STEAM BOILERS, POWER-GENERATING FUEL, BURNERS, AND BOILER AUXILIARY EQUIPMENT

Generation and Reduction of Nitrogen Oxides in Firing Different Kinds of Fuel in a Circulating Fluidized Bed

V. A. Munts, Yu. G. Munts, A. P. Baskakov, and A. S. Proshin

Ural Federal University, ul. Mira 19, Yekaterinburg, 620002 Russia

Abstract—The processes through which nitrogen oxides are generated and reduced in the course of firing different kinds of fuel in a circulating fluidized bed are addressed. All experimental studies were carried by the authors on their own laboratory installations. To construct a model simulating the generation of nitrogen oxides, the fuel combustion process in a fluidized bed was subdivided into two stages: combustion of volatiles and combustion of coke residue. The processes through which nitrogen oxides are generated and reduced under the conditions of firing fuel with shortage of oxygen (which is one of efficient methods for reducing nitrogen oxide emissions in firing fuel in a fluidized bed) are considered.

The process through which nitrogen oxides are generated in a fluidized bed in the course of burning the particles of solid kinds of fuel was studied on an experimental setup made in the form of an electric furnace fitted with a cylindrical heating chamber with an inner diameter of 50 mm and an air distribution hood welded into the bottom. During the experiments, we checked the temperature of fluidized bed composed of 460-μm fractions of fused alumina (or ash particles 2.5 mm in size) and air flowrate. In addition, the composition of combustion products was continuously measured using different types of gas analyzers (GIAM-5 for CO_2, Bekman 951 A for NO_x, GIAM-5M for CO, and DET-V for O_2) and a computerized data acquisition and processing system. Brown coal from the Moscow region, Berezovo coal, Donetsk anthracite, Kuznetsk lean coal, undersized coke of Kuznetsk coal, Estonian shale, and Volga shale were used as fuel [1].

For carrying out the experiments, we sieved fuel fractions with particles having medium sizes of 0.8, 1.5, 2.5, 4, 6, and 8.5 mm; small-weight charges (0.5–2 g) were fired in the fluidized bed at different temperatures.

Experiments involving preliminary blowing of fluidized bed with air at a temperature of 900°C showed that so-called thermal nitrogen oxides (i.e., those generated from the molecular nitrogen contained in air according to Zeldovich' mechanism [2]) are not generated under the conditions of the experiment. In view of this, all generated nitrogen oxides were subsequently regarded as fuel ones, originated from the nitrogen contained in fuel.

The data shown in Fig. 1 illustrate how nitrogen oxides and carbon dioxide are generated in firing small-weight charges (0.5 g) composed of particles of coal from the Moscow region and anthracite. For all coals with a high content of volatiles, an interconnection between the changes of CO_2 and NO_x concentrations is observed: during the combustion of volatiles, a synchronous and very rapid growth of C_{NO} and C_{CO_2} concentrations takes place, and during the combustion of coke residue these concentrations decrease gradually to zero. If fuel with an insignificant content of volatiles is fired, the maximum of CO_2 and NO_x concentrations is not so prominent: nitrogen and carbon oxides are generated more uniformly. For quantitatively estimating the generation of CO_2 and NO_x, we calculated their relative masses m_{NO_x} and m_{CO_2}, that have released by a certain moment of time τ using the following expressions:

$$m_{NO_x}(\tau) = \frac{\int_0^\tau C_{NO_x} d\tau}{\int_0^{\tau_{b\text{-}o}} C_{NO_x} d\tau}; \quad m_{CO_2}(\tau) = \frac{\int_0^\tau C_{CO_2} d\tau}{\int_0^{\tau_{b\text{-}o}} C_{CO_2} d\tau},$$

where $\tau_{b\text{-}o}$ is the experimentally determined full time for which the fuel charge burns out.

At the combustion stage, nitrogen oxides are generated more intensely than CO_2. The relative fraction φ_N of nitrogen oxides released for the time of visible combustion of volatiles is a quantitative parameter using which this intensity can be estimated. Figure 2a shows this parameter as a function of the content of volatiles in the fuel.

It should be noted that the authors of the majority of proposed calculation procedures [3–5] postulate