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Combustion behaviour of pulverised coal in high temperature air condition for utility boilers

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HIGHLIGHTS

- Novel burner can realise both conventional and HTAC mode without any unstable.
- HTAC can be established with a combustion air temperature as low as 185 °C.
- Substantial NO_x reduction can be achieved under HTAC mode.

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ABSTRACT

High Temperature Air Combustion technique (HTAC) is expected to improve the combustion efficiency and NO_x emissions of fossil fuels. This paper presents the results from experimental measurements under steady combustion mode conditions and during the change from conventional air combustion mode to HTAC mode of a newly proposed burner configuration. A 1.2 MWth pulverised coal fired furnace has been used to evaluate the characteristics of HTAC and conventional combustion. To realise both the HTAC and the conventional modes, is one of the important HTAC technological tasks for practical use in utility boilers. During the start-up process, HTAC operation mode cannot be achieved because the air for combustion is still cold. Therefore burner configurations for both modes, conventional and HTAC, are required. In this study, a new burner is proposed and the start-up procedure of pulverised coal fired boilers adopting HTAC is demonstrated. The newly proposed HTAC burner enables successful operation mode switching in both ways between conventional and HTAC modes.

The study shows that HTAC can achieve NO_x reduction whilst maintaining sufficiently high combustion efficiency. The flat and high in-furnace temperature suggests a possibility of being able to use a smaller boiler furnace.

1. Introduction

Reduction of environmental impact and improvement of plant efficiency are essential in coal fired power stations. Air staging is a well-known technique for NOx reduction and has been studied by various researchers [1–3]. It was concluded that residence time and stoichiometric ratio in the primary combustion zone have a strong effect on NO_x emissions. Over the past two decades, the technology of high temperature air combustion (HTAC) has been developed and researched as a clean and highly efficient process for pulverised coal combustion. HTAC technology is also referred to as Excess Enthalpy Combustion, Flameless Oxidation or Mild combustion [4–8]; it has already been applied to industrial furnaces and heating furnaces [9,10]. A typical way of high temperature air generation is to use a regenerative heat exchanger [11]. This is where flue gas and air supply directions are frequently changed for heat storage and release; fuel supply also has to be switched at the same timing. This fuel switching is the most difficult problem in the application of HTAC in pulverised coal firing. There is a grinding process for producing pulverised coal, causing time lags in the order of several minutes. The indirect firing system (bin storage system) can be applied for avoiding the lag due to grinding, but even in this case a time lag remains due to the distance between coal feeder and burner. The measure proposed here is to generate high temperature air continuously and thereby realise HTAC of pulverised coal without the need of fuel switching. It is suggested to

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mix high temperature flue gas with secondary combustion air to produce a hot combustible mixture of low oxygen content. The concept of this process is shown in the paper by Wünning et al. [5].

There is a large amount of research on pulverised coal [12–19]; however, they are focused on combustion characteristics such as NO_x emissions and burnout. To the authors' knowledge there is no study which is attributed to the burner start-up process.

Suda et al. [12] evaluated the combustion characteristics of pulverised coal in HTAC and obtained significant ignition improvement and decrease of NO_x emissions. Kiga et al. [13] also confirmed that combustion with high temperature air can reduce NO_x emission and improve burnout efficiency. Weber et al. [14] examined the MILD combustion of natural gas, heavy and light oils, and pulverised coal in highly preheated air using a 0.58 MWth furnace. They found that the temperature and concentration fields were uniform, and claimed a high NO_x reduction potential. Li et al. [15] investigated the characteristics of MILD oxy-combustion and air combustion of light oil and pulverised coal in 0.3 MWth pilot-scale furnace. In their experiments, the burnout had generally been poorer for the MILD combustion than the conventional combustion. Stadler et al. [16] investigated the MILD combustion of pulverised coal in various oxidising atmospheres such as air, Ar/O_2 and CO_2/O_2. They showed that there is a potential for reduction of O_2 concentration with MILD oxy-combustion. Mancini et al. [17] performed CFD for evaluation of HTAC technology implementation to pulverised coal boilers. As reviewed above, many researchers have investigated HTAC of pulverised coal, but little research considers an actual boiler operation. Early establishment of HTAC mode in the start-up process yields NO_x reduction for a longer period of operation.

