Powder Technology 332 (2018) 178–187

Contents lists available at ScienceDirect

Powder Technology

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

Effect of transverse rib on heat transfer between circulating fluidized bed and membrane fins of water wall membrane tubes

Jiraroch Somjun, Anusorn Chinsuwan *

Mechanical Engineering Department, Faculty of Engineering, Khon Kaen University, Khon Kaen 40002, Thailand

ARTICLE INFO

Article history:
Received 28 September 2017
Received in revised form 16 January 2018
Accepted 19 March 2018
Available online 22 March 2018

Keywords:
CFB
Bed to wall heat transfer
Particle convection
Heat transfer enhancement
Membrane water wall tube

ABSTRACT

Overall heat transfer between circulating fluidized beds (CFB) and the ribbed membrane fins of a water wall tube was investigated experimentally in a cold model circulating fluidized bed riser. The riser had a cross sectional area of $0.1 \times 0.2\ m^2$ and the height from the distributor plate to the riser exit was 3.9 *m*. Three isosceles triangular cross section prisms having a height to base width ratio (e/B) of 0.54 corresponding to the height to riser diameter ratios (e/D) of 0.019, 0.038 and 0.06, respectively were used as ribs. The ribs were installed transversely on the fins with three rib spacings (S) of 0.4 *m*, 0.5 *m*and 0.6 *m*. Local sand having an average diameter of 315 μm was used as the bed material. It was found that the heat transfer coefficients and the cluster solid fractions of the ribbed membrane fins were higher than those of the membrane fin, and varied with the rib spacing and the rib height to diameter ratio in the same manner. In addition, cluster contact time of the ribbed membrane fins was shorter than that for the membrane fin without ribs.

1. Introduction

As it has many advantages such as fuel flexibility, high efficiency, adaptability to load change, and low emission, the circulating fluidized bed (CFB) boiler has become increasing popular in the electrical generation market. Installations are growing exponentially in both the number of units and capacity in the last decades. Recently, CFB boilers are operating in capacities up to 600 MW_e [1].

High unit capacity requires a large amount of footprint area, materials, and also high construction cost which causes high initial cost. Improvement of the furnace side heat transfer coefficient is one way to reduce the cost.

A water wall membrane fin is used as the furnace wall of CFB boilers so that heat transfer enhancement can be achieved by enhancing the heat transfer of the tube portion, the fin portion or both portions. Some information about the heat transfer enhancement of the tube portion can be found in the literature [2–4]. However, literature reporting the enhancement of the fin portion is very rare. As the fin has tubes on both its sides, the flow of clusters along the fin is restricted by the tubes. Furthermore, the tubes also obstruct the turbulence, which affects the flow. These prolong the cluster contact time and obstruct renewal clusters coming into contact with the fin. As a result, the heat transfer coefficient of the fin tends to be lower than that of the tube [5,6]. Hence, an enhancement of the heat transfer of the fin portion should improve its heat transfer coefficient.

Sand is usually used as the bed material or solid particles in the boiler furnaces. The flow inside it has a core – annulus structure [7]. The solid particles from the core, which has relatively dilute solid particles flowing up, move to the furnace wall and flow down along the wall as particle clusters, before they disperse and move to the core again. Heat transfer between the bed and the wall takes place during the downward flow of the clusters. As the wall is not fully covered by the clusters, but alternately covered by cluster and dilute phases, the overall heat transfer is dependent on the cluster wall coverage fraction, and the heat transfer from the dilute and cluster phases.

According to the cluster renewal model [8–17], the cluster phase heat transfer coefficient is dependent on the solid fraction, the thermal conductivity and the contact time of the cluster, whereas in the dilute phase the heat transfer coefficient is dependent on the flow behavior near the wall, which also affects the parameters influencing the cluster phase heat transfer. Hence, an improvement of the wall configuration in such a way that it can induce more high temperature solid particles to hit the wall, replacing the air near the wall by the high temperature air from the furnace core, and reducing the contact time, can enhance the heat transfer. For flow inside ribbed ducts, the ribs induce secondary flow in the form of a pair of vortices which convey the cold and higher momentum fluid from the core region towards the duct wall and augment heat transfer [18,19]. This concept may be used to enhance the heat transfer of the fin portion [20].

Bed to wall heat transfer in CFB boilers were studied by experiment [15] and mathematical modeling such as fuzzy logic approach [21–23] or neutral network approach [24]. However, literature on experimental data of heat transfer enhancement between membrane fins of the water

* Corresponding author.
E-mail address: anuchi@kku.ac.th (A. Chinsuwan).

https://doi.org/10.1016/j.powtec.2018.03.050
0032-5910/

wall membrane tube of a CFB boiler and the fluidized bed is very rare. Hence, the aim of this work is to investigate the heat transfer of the membrane fins having isosceles triangle transverse cross section ribs. In addition, the effects of the rib spacing and the rib height to riser diameter ratio on dilute phase and cluster phase heat transfer are investigated. The results reveal the behavior of the heat transfer of the ribbed membrane fins which can be used to improve the furnace side heat transfer of CFB boilers.

