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Effect of Velocity and Particle Size on the Coefficient of Heat Transfer in Fluidized Bed Heat Exchanger

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ABSTRACT - Fluidized bed Heat exchangers are important inmany industrial applications. Understanding how a fluidized bed as a multiphase flow system operates will improve its capabilities and operations. Minimum fluidization velocity and local gas holdup are important parameters used to characterize the hydrodynamic behavior of a material inside the fluidized bed.

Fluidization is the phenomenon of imparting the properties of a fluid to a bed of particulate solids by passing atmospheric air through the material. Fluidized beds are reactors in which fluidization of particulate solids takes place. Fluidized beds are an important asset in many industrial processes because they present several advantages that include a high rate of heat and mass transfer, low pressure drops, and uniform temperature distribution.

Experiments have been carried out in a setup i.e. in a fluidized bed heat exchanger, to find out the Heat transfer coefficient between different silica sand particles and in different velocities of air. The whole sand bed is heated by cartage heater. An experiment is performed with three different sand particles with different diameter and ten different gas velocities. The bed particles are chosen by taking Geldart's criteria. Silica sand particles are of diameter 300-450μm, 425-650μm and 600-850μm. Fluidization is carried out by using air having normal temperature.

It was found in literature survey that Higher rate of heat transfer is obtained by increasing the flow rate and by decreasing the size of the particle.

The experimental results showed that the Heat transfer coefficient is increased with increasing the air velocity. It is also found that the Heat transfer decrease by increasing the particle size for Geldart B group particles.

Keywords: Fluidization, Fluidized bed heat exchanger, Bubbling Fluidization,Silica sand, heat transfer, Thermal coefficient, Heat Transfer coefficient, Operating variables,Gas velocity

1. INTRODUCTION

The major objectives of this work are to study the heat transfer effect on the fluidized bed, to determining the heat transfer rate at different points in the fluidized bed, to determine the effect of heat transfer at different sand particle and with varying velocity of air. A setup of thermal-coil is inserted in the fluidized bed to study the effect of heat transfer rate from the particle to fluid that is air bubbling Gas-Solid fluidized bed in order to find the suitability of sand as a bed material in Gas-Solid fluidized bed An experiment has been carried out in a setup of fluidized bed heat exchanger with atmospheric air as a fluidizing medium and silica sand of diameter 300-450μm, 425-650μm and 600-850μm diameter.

When a gas flow is introduced through the bottom of a bed of solid particles, it moved upward through the bed via the empty spaces between the particles. At low gas velocities, aerodynamic drag on each particle has also low, and thus the bed remained in a fixed state. Increased in the velocity, the aerodynamic drag forces started to counteract the gravitational forces caused the bed to expand in volume as the particles moved away from each other. Further increasing the velocity, it is reached a critical value at which the upward drag forces exactly equal the downward gravitational forces, caused the particles to become suspended within the fluid. At this critical value, the bed is said to be fluidized and is exhibit fluidic behavior. By further increased in gas velocity, the bulk density of the bed is decreased, and its fluidization became more efficient, until the particles no longer formed a bed and are "conveyed" upwards by the gas flow. When it fluidized, a bed of solid particles behaved as a fluid, like a liquid or gas.

A large amount of research is done on this technology due to the advantages of fluidized bed reactors. Most current research have been done to explain how the velocity of gas affects the heat transfer in fluidized bed under varying particle size and velocity of air. Lots of literature available on the heat transfer coefficient, but there is considerably less literature available on the heat transfer coefficient in that they give effect of different velocities on heat transfer in presence of horizontal cartage heater.