In this research, a new burner is proposed to apply HTAC technology to the pulverised coal fired boiler. In the present experimental work, the performance of a HTAC burner is tested which allows both conventional and HTAC modes. To confirm the applicability of HTAC technology, temperature and oxygen concentration are set lower than in previous studies. The mode switching from conventional to HTAC mode will be demonstrated in Section 3.1. NO_x and burnout are measured to investigate the influence of staged air supply on performance in HTAC mode (Section 3.2). Finally, the temperature distribution within the furnace is examined in Section 3.3.

2. Experimental

2.1. Experimental setup

The combustion experiments are carried out in a bench-scale furnace whose maximum firing rate of pulverised coal is 150 kg/h. The schematic flow diagram is shown in Fig. 1. The furnace has an inner diameter of 1.3 m and is 7.5 m long. It is equipped with refractory-lined fire bricks and a water-cooled jacket with observation ports along the furnace axis. Secondary air can be supplied

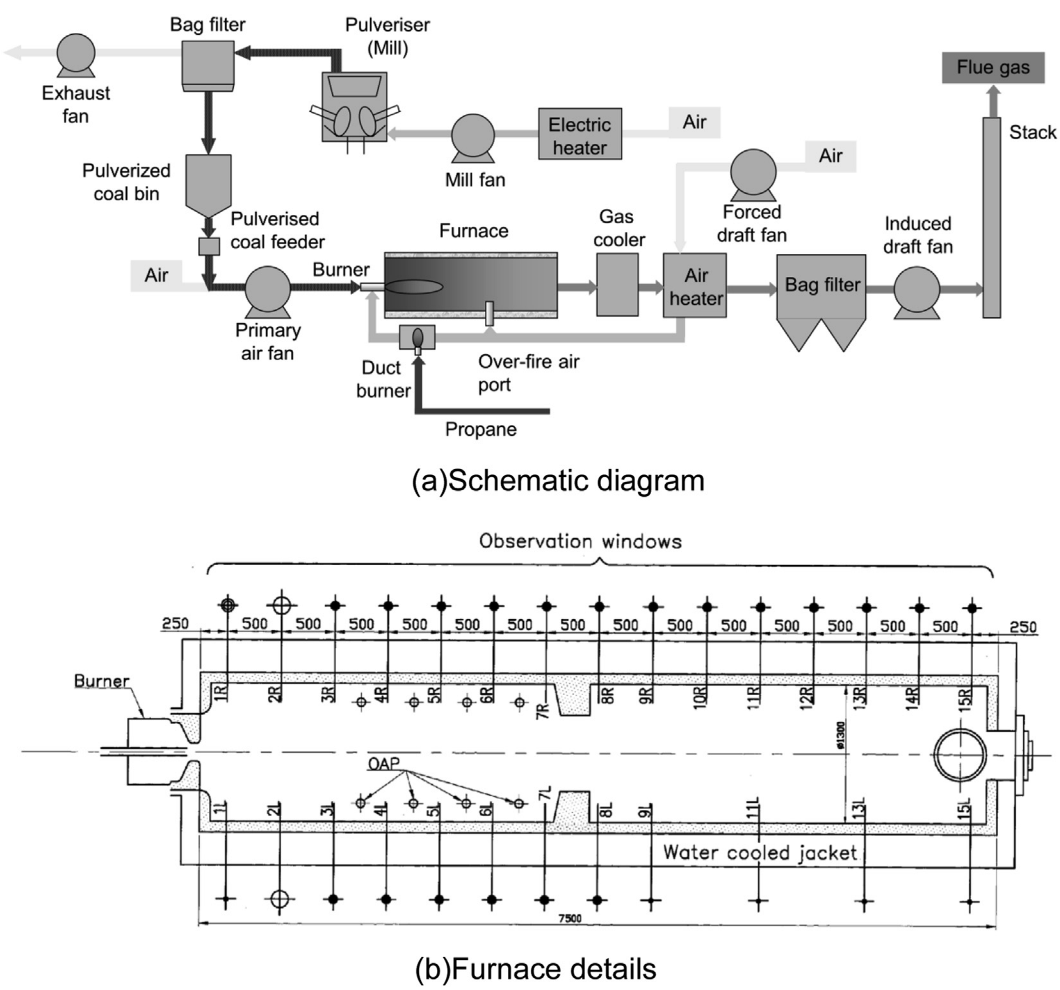

Fig. 1. Experimental facility (1.2 MWth).