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Research Paper

Numerical simulation and cold experimental research of a low-NO_x combustion technology for pulverized low-volatile coal

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HIGHLIGHTS

- A horizontal rich/lean burner and polygonal tangential fired furnace were studied.
- Factors influencing the flow in the horizontal fuel-rich/lean burner were studied.
- The polygonal tangential air system enhances the multi-scale staged combustion.
- The retrofit of power plant boilers demonstrated this burner reduced NO_x by 56%.

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ABSTRACT

Large quantities of low-volatile coal are utilized in power plants throughout China. With increasingly stringent environmental regulations, it is important to develop and deploy low-NO_x combustion technologies for pulverized coal boilers burning low-volatile coal. The objective of this study was to investigate a novel decoupling combustion system for low-volatile coal via experiments and computational fluid dynamics (CFD). The combustion system includes horizontal fuel-rich/lean low-NO_x burners (LNB) and the associated air distribution system for a polygonal tangentially fired boiler (PTFB). The effects of coal particle diameter and coal feeding rate on the gas/particle flow characteristics of the burner, and the cold state aerodynamic field of the PTFB were analyzed in detail. The structural design of the LNB results in advantageous gas/particle flow characteristics and the PTFB improved the distribution of the flow field. The CFD models and simulation results were validated by comparing with those of cold experiments data. The simulation results demonstrated that this low-NO_x combustion technology enhances staged combustion at different scales, which can reduce NO_x generation significantly. In the industrial application on a 300 MW pulverized coal boiler, installation of the LNBs improved the stability of low-volatile coal combustion and reduced NO_x emissions significantly. These research findings provide valuable guidance to the design of low-NO_x combustion system for pulverized coal boilers using low volatile coal.

1. Introduction

Tangentially–fired boilers are popular because tangential combustion can adapt to fluctuating coal quality and is efficient in air staging to control NO_x emissions [1–3]. In large-scale tangentially-fired boilers, rich-lean burners are usually employed [4]. A significant portion of coal produced in China is of low grade with low volatility, but it is very difficult to maintain a stable flame and high combustion efficiency with low-volatile coal, particularly with a low load [5–7]. When burning low-volatile coal, burners designed to burn high quality coal usually are not able to meet expected flame stability, fuel adaptability, rapid load change response, no slagging propensity, high combustion efficiency and also pollution control ability [8,9]. The over fire air OFA, controls the fuel-NO_x and thermal-NO_x generation by maintaining a large-scale reducing atmosphere in the main combustion zone and burning out the remaining coal. However, due to the slow discharge of char nitrogen from the low-volatile coal, a long distance from the

