Applied Energy 180 (2016) 104–115

Contents lists available at ScienceDirect

Applied Energy

journal homepage: www.elsevier.com/locate/apenergy

Effect of the separated overfire air location on the combustion optimization and NO_x reduction of a 600 MW_e FW down-fired utility boiler with a novel combustion system

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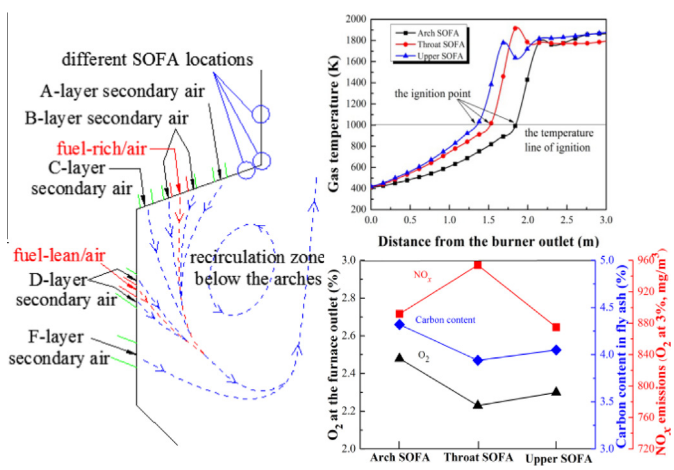
HIGHLIGHTS

- A novel combustion system is applied to reduce NO_x emissions of a down-fired boiler.
- Influence of SOFA locations is evaluated.
- The upper-furnace SOFA is advisable with considering burnout rate and NO_x emissions.
- NO_x reduction of 50% is obtained without producing negative effects.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 20 April 2016
Received in revised form 23 July 2016
Accepted 25 July 2016

Keywords:
Down-fired boiler
SOFA location
Combustion characteristics
NO_x emissions

ABSTRACT

A novel combustion system has been applied to a 600 MW_e down-fired boiler to reduce NO_x emissions without producing an obvious increase in the carbon content of fly ash. The system mainly includes moving fuel-lean nozzles from the arches to the front/rear walls, and re-arranging the staged air, as well as introducing separated-over-fire air (SOFA). This paper evaluates the effects of the SOFA locations (on the arches, on the throat, and on the upper furnace) on the combustion and NO_x emissions characteristics using simulations. The numerical results are in good agreement with the measured results. Compared to the original combustion system, significant NO_x reduction (approximately 50%) is found for all three SOFA location settings. Taking economic efficiency and NO_x emissions into account, the SOFA on the upper furnace is adopted in the actual modification, and no negative effects are observed.

1. Introduction

Down-fired boilers are widely used in the generation of power by firing low-volatility and poor-reactivity coal [1]. There exist four

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http://dx.doi.org/10.1016/j.apenergy.2016.07.102
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Nomenclature

FW	Foster Wheeler
Babcock & Wilcox	B&W
Mitsui Babcock Energy Limited	MBEL
MIMSC	multiple-injection and multiple-staging concept
CHELNO	combined high-efficiency and low-NO_x technique
OFA	overfire air
SOFA	separated overfire air
WSGG	weighted sum of grey gases

types of down-fired utility boilers in industry applications: Babcock & Wilcox (B&W), Stein, Mitsui Babcock Energy Limited (MBEL), and Foster Wheeler (FW) down-fired boilers. The arches divide the furnace into two parts: the lower furnace region and the upper furnace region. The burners are positioned on the arches, and the air or coal/air mixture jets from the front and rear arches penetrate downwards into the hopper region, converge at the centre of the furnace, and then flow upwards into the upper furnace [2,3]. Adopting this particular design can achieve a high temperature in the lower furnace and a long travel path for the pulverized coal particles; however, certain problems, such as poor combustion stability, slagging in the furnaces, high carbon content in the fly ash, and high NO_x emissions, remain [4,5].