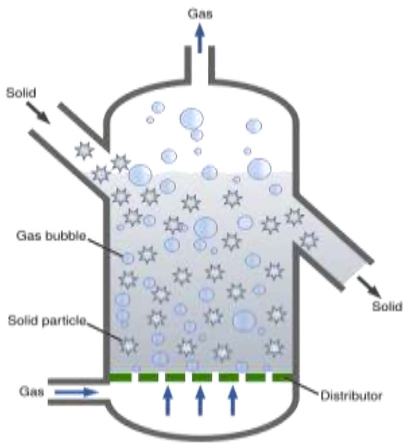

Figure1: schematic drawing of a fluidized bed

Anusaya M. Salwe, 2013 made her study on Local heat transfer coefficient around a horizontal heating element in gas-solid fluidized bed and concluded that the heat transfer rate is observed maximum at the 0 degree and minimum at 180 degree from the bottom of the chamber. They also carried out experiments in a laboratory gas-solid fluidized bed heat exchanger. Heat transfer coefficient between immersed heated tube and bubbling fluidized bed is found experimentally around a tube. An experiment is performed with three different particle diameter and ten different superficial gas velocities. The bed particles used were Geldart B silica sand particles of diameter 200µm, 350µm and 500µm. Fluidizing media used was atmospheric air. The experimental result shows that Heat transfer coefficient is increase with increase in the air velocity and it is found to be decreased by increased in the particle size for Geldart B group particles. G.K.Roy& K.J .R. Sarma(1970) concluded that the heat transfer in fluidized bed is by convection. Francesco Miccio, Andrea De Riccardis, Michele Miccio (2009) determined the heat transfer coefficient for bubbling fluidized bed. Araí A. BernárdezPécora and Maria Regina Parise, (2006) concluded that Heat transfer coefficient increases with the solid particle mass flow rate. Jelena N. Janevski, BranislavStojanović, (2004) concluded that thermal conductivity depends on the intensity of mixing and heat transfer rate is higher in axial direction than radial direction.

2. EXPERIMENTAL PROGRAMME

The two-dimensional fluidized-chamber (shown schematically in Fig. 1) is 150 mm in length, 120 mm width and 800 mm tall (internal dimensions), constructed of 1 mm thick galvanized sheets. This fluidizing air is regulated by butterfly valve before passing through a sintered-metal plate distributor. Metal distribute plate is fixed in between fluidizing chamber and lower rectangular funnel. Pressure drop across the distributor is sufficiently high that at most fluidizing conditions it exceeds the pressure drop over the rest of the bed.

Fluidized bed heat exchange chamber contains bed of sand particles which is of same dimension as that of fluidizing chamber; the height of sand bed is 120 mm with inserted cartage heater (thermal coils[7]) as well as systems of air supply, and heat supply from the dimmer stat[8]. The heating coil is located 100 mm above from the bottom of the fluidized bed. The heater has dimension of 15 mm diameter. The surface of the active side of the heater is inserted in the sand particles. Air enters from the blower[1] and is transferred through the pipes towards the nozzle[6]connecting the distributor plate in the fluidized bed and the blower pipeline. Quartz sand[3] with diameters in the range of 300-450µm, 425-650µm and 600-850µm was employed in fluidized bed. The power of the heat exchanger can be varied using a dimmer stat.

Air from the blower is supplied from the atmosphere and ambient temperature and pressure. The air from the blower is connected through a butterfly valve where the velocity of the air coming can be controlled.

