An Experimental Study on the Combustion Characteristics of a Low NOx Burner Using Reburning Technology

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The combustion characteristics of a low NOx burner using reburning technology have been experimentally studied. The reburn burner usually has three distinct reaction zones which include the primary combustion zone, the reburn zone and the burnout zone by provided secondary air. NOx is mainly produced in a primary combustion zone and a certain portion of NOx can be converted to nitrogen in the reburn zone. In the burnout zone, the unburned mixtures are completely oxidated by supplying secondary air. Liquefied Petroleum Gas (LPG) was used as main and reburn fuels. The experimental parameters investigated involve the main/reburn fuel ratio, the primary/secondary air ratio, and the injection location of reburn fuel and secondary air. When the amount of reburn fuel reaches to the 20-30% of the total fuel used, the overall NO reduction of 50% is achieved. The secondary air is injected by two different ways including vertical and parallel injection. The injector of secondary air is located at the downstream region of furnace for a vertical-injection mode, which is also placed at the inlet primary-air injection region for a parallel-injection mode. In case of the vertical injection of the secondary air flow, the NOx formation of stoichiometric condition at a primary combustion zone is nearly independent of the reburn conditions (locations, fuel/air ratios) while the NOx emission of the fuel-lean condition is considerably influenced by the reburn conditions. In case of the parallel injection of the secondary air, the NOx emission is sensitive to the air ratio rather than the fuel ratio and the reburning process often coupled with the multiple air-staging and fuel-staging combustion processes.

Key Words: Low NOx Burner, Reburning, NOx formation, N2 conversion, Swirl

1. Introduction

Due to the increasingly tighter emission regulations, the NOx control technologies have become more sophisticated. Among the NOx reduction technologies, it is generally well-known that the reburning method effectively reduce the NOx emission in the coal combustion process. This reburning concept was first proposed by Wendt et al. (1973). In their reburning approach, nitrogen oxides are converted to nitrogen by injecting the clean secondary fuel into the downstream region of the primary substoichiometric combustion zone. Myerson (1974) suggested the reduction mechanism of nitric oxide by hydrocarbons. In the early 1980s, researchers at Mitsubishi first applied the reburning concept to a full-scale boiler and more than 50% reduction of NO was achieved (Smart & Morgan, 1994).
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Recently, in order to increase the NO reduction efficiency, Large-scale application (Smart & Weber, 1989) and AR (advanced reburning) (Lanigan et al., 1995) have been quite popular.

In the reburn-based boiler shown in Fig. 1, the reburn burner usually has three distinct reaction zones which include the primary combustion zone, the reburn zone and the burnout zone by a provided secondary air. NOx is mainly produced in a primary combustion zone and a certain portion of NOx can be converted to nitrogen in the reburn zone. In the burnout zone, the unburned mixtures are completely oxidated by supplying secondary air. Figure 2 shows the reaction pathways involved in the reburn process. NO formed in the primary combustion zone is quickly converted to HCN by reacting with hydrocarbon radicals (CHi) which are generated in the reburn process (Lyerson, 1974). The fast conversion of HCN to NHi subsequently occurs. NHi then forms NO by reaction with an O or OH radical or creates N2 by reacting with NO. The path favoured for the reaction of the NHi radical is determined by the flame temperature and equivalence ratio. Under globally fuel-rich conditions the reaction is leading to N2 formation while the reaction pathways leading to NO are dominant in an oxidizing environment.

Unlike the conventional reburning systems, in this study, the reburning process has been applied to a coaxial swirling gas-fired burner where the reburn fuel is supplied by penetrating the central region of primary combustion zone and the aerodynamically controlled secondary air is supplied to the burnout zone. The schematic diagram of the present reburning process is illustrated in Fig. 3. Experiments have been carried out for the wide range of key design parameters including the reburn fuel injector position, reburn fuel fraction, primary and secondary air ratio. Effects of these parameters on the NOx emission characteristics are discussed in detail.

2. Experimental Setup

2.1 Burner

Figure 4 shows the configuration and dimension of the burner utilizing the reburning process. The capacity of this burner is about 232.6kW (th) and LPG is used as the main and reburning fuels. The burner consists of the primary and secondary air and fuel supply devices. The primary air was supplied through 45° angle swirler for flame stability. The secondary air supplying for the burnout zone is injected by two different ways; (a) vertical injection at downstream region (x = 1.3m) of the combustor and (b) parallel injection at the primary air inlet location, and the swirl strength can be adjusted by using the movable block swirl generator. The six-hole fuel nozzle is located on the central zone of the annular primary-air swirler for the efficient mixing. A reburn fuel nozzle is installed at the burner center.