IPASJ International Journal of Mechanical Engineering (IIJME)

Web Site: http://www.ipasj.org/IIJME/IIJME.htm

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Volume 2, Issue 3, March 2014

Experimental Analysis and Comparison of Heat Transfer with Different Particle Diameter and Power in Fluidized Bed

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Abstract

This research project is an in-house project and being conducted as to verify the previous data related to fluidized bed heat exchanger. Heat transfer coefficient between immersed heated tube and bubbling fluidized bed is found experimentally for different velocity of air. An experiment is performed with three different silica sand diameters and at different superficial air velocities. The bed particles used were Geldart B silica sand particles of sizes ranging from 300-425µm, 425-650µm and 650-850µm. Fluidizing media used was atmospheric air. Heat transfer coefficient is increased with increasing the air velocity and it is found to decrease by increasing the particle size. The comparison of power, velocity, heat transfer coefficient with different diameter of particles performed in this research work. It is observed that they showed a good agreement with each other.

Keywords: Fluidized bed, Heat transfer coefficient, Power, Velocity of air.

1. INTRODUCTION

Fluidized bed heat exchanger is an important factor in many industrial applications. This research project intensifies the study on various parameters and correlating them for the heat transfer coefficient at different velocity and at different power for different sizes of sand particle under Geldart grouping. The sand particle having sizes ranging from 300 µm – 850 µm where fluidized in the bed, with a working medium as air. The key objectives of this work is to study the bubbling Gas-Solid fluidized bed in order to find the suitability of sand as a bed material in Gas-Solid fluidized bed and to, find the local heat transfer coefficient around a horizontal heating element immersed horizontally in bubbling fluidized bed.

Many researchers have studied the effect of various parameters like fluidizing velocity and particle diameter on the average heat transfer coefficient between the fluidizing bed and immersed heating element, but there is considerably less literature available on the heat transfer coefficient around the horizontal tube and fluidized bed of sand. Some of the most relevant previous studies are made by 1) G.K.ROY & K.J .R. SARMA, concluded that the heat transfer between particle and air is by convection in fluidized bed.2) Francesco Miccio, Andrea De Riccardis, Michele Miccio they determined the heat transfer coefficient for bubbling fluidized bed. 3) Araí A. Bernárdez Pécora and Maria Regina Parise, concluded that Heat transfer coefficient increases with the solid particle mass flow rate. 4) Jelena N. Janevski, Branislav Stojanović, concluded that thermal conductivity depends on the intensity of mixing of particles and air and heat transfer rate is higher in axial direction than radial direction.

2. EXPERIMENTAL SETUP

Below Figure 1 shows the experimental setup. The column erected is of rectangular cross-section 15x12 cm^2 and height of 80 cm made of galvanized aluminum sheet, and acrylic glass is used on the third side to visualize the fluidization phenomenon and to record the bed height. Distributor plate is fitted at the bottom of the column made of multiple iron wire mesh. A cartridge heater of diameter 2 cm enveloped in a copper tube of thickness 2 mm and fitted horizontally inside the rectangular column. The cartridge heater is capable to produce heat energy of 500 Watt heat energy. The axis of the cartridge heater is at a height of 8 cm from distributor plate at the bottom of the column. Figure 2 shows the copper tube and the cartridge heater with the arrangement of the thermocouples on its surface. The thermocouples are arranged on the surface of the copper tube radially. And other two are fitted at top and bottom of the copper tube at a distance of 1 cm respectively, assuming that the heat flow rate is only in radial direction of the copper tube. All the readings are taken at steady state.

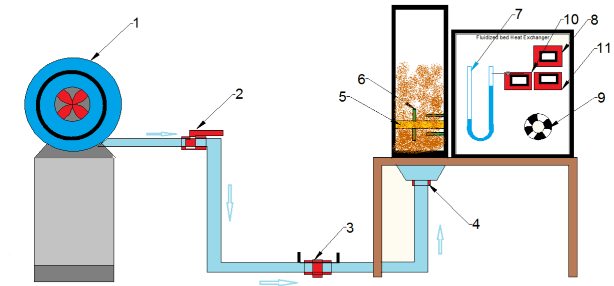


Figure1 : 1.Blower,2.Air regulator, 3.Orifice, 4.Funnel, 5.Heater, 6.Thermocouples, 7.Manometer, 8. Temp. indicator, 9.Dimmerstat, 10&11. Voltmeter and Ammeter

Figure 2: Actual Experimental Setup

3. INSTRUMENTATION

The setup consists of cartridge heater with a rating of 500 watt. The power supply to the cartridge heater is given with the help of dimmer stat, which effectively vary the power input to the heater. The reading of the power supplied is determined with the help of voltmeter and ammeter. The whole setup consists of seven K- type thermocouple. Two thermocouples are assigned on the surface of the copper tube at 0^0 and 180^0 from the bottom. Next two are arranged near the periphery of the copper tube at a distance of 1 cm from the axis of the cartridge heater. Other is located above the bed to determine the air temperature. A blower of capacity 10 m^3/min is used to supply the air to the fluidized bed column through distributor plate. A butterfly valve is fixed on the way of outlet to the blower to regulate the air supply. A differential manometer is connected across an orifice meter to read the air velocity.