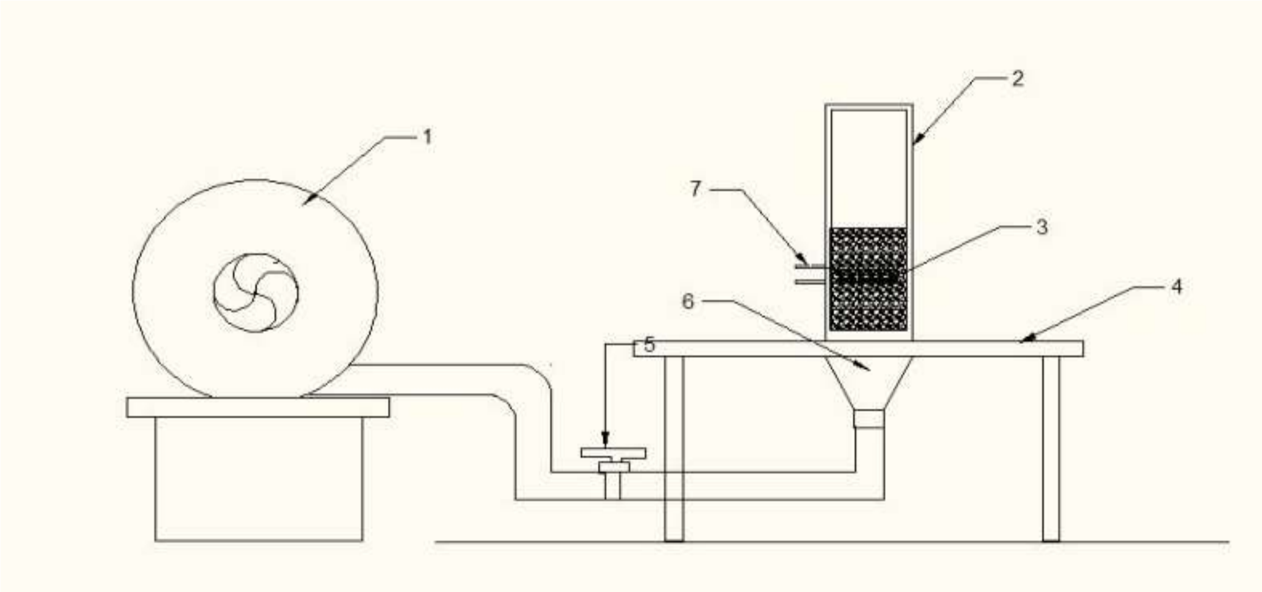

Figure 2: General Experiment setup

(1.Blower, 2.Fluidised bed chamber, 3.Be particles, 4.Support, 5.Valve (butterfly valve),

6. Distributor plate setup, 7.Thermal coils (with fins and without fins))

Readings are taken by taking one sand particle at different velocities. All the readings are taken at a steady state. Likewise all the readings are taken for different sand particle, with varied velocity of air.

2.1 INSTRUMENTATION

In the setup, different 4 number of k type thermo couples are attached to the chamber in contact with sand bed, for getting different temperature reading from different places of fluidized bed. 2 more thermo couples are attached on the upper and lower surface of cartage heater for giving the temperature reading. A Voltmeter and Ammeter is used to vary the voltage and current. A blower of the capacity 1.5 m^3/min. is used to supply compressed air to the fluidizing column through diffuser and distributor plate. A butterfly valve mounted over an inlet pipe allows regulating the rate of flow of air. A differential manometer is connected across an orifice meter. Readings of the manometer is calibrated to get the velocity of the inlet air. Another differential manometer is connected to the fluidizing medium to find the pressure drop across the column.

3. RESULTS

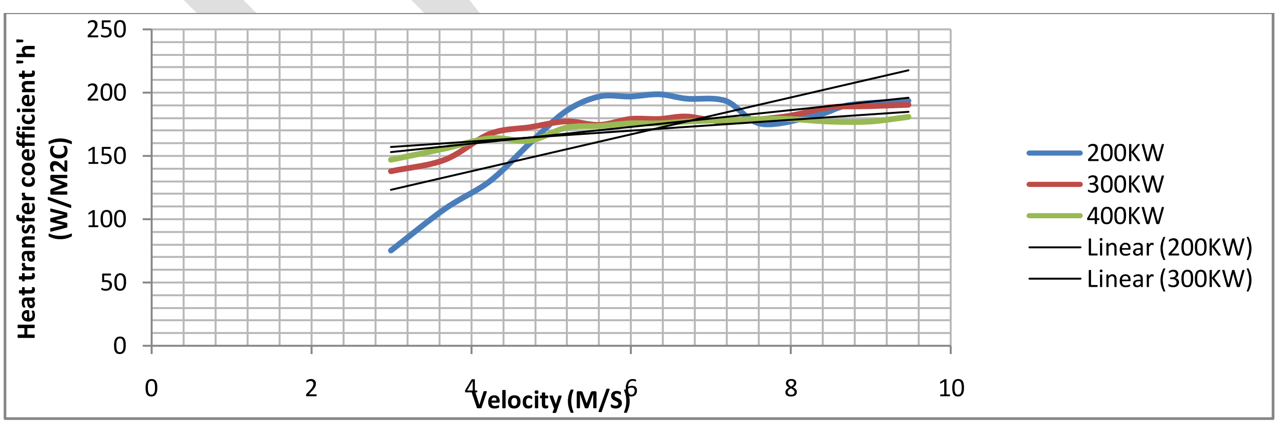

Figure 3: Distribution of heat transfer coefficient in different velocities for Sand particles size 300-450µm.