2. Experimental setup

The experiment was performed in a cold model fluidized bed riser having a cross sectional area of $0.1 \times 0.2\ m^2$and a height from the distributor plate to the riser exit of 3.9 *m* as shown in Fig. 1. It is fabricated from carbon steel. A high pressure blower is used to supply fluidization air. The air at temperature of about 45 $^{\circ}C$ enters the riser via the distributor plate located at the bottom of the riser. Local sand which has an average diameter of 315 μm is used as bed material. The sand particles leaving from the riser are captured by a cyclone at the top of the return pipe. The loop seal at the bottom of the riser is used as a particle control valve. The solid circulation rate is controlled by adjusting the aeration rate supplied at the bottom of the loop seal. The supplied air flow rate is adjusted by the pass valve installed at the supply pipe between the blower and the riser. The flow velocity is measured by a Pitot tube installed in the supply pipe.

The test section has a height of 0.6 *m* and is installed at 1.95 *m* above the distributor plate. Its detail is shown in Fig. 2. Solid wooden half cylinders being 25.4 *mm* in diameter are used as water wall tubes. They are installed on 6 *mm* thickness plywood with spacings of 50 *mm* to form the membrane fin water wall tube. Two pressure taps are installed at the top and the bottom of the test section to measure the cross sectional average suspension density of the bed across the test section.

On the membrane fin between the tubes, ten optical sensors and nine heat transfer probes are installed at equal spacing along the test section height. Details are shown in Fig. 3. The heat transfer probe has a surface area of $25.4 \times 25.4\ mm^2$and is fabricated from silver brazing

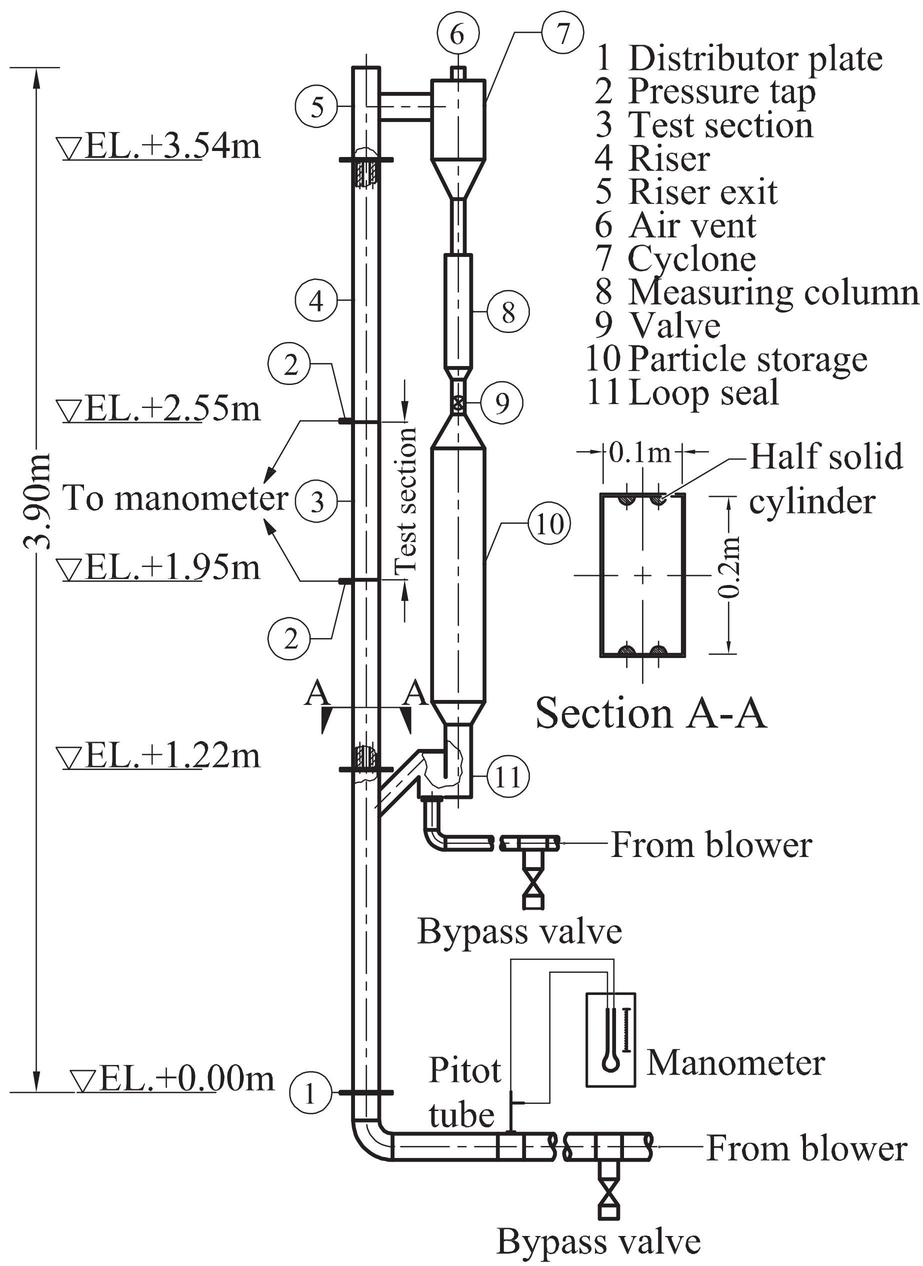

Fig. 1. Arrangement of the experimental rig.