To significantly reduce NO_x emissions before the gas denitration system and control denitration costs, various low-NOx combustion technologies, such as the modification of the combustion system and the optimization of the operating parameters, have been adopted. The former is a relatively high-efficiency method to reduce NO_x emissions; such technology includes applying low-NO_x burners, rearranging the burner design, staging the air/fuel, and introducing over fire air (OFA) [6–9]. Leisse and Lasthaus [10] retrofitted a B&W boiler by replacing the burner and introducing OFA to achieve NO_x reduction of approximately 41% and relatively low carbon content in the fly ash. Burdett [11] performed some industrial-sized measurements to investigate the influences of the air staging level on NO_x emissions for a Stein down-fired boiler. Li et al. [12] reported the "Multiple-Injection and Multiple-Staging Concept" (MIMSC) for MBEL boilers, and the measured results showed that NO_x emissions decreased by 50% without producing an obvious increase in the carbon content of the fly ash. FW down-fired boilers share of a considerable market share in China. And for this type boilers, various low NO_x techniques have also been applied to actual modifications. The FW Company introduced two technologies (as shown in Fig. 1). One technology is the "Fuel Preheat Nozzle" [13], which adopts a short fuel nozzle and a hollow cylinder to achieve the following advantages: enhancing the fuel-rich concentration, strengthening rigidity of the fuel-rich coal/air flow, more intensively mixing the hot B-layer secondary air and the fuel-rich coal/air streams near the burner outlet, and producing more char, which is favourable for achieving lower NO_x emissions. The other technology is "Vent-to-OFA" [14], which supplies fuel-lean/air mixtures through OFA nozzles into the furnace, thereby promoting coal ignition due to the vent air carrying away moisture from the coal. With the above two technologies, NO_x emissions can be reduced by 50% and the flame stability is enhanced; however the level of carbon in fly ash is relatively high. Li et al. [15] proposed a combined high efficiency and low NO_x technology ("CHELNO", as shown in Fig. 2). This technology mainly consists of three main aspects: (1) inclining the F-layer secondary air to extend the flame penetration depth and postpone the mixing of the coal/air stream with the F-tier secondary air to inhibit NO_x formation; (2) moving fuel-lean nozzles from the face-fire side to the back-fire side to promote coal ignition and to control NO_x formation through regulation of the fuel-rich/-lean combustion; and (3) introducing OFA to further reduce NO_x formation. Fang et al. [16] inclined the F-layer secondary air in place of the original horizontal jets for a FW down-fired boiler, and the performance of the boiler was improved in terms of to coal ignition, coal burnout, and NO_x reduction. Of these low-NO_x combustion technologies, the adoption of OFA is a relatively optimal choice. However, the introduction of OFA also changes the coal combustion atmosphere and may increase the carbon content in the fly ash. Thus, it is necessary to take some measures to reduce NO_x emissions without producing an obvious increase in the carbon content of fly ash.

A novel combustion system was specifically applied to a 600 MW_e FW down-fired boiler to reduce high NO_x emissions without producing an obvious carbon increase in the fly ash. The application of the system mainly involves moving the fuel-lean nozzles from the arches to the front/rear walls, rearranging the staged air, and introducing separated-overfire-air (SOFA). Of these steps, the SOFA location is very important for this novel combustion system, because it may influence combustion and

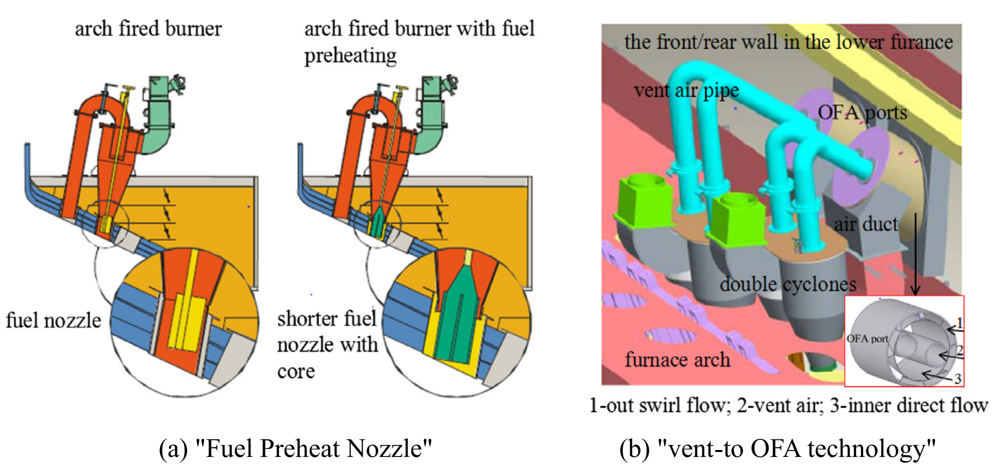

Fig. 1. Schematics of the modification with "Fuel Preheat Nozzle" and "vent-to-OFA technology" [13,14].