Experimental Thermal and Fluid Science 62 (2015) 21–28

Contents lists available at ScienceDirect

Experimental Thermal and Fluid Science

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

An experimental comparison of the airflow characteristics of four-walls tangential firing and four-corners tangential firing

Ming Qin *, Shaohua Wu, Jian Chen, Chao Kong, Lizhe Chen

School of Energy Science and Engineering, Harbin Institute of Technology, 92, West Dazhi Street, Harbin 150001, PR China

ARTICLE INFO

Article history:
Received 12 August 2014
Received in revised form 7 November 2014
Accepted 19 November 2014
Available online 26 November 2014

Keywords:
Four-walls tangential
Four-corners tangential
Airflow characteristics
Tracer
Particle dynamic analyzer

ABSTRACT

A new kind of tangential firing—four-walls tangential firing (FWT)—has been gradually adopted in large utility boilers, particularly supercritical boilers. It is necessary to determine the airflow characteristics of this new method. In this study, we use a cold modeling experimental device in laboratory based on the prototype of one 660 MW power supercritical boiler with FWT. From results of particle tracing and particle dynamic analyzer measurements, we study the airflow characteristics in the furnace. We also compare the observed airflow characteristics with those of traditional four-corners tangential firing (FCT). We are able to discern differences in airflow characteristics between FWT and FCT. We find that for FWT, the rigidity of the jets is not only influenced by the rotating airflows, but also by the adjacent upstream jets. Furthermore, the airflow velocities close to the wall of FWT are significantly higher than those of FCT and the directions of the airflow are almost all oriented toward the wall.

1. Introduction

Tangential firing is the primary method used for pulverized coal combustion. Its advantages include its adaptability to different coal types, its ability to burn low-grade coal, and its ease of low NO_X combustion [1–3]. As a result of the multiple types of coal used by power stations, pulverized coal combustion mostly uses tangential firing [4,5]. For tangential firing, the burners are traditionally arranged at the four corners of the furnace. This type of firing is accordingly referred to as four-corners tangential firing (FCT). The so called tangential firing is that the airflow from the whole burners could form a designed circle (or imaginary circle) in the furnace in order to create an intensive swirling airflow. During operation, the upstream airflow and flame can ignite the adjacent downstream pulverized airflow in the direction of the airflow, forming an entire intensive swirling flow field, thereby guaranteeing stable combustion [6–8]. Therefore, for tangential firing, forming a proper overall aerodynamic field in the furnace is crucial. During operation, the real circle size is significantly larger than the designed circle. Also, because of the variety of jet rigidities along the height of the furnace burners, the real circle sizes differ [6,9].

With the raising of utility boiler parameters, a new type of tangential firing has been developed by MHI Co of Japan. This new kind of tangential firing is called four-walls tangential firing (FWT) [10–12]. As seen in Fig. 1, the burners in FWT are arranged at the four walls of the furnace and the size of the tangential circle of FWT is much larger than that of FCT. This firing technique is gradually being adopted by large utility boilers. Guo et al. [13] took the cold industrial test on the variation of the tangential circle in furnace. The study indicated that the airflow characteristic of FWT is different with what of the traditional FCT. In fact, previously, FWT was once used in some small utility boilers [14–17]. However, size of the deigned tangential circle of that kind of FWT is small, similar to what of FCT. Comparatively, the designed tangential circle of the new FWT technique is clearly larger.

The objective of this experiment is to study the airflow characteristics in furnace of the new type of FWT, and compared with which of the traditional FCT.

We adopted a technique of cold modeling in a laboratory, using a flow tracer and particle dynamic analyzer (PDA) measurements to investigate the airflow characteristics of the new FWT compared with FCT.

2. Experimental set-up

The experiment used one 660 MW supercritical boiler as the prototype which applied FWT and fired lignite coal. The burners' arrangement is seen in Fig. 2. Each burner is divided into two groups. There are six primary air (PA) nozzles (one for spare), others are secondary air (SA) nozzles. The velocity of PA and SA

* Corresponding author.
E-mail address: qinming7632@163.com (M. Qin).

http://dx.doi.org/10.1016/j.expthermflusci.2014.11.011
0894-1777/

are 26 m/s and 47 m/s respectively, and their momentum ratio is 1:3.58.

As the theory of similarity and modeling [18,19], cold modeling experiment should mainly meet the following conditions: (1) geometric similarity of structure, (2) the same momentum ratio of PA to SA and (3) flowing in the secondary self modeling area. Li [20] recommends that for the study on airflow characteristics or mixing in the furnace, Reynolds number of nozzle jet above 1×10^4 is sufficient, and for furnace with tangential firing, the number should be above $2–3 \times 10^4$.

The experimental study adopted geometric similarity; the ratio of the model to the full scale is 1:17. The furnace cross section size of the experimental set up is 1.2 m (width) × 1.18 m (depth). Table 1 shows the major design parameters of the model.

Fig. 3 shows the experimental set up.