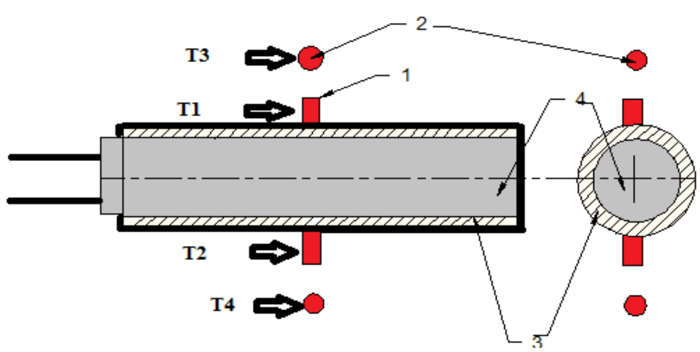


Figure3: Shows Thermocouple and Cartridge heater setup inside the chamber.

Bottom is 0^0 & 180^0 is on top of heater
1 & 2 K-Type Thermocouples (shows T_1 and T_2 on the surface and around the heater T_3 and T_4)
3. Copper tube 4. Cartridge heater

4. BED MATERIAL

The bed material used in this work was silica particles since it can get easily fluidized. The can be classified as Group B according to Geldart's classification. Standard Sieve analysis is carried out in laboratory for taking the bed sample size of silica sand. Density of sand is measured directly using an Archimedes principle.

Table 1: Properties of bed materials

Properties \ Bed material	Sand 1	Sand 2	Sand 3
Diameter D_p (μm)	300- 425	425- 600	600-850
Density ρ (Kg/m3)	2600	2600	2600
Umin f (m/s)	3.00	3.4	3.6
Umax f (m/s)	9.47	9.23	9.1

5. GOVERNING EQUATIONS

There may be many equations available for finding different heat transfer rate in the fluidized bed heat exchanger. But in this experiment considering the ideal conditions the basic heat transfer rate Q is takes out with the following

$$Q = H\,A\,\Delta T$$

The modified form for finding out the heat transfer coefficient H is

$$H = \frac{Q}{A\,\Delta T} \quad \text{------------------------------ (1)}$$

And,

$$\Delta T = \left(\frac{T1+T2}{2} - \frac{T4+T3}{2}\right)$$

where,
ΔT, Local Temperature difference
Q, power supplied
H, Heat transfer coefficient
A, Cross sectional area of the fluidization bed chamber

Power is supplied from the heater having a full capacity of producing a power of 500 Watt at 230V and 5A. The power supplied could be found by

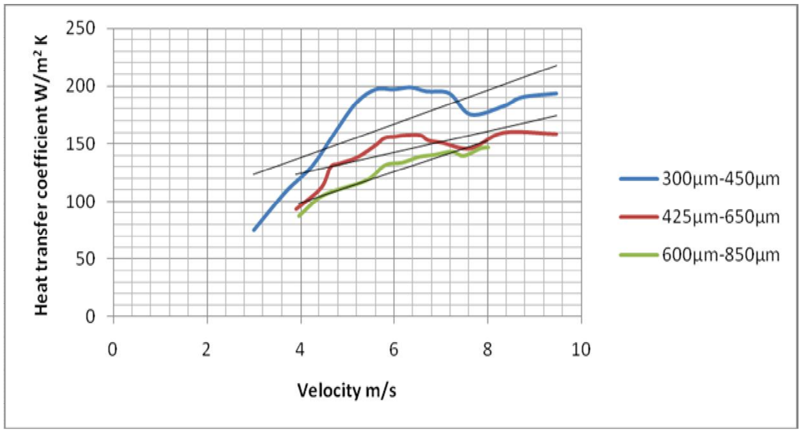
$$Q_H = V*I$$

where,
V, voltage
I, current
This power Q_H is substituted in the equation (1)
Thus, heat transfer coefficient H is found in all the below graph and so is compared with different other parameters.