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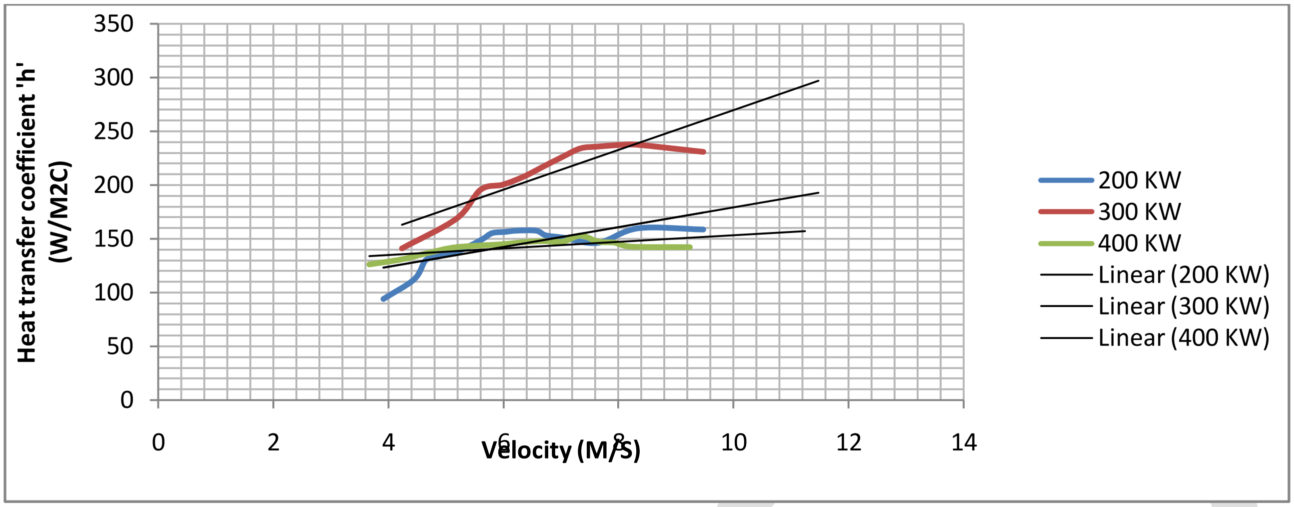

Figure 4: Distribution of heat transfer coefficient in different velocities for Sand particles size 425-650µm.

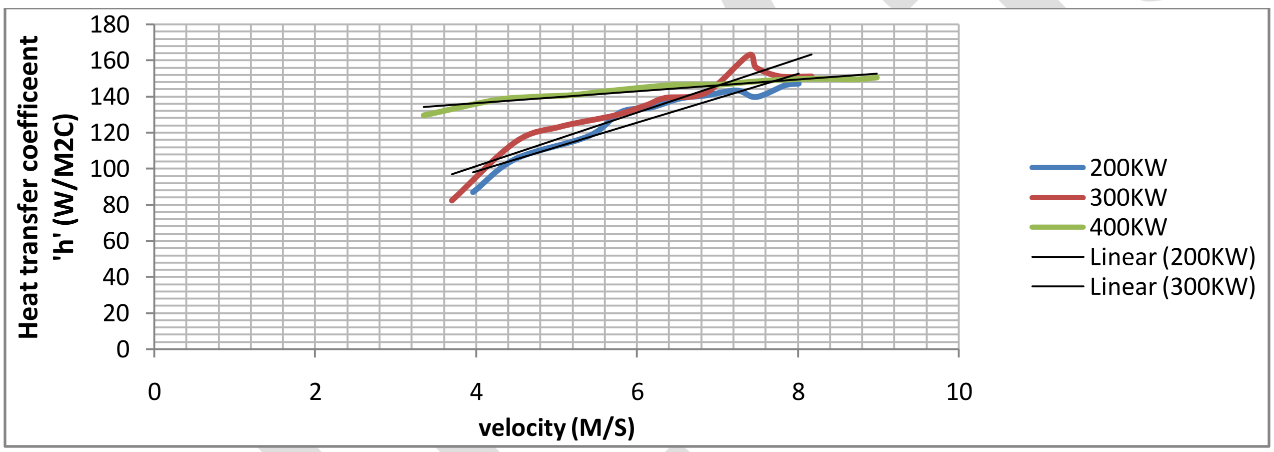

Figure 5: Distribution of heat transfer coefficient in different velocities for Sand particles size 600-850µm.

4. CONCLUSIONS

[1] Silica sand is having good fluidizing properties.
[2] The overall heat transfer coefficient h increases with increase in velocity and as the particle size increase, the heat transfer coefficient decreased. This is proved in fig.3, 4 and 5.
[3] Heat transfer coefficient between heated tube and silica sand varies between 80 to 250 W/m^{2}K.

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