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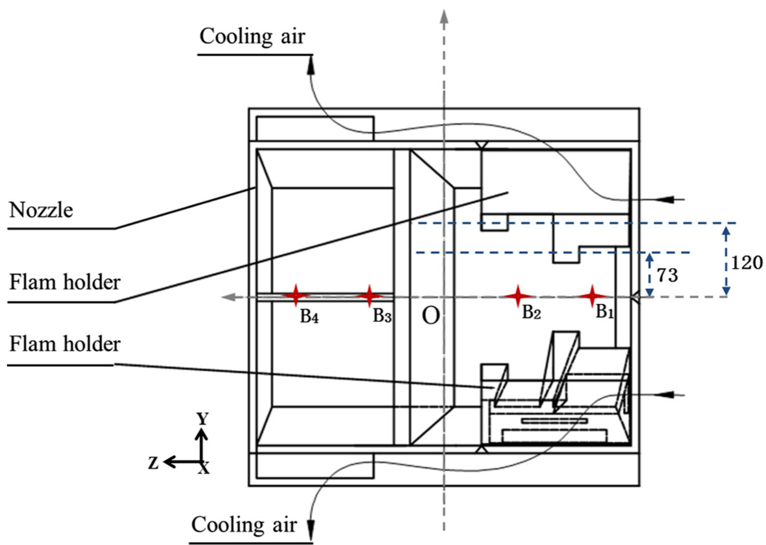
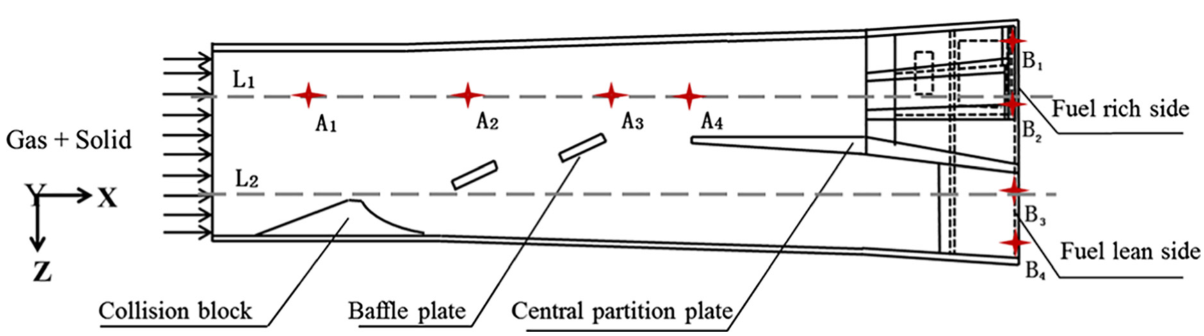
main combustion zone to the OFA is needed to control the emission of NO_x. Unfortunately, this leads to poor burn out efficiency, and reheater overheating issues [10], especially for the char of the low-volatile coal, due to the short over fire combustion time. In conclusion, both micro (rich/lean burner) and macro (OFA) air-staged combustion technologies suffer from the coupling relationship of NO_x emissions and combustion efficiency, which means that rich oxygen and high temperature accelerates combustion but results in high NO_x emission. On the contrary, lean oxygen and low temperature condition efficiently reduces NO_x emission, but also decreases the combustion efficiency.

Carbon monoxide (CO), hydrocarbons (C_mH_n) and hydrogen (H_2), which are the main coal pyrolysis gasification products at the beginning of the combustion, are present in high concentration in the combustion zone and reduce the NO_x produced at this stage; Furthermore, char itself can serve as a heterogeneous catalyst in NO_x reduction, and the reduction rate can be as high as 93% [11,12]. Based on the above principles, a Chinese patent CN102620291A was developed by Li et al., and a coal decoupling combustion theory was initiated [13]. Since the low-volatile coal combustion conditions such as composition, concentration and temperature of pulverized coal combustion process differ at each stage, the NO_x conversion and inhibition mechanisms at each stage have obvious differences. Therefore, it is preferred to analyze and control NO_x conversion in depth via a multi-scale low-NO_x combustion method. A multi-scale decoupling combustion system, including a horizontal fuel-rich/lean burner (CN202452487U) and the associated PTFB (CN103134049A), was developed for the low-volatile coal in power plants [14,15]. The objective of this study was to introduce this system, investigate the cold characteristics and analyze the low-NO_x combustion ability of this system through the combustion mechanism analysis, CFD simulation and



(a)



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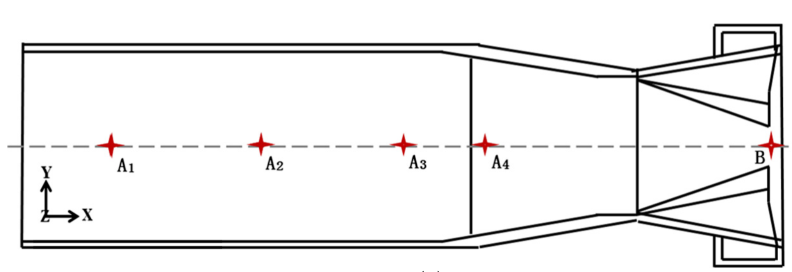

(c)

Fig. 1. Sketch of the burner: (a) front view, (b) top view, (c) left view. (Unit: mm) Ai: pressure measure point; Bi: velocity measure point.