6. RESULTS

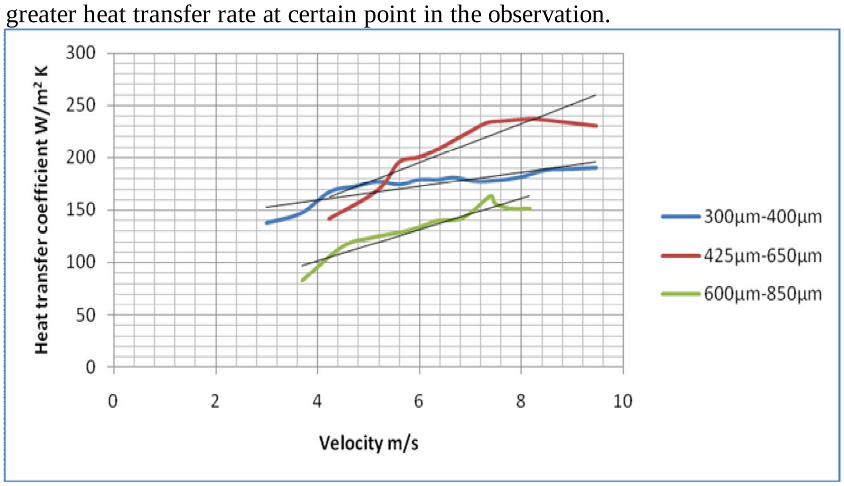
The experiment have recorded many observations. Following graph shows all the information collected during the experiment at a glance.

Graph 1 is the comparision between heat transfer coefficient and velocity of air at 200 watt. The observations where takes for different sand particle sizes. This shows the maximum heat transfer rate when the particles are small in size and larger particle shows comparitively lesser heat transfer rate.



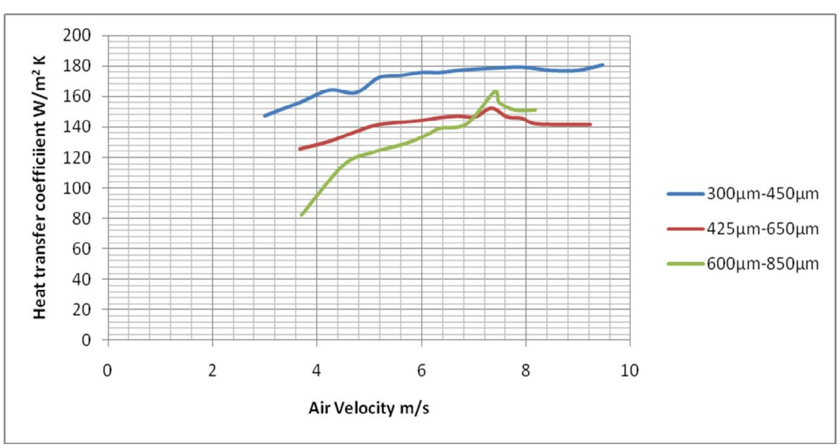
Graph1: Comparison between heat transfer coefficient and velocity of air @ 200 watt

Graph 2 is also observed under the same circumstances as the above graph 1, but the only difference here is the power supply is increased to 300 W. Although some deviation on graph 2 show anomalous behavior of sand particle. The medium size particle shows a greater heat transfer rate at certain point in the observation.



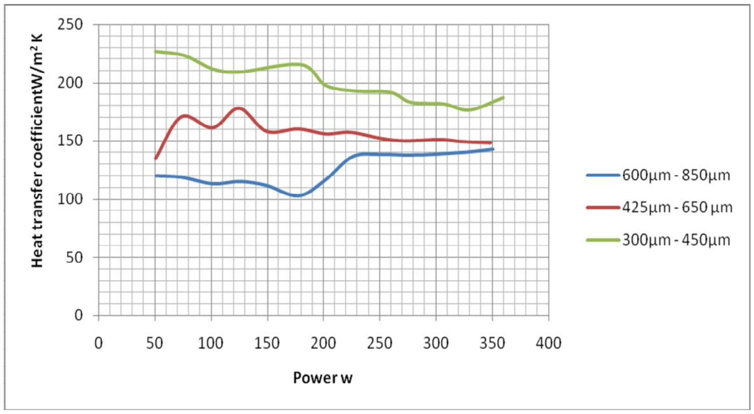
Graph 2: Comparison between heat transfer coefficient and velocity of air @ 300 watt

Graph 3 is also the same but with 400 W of heat is supplied in the bed. The heat transfer rate observed is also as predicted that smaller particles result in more heat transfer.



Graph 3: Comparison between heat transfer coefficient and velocity of air @ 400 watt

Graph 4 is different from all the above, Here the comparison of sand particle with different power supply and on different sand particles are noted. The velocity of air is kept constant at 4.96 m/s. Then the power is varied and the heat transfer rate is observed for various sand particles. Although the behavior of sand particle is predictable as before i.e smaller the sand particle more will be the heat transfer effect obtained in the fluidization bed.



Graph 4: Comparison between heat transfer coefficient and power @velocity of air 4.96 m/s

6. CONCLUSION

1) Silica sand is having good fluidizing property.
2) Velocity of air always show linearity with heat transfer coefficient
3) As the particle size increases the velocity and heat transfer rate decreases.
4) In general we assume that heat transfer coefficient is directly proportional to power supplied but from the comparison graph of power and heat transfer coefficient graph 4. It can be concluded that heat transfer coefficient becomes constant after certain limit.
5) Heat transfer coefficient for the granular material like Silica sand of size range 300µm to 850µm ranges from 75 W/m^2 K to 245 W/m^2 K.

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