The burners were designed to be replaced, i.e., they can be arranged either at the four walls or at the four corners. During testing, the positions without burners were covered with sealing plates to simulate each arrangement of burners. The flow rate of each nozzle could be adjusted by the manual valve connected with it to reach the required operating parameters. Each connecting pipe was allocated one backrest and one U tube to measure the flow pressure, and after conversion, nozzle jet speed could be gained. Before testing, all measuring instruments were calibrated and determine the corrected coefficient.

The experimental system is shown in Fig. 4.

The serial number of the air feeding pipes connected to the nozzles can be seen in Table 2.

During the tracer experiment, nozzles connected with the No. 2, 4, 6, 7, 10, and 11 pipes, which are shown in Table 1, are selected to feed glass beads to observe the airflow characteristics of various cross sections of the furnace. Meanwhile, a camera is set on top of the experimental device for recording. The use of polarizer could filter out other layers of particles in the recording picture. Glass beads mixed with air are fed into the furnace through the nozzles; the fines (10 μm) are simulated air and the coarse (40 μm) are simulated pulverized coal [21].

For comparison, the same burners are arranged at the four walls and the four corners, respectively. During experiment, the operating parameters, such as airflows and velocities were held constant. The following experimental conditions were tested: (1) the airflow characteristics in the furnace, for both FWT and FCT and (2) the jet characteristics of the PDA measurements near the primary air (PA) nozzles, for both FWT and FCT.

The experimental study use flow tracer and particle dynamic analyzer (PDA) measurements. PDA could measure flowing parameters of two phrases of gas–solid [22–24]. The principle of PDA test is the principle of phase Doppler. It could measure particle velocity, size, and concentration of two phrases of gas–solid, and the test is non-contacted. When measuring, laser focusing point moves with the 3D coordinate frame, realizing the continuous measurement automatically, the maximum displacement is about 590 mm. So limited by the displacement, during experiment, PDA was just used to measure jet parameters outside of some nozzles. The measuring range and accuracy of PDA are shown in Table 3.

During PDA testing, the feeding positions of all the particles are set at the third lowest PA nozzles. For applying PDA, the furnace walls are used toughened glass. Fig. 5 shows the PDA testing.

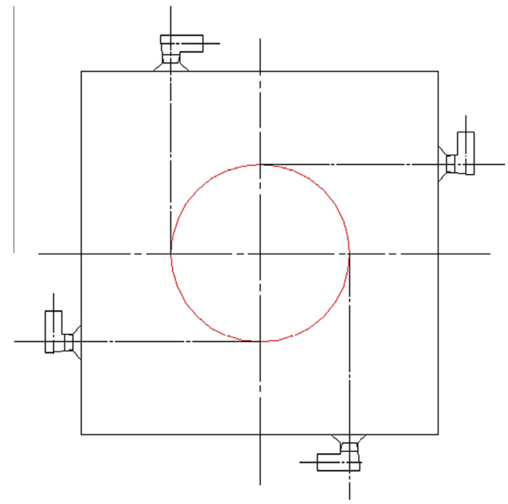

Fig. 1. Schematic of FWT.

Each burner is allocated one particle feeder. For uniform feeding, feeders were calibrated before testing, and during test the four feeders at same layer were operated simultaneously.

3. Experiment

3.1. FWT experiment

3.1.1. Tracer experiment

When experiment, the operation parameters were adjusted to the design parameters, the average velocity of PA is 9.49 m/s and SA is 12.17, their momentum ratio is 1:3.84.

The glass beads were fed through the nozzles connected to the No. 2, 4, 6, 7, 10, and 11 pipes. The jet flow traces are shown in the following figures; these data were recorded by the camera set on top of the experimental device (see Figs. 6–11).

From the above figures, it can be seen that the jets from the No. 11 pipes, which linked the lowest PA nozzles, deflected substantially to the wall. The jets from the adjacent No. 10 pipes connected with the low secondary air nozzles also deflected clearly, although the deflection was less than that of the No. 11 pipes because of the jet rigidity of the SA, which is stronger than that of the PA.

Along the burner height upwards, jets rigid are obviously strengthening and deflection are ease, as in the case for the PA nozzles of the No. 7 pipes and the SA nozzles of the No. 6 pipes. However, for the lowest SA nozzles of the No. 4 pipes of the second group burners, the airflow deflections become more significant again. Furthermore, the air rigidity of the top SA nozzles of the second group burners connected with the No. 2 pipes apparently shows an increase.

We have shown that the primary reason for the significant jet deflection of the lowest SA nozzles is that, in FWT at the low area of the burner, the jets are clearly affected by the jets of the same layer from the adjacent upstream burners. Up along height of the burners, with a gradual increase in the rotating airflow, the rotating air layer becomes thicker and the influence of the jet on the adjacent upstream burner weakens. Therefore, the jet deflection

Table 1
Design parameters of the model.

PA speed ($m\ s^{-1}$)	SA speed ($m\ s^{-1}$)	Momentum ratio of PA to SA	Total flow rate ($m^3\ h^{-1}$)	Re of nozzles' jet	Re of furnace
9.0	12.34	1:3.58	3566	$>2.5 \times 10^4$	5.34×10^4