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Heat transfer characteristics in a horizontal swirling fluidized bed

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ABSTRACT

An innovative horizontal swirling fluidized bed (HSFB) with a rectangular baffle in the center of an air distributor and three layers of horizontal secondary air nozzles located at each corner of fluidized bed was developed. Experiments on heat transfer characteristics were conducted in a cold HSFB test model. Heat transfer coefficients between immersed tubes and bed materials in the HSBF were measured with the help of a fast response heat transfer probe. The influences of fluidization velocity, particle size of bed materials, measurement height, probe orientation, and secondary air injection, etc. on heat transfer coefficients were intensively investigated. Test results indicated that heat transfer coefficients increase with fluidization velocity, and reach their maximum values at 1.5–3 times of the minimum fluidization velocity. Heat transfer coefficients are variated along the circumference of the probe, and heat transfer coefficients on the leeward side of the probe are larger than that on the windward side of the probe. Heat transfer coefficients decrease with increasing of measurement height; heat transfer coefficients of the longitudinal probe are larger than that of the transverse probe. The proper secondary air injection and particle size of bed materials can generate a preferred hydrodynamics in the dense zone and enhance heat transfer in a HSFB.

1. Introduction

Circulating fluidized beds (CFBs) have been successfully used in fossil fuel combustion, coal and biomass gasification, and fluid catalytic cracking. In combustion and gasification, CFB technology offers significant advantages such as fuel flexibility, in-bed sulfur capture, and relatively low NO_x emissions with high efficiencies [1,2]. The advanced swirling fluidized bed combustion (SFBC) is one of the alternative ways to improve FBC performance by introducing the secondary air through the tangential direction into the combustor, in which the residence time distributions of feed materials as well as gas products in the reactor can be controlled. The swirling fluidized bed combustion technology can be applied in waste management to reduce an amount of wastes in communities, cities, or countries all over the world. The SFBC is expected to possess the following advantages: (1) high combustion efficiency, (2) wide fuel flexibility, (3) low emissions, (4) enhanced mass/heat transfer, and (5) large firing intensity [3,4].

In many fluidized bed applications, it is necessary to add or extract heat in order to maintain the operating temperature at a desired value. The design and scale-up of heat transfer surfaces require the knowledge of the bed hydrodynamics and heat transfer coefficient at the wall surfaces in contact with the fluidized mass [5,6]. However, the thermo-physical behaviors of gas–solid in a fluidized-bed reactor are highly complicated and sometimes random owing to the irregular contacting and flow behaviors of gas and solid. Numerous experimental investigations have been carried out to measure heat transfer in CFBs at room and high temperatures. Grace [7], Leckner [8], and Basu and Nag [9] have presented comprehensive reviews of CFB heat transfer. Tian et al. [10,11] studied heat transfer of an immersed tube in an internal circulating fluidized bed, and indicated heat transfer characteristics were found to be significantly different from that in a bubbling bed. Up to now, a few published works are available to explore hydrodynamics and heat transfer in a horizontal swirling fluidized bed, especially heat transfer among gas–solid and immersed surfaces.

In this paper, a HSFB with a rectangular baffle in the center of an air distributor and three horizontal secondary air nozzles located at each corner of fluidized bed was developed. Heat transfer characteristics in a horizontal swirling fluidized bed were studied under different operating conditions. Heat transfer coefficients between the immersed tubes and bed materials were measured with the help of a fast response heat transfer probe. The effects of fluidization velocity, particle size of bed materials, measurement height, probe orientation, and secondary air injection rate, etc. on heat transfer were intensively analyzed.

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