and mixed with oxygen in a mixer at first. The product gas was analyzed by a gases analyzer, Rosemount Analytica NGA 2000. Species analyzed were O_2, CO_2, CO, NO, N_2O and NO_2 with a precision of 1%. The pulverized coal was put into the sodium salt solution, whose volume was controlled to add the certain content of sodium acetate into coal. After sufficient mixing, the mixture was kept at 110 °C for 24 h to desiccate. The stove was heated up to 1200 °C and kept at 1200 ± 6 °C by the automatic temperature controller, then the carrier gas and oxygen whose fluxes had been turned to the needed value flowed into the quartz tube. Then the vessel with 0.2 g pulverized coal sample was put into the tube quickly and the test began immediately. The test was not ended until no change of flue gas composition was detected, and the combustion process lasted about 7 min. The oxygen flux in whole combustion process was set to keep the excess air ratio be 1.2. The total flux was limited by the minimum detectable flow of NGA 2000, 5 L/min, which was obtained by tuning argon flux in any case.



1-argon bottle, 2-oxygen bottle, 3-flow meter, 4-pressure meter, 5-mixer, 6- quartz tube, 7- porcelain vessel, 8- tube stove, 9-gas analyzer

Fig. 1 – Schematic diagram of the tube stove.

The tests of sodium compounds' effects in SNCR and reburning process were carried out in a drop tube furnace shown in Fig. 2. A corundum tube with 50 mm inner diameter and 1.0 m length was used as the reactor furnace and heated by electricity and covered by adiabatic material. In the gas burner, liquefied gas and ammonia from the gas bottles burned to produce simulated gas with NO. NO concentration in simulated gas fluctuated due to the wavy flow of ammonia and the average NO concentration in a test was adopted. The simulated gas was analyzed by a Testo 350XL gas analyzer before flowing into the furnace. NO was analyzed by Testo 350XL with the precision of ±5%. The reburning coal or the urea solution was injected into the simulated gas at the inlet of the furnace, at that time the NO reduction process began and continued in the furnace. The reburning coal was fed by a screw feeder and conveyed into the furnace by air. The urea solution was conveyed by a peristalsis pump and sprayed into the furnace. At the bottom of the furnace the flue gas was analyzed by NGA 2000 to gain NO emission after reburning or SNCR process.

Shenhua coal and Geliping coal whose data were listed in Table 1 were adopted in the experiments. Shenhua coal was bituminous coal and had high volatile content, while Geliping coal was semi-anthracite coal and had lower volatile content. Each test carried out in the drop tube furnace lasted for 1 h without any adjusting after the main parameters were stable. All main parameters such as temperature, NO emission, oxygen content, urea solution flow, the gas flow, were recorded every 10 min. When the deviation of the recorded data was lower than 5%, the test was valid. Hence the results of the tests were ensured to be reliable.

3. Results and discussion

3.1. *Effects of sodium compounds in coal combustion process*

The experiments of sodium compounds' effects on NO generation in coal combustion process were carried out in