International Journal of Heat and Mass Transfer 54 (2011) 2228–2233

Contents lists available at ScienceDirect

International Journal of Heat and Mass Transfer

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

Technical Note

Heat transfer in gas–solid fluidized bed with various heater inclinations

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ARTICLE INFO

Article history:
Received 30 March 2010
Received in revised form 9 September 2010
Accepted 3 November 2010

Keywords:
Fluidized bed
Gas–solid
Heat transfer
Inclined heater

ABSTRACT

The study explored the heat transfer properties in an air-fluidized bed of sand, heated with an immersed heat transfer tube positioned at several angles of inclination. Operating with fluidizing velocity up to 0.5 m/s; and particles of 150–350 μm diameter, the effect of air velocity and particle size on the average and maximum achieved heat transfer coefficient was examined for the heat transfer tube at angles of inclination in the range 0–90°. Experimental results showed that the angle of inclination altered the bubble size and behavior close to the heat transfer tube hence the expected heat transfer coefficient, with the influence of tube inclination being less pronounced for smaller particles. The optimum angle of inclination was in the range of 10–15° relative to the direction of the flow, while the heat transfer coefficient had its lowest values at the angle of 45°, and thereafter improved upon transition to 90°. Upon comparison with existing correlations, a correction factor is proposed to account for the impact of the angle of inclination on the heat transfer coefficient calculated by the Molerus–Wirth semi-empirical correlation.

1. Introduction

The isothermal environment and high heat transfer efficiency between a fluidized bed and immersed objects; offers significant advantages over conventional reactors. However, the reliable prediction of the heat transfer behavior in a certain fluidized system requires knowledge of many interacting factors such as the size of fluidization vessel, the design of the fluid distributor and vessel internals, and the operating temperature and pressure [1,3].

Heat transfer studies involving a tube or a bundle of immersed vertical/horizontal tubes are frequently encountered in literature [3–13]. In addition, other less-frequent studies dealt with the problem of fluidized beds incorporating inclined heat transfer surfaces [3–6], with conflicting results as seen below.

Experiments by Gelperin et al. [3], showed no appreciable systematic increase in the heat transfer coefficient with the change in the angle of attack; that is, the angle between the centerline of the tube, and the direction of airflow. There was only a slight tendency for the heat transfer coefficient to increase upon the gradual transition form horizontal to the vertical position. The maximum heat transfer coefficient was 5–6% higher in the case of vertical tubes. On the rising branch of the heat transfer coefficient–velocity curve, the coefficients showed 5–7% uncorrelated deviation from their maximum.

Genetti et al. [4] investigated the effect of the inclination on the heat transfer characteristics of bare and finned tube elements. Their tests showed a minimum value for the tube to bed coefficient when the tube was inclined at an angle of 45° to the vertical within the bed. In addition, coefficients were observed to reduce as the angle of inclination from the horizontal increased. A reduction of 32% from the value obtained in the horizontal position occurred when the finned tube was mounted at an inclination of 60° in the bed.

Philippovsky and Baskakov [5] studied the temperature distribution close to a heat transfer plate; heated on one side, and immersed at different angles of inclination in a fluidized bed of rectangular cross section. They observed a considerable change in the value of the heat transfer coefficient, from 200 W/m^2 °C in the upstream horizontal position, to a value of 450 W/m^2 °C upon the transition to an inclination of 10° to the vertical; and a reduction from 300 W/m^2 °C in the vertical position, to 60 W/m^2 °C in the downstream position.

Stojanovic and Stojiljkovic [6] investigated the influence of the fluidization velocity on heat transfer between a fluidized bed rectangular in cross section and an inclined heat transfer tube. The obtained heat transfer coefficients showed similar tendency of change with increasing the fluidization velocity, for all the heater inclinations.

They observed a maximum value of heat transfer coefficient to appear at the angle of inclination of 10–15°, and found angles of inclination beyond 60° to have insignificant influence on the change in heat transfer coefficient.

The purpose of the present study is to assess the influence of the angle of inclination on the heat transfer process between a heat transfer tube and an air-solid fluidized bed under different gas velocities and with different particle diameters, and compare the

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doi:10.1016/j.ijheatmasstransfer.2010.12.028