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Parametric studies and effect of scale-up on wall-to-bed heat transfer characteristics of circulating fluidized bed risers

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ABSTRACT

In the present work a comparative study of steady state wall-to-bed heat transfer was conducted along the risers of height 2.85 m of three different circulating fluidized beds (CFBs) with bed cross sections of 0.15 m × 0.15 m, 0.20 m × 0.20 m, and 0.25 m × 0.25 m, respectively. Experiments were conducted on each CFB unit for five superficial air velocities (U = 2.5 m/s, 2.75 m/s, 3 m/s, 3.3 m/s, and 4 m/s) and two different weights of sand inventory per unit area of the distributor plate (P = 1750 N/m^2 and P = 3050 N/m^2) with average sand particle size of 460 μm. Bed temperature distributions across the three risers were measured and compared at different heights (1.04 m, 1.64 m, and 2.24 m above the distributor plate). Axial distribution of heat transfer coefficient along the height of riser was evaluated and compared for the three bed cross sections. Effect of superficial velocity of air, sand inventory, and bed cross section on bed temperature and heat transfer coefficient was investigated. An empirical correlation was developed for the bed Nusselt number as a function of various non-dimensional parameters based on the parametric study. The correlation was compared with available literatures.

1. Introduction

Use of circulating fluidized bed (CFB) boilers in power generation is gaining popularity mainly due to its environmental compatibility and high efficiency. A large number of CFB units are installed for power generation throughout the world [1]. These units require fast control of temperature with quick change of load which is accomplished with addition or removal of thermal energy of fuel–air mixture. Therefore fluidized beds are designed to contact the fluidized medium with heat transfer surfaces like membrane water walls. Design and scale-up of these surfaces require knowledge of the heat transfer coefficient at the wall surfaces in contact with the fluidized medium. Present work is an attempt towards the evaluation of the heat transfer characteristics with different square cross-section of 3 (three) CFB Units.

Extensive literature is available on heat transfer and hydrodynamics of single riser of CFB [2–8,23,24]. Similarly, large numbers of papers are available on the effect of scale-up on CFB hydrodynamics [9–14]. However, scale-up studies on heat transfer are limited to a few papers only [15–17].

Chen et al. [15] reported mechanistic models, which were based on the surface renewal concept. These models may be used for design heat transfer systems for both bubbling dense beds and fast circulating fluidized beds. Predictions of these models are in good agreement with available heat transfer data, with few points lying outside of ±25% bands. Mickley and Trilling [16] and Danziger [17] reported empirical correlations to evaluate bed Nusselt number from scale-up of two circular risers of different diameter. However, it was observed from literature that the hydrodynamics characteristics differ significantly with the geometry of the bed cross section [18] and bed hydrodynamics strongly influences the heat transfer characteristics [19]. Risers of square and rectangular cross-sections are now widely employed in circulating fluidized bed applications [18]. Hence, there is high demand for scale-up study of CFB on heat transfer characteristics with square cross-sections.

Therefore in the present work, effect of scale-up on wall-to-bed heat transfer characteristics is studied using three CFB units of height 2.85 m with bed cross sections of 0.15 m × 0.15 m, 0.20 m × 0.20 m, and 0.25 m × 0.25 m, respectively. To accomplish the scale-up study, experiments were conducted under similar operating conditions with five superficial air velocities (U = 2.5 m/s, 2.75 m/s, 3 m/s, 3.3 m/s, and 4 m/s) and two different weights of sand inventory per unit area of the distributor plate (P = 1750 N/m^2 and P = 3050 N/m^2). Sand particles with average size 460 μm were used in all the experiments. Effect of bed cross section on the heat transfer coefficient and bed temperature was compared for all the three beds. A new empirical correlation was developed for bed Nusselt number as a function of Reynolds number, non-dimensional density parameter and non-dimensional geometrical parameter. Ef-

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