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Fluidized Bed Heat Transfer Unit

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Abstract

An experimental has been carried out on heat transfer in a fluidized bed. This experiment involves passing a fluid, typically a gas, upward through a bed of particles supported by a distributor to fluidize a bed of solids and convert a solid particle to become have many properties of a liquid. The experiment's aims are to compute the heat transfer coefficient and demonstrate how fluid velocity affects pressure drop. The main result that can show is when the fluid is passed upward through a bed of particles thus pressure loss due to frictional resistance increase as fluid flow increases. Increases in flow rate also result in an increase in heat transfer coefficient.

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Results

Table 1 : Raw data for fluidized bed heat transfer unit

Flow rate	T_1 (°C) Bed Temp.	T_2 (°C) Heater Temp.	T_3 (°C) Air Temp.	Voltage (V)	Current (A)	ΔP (cmH_2O)	Observation
2	28	85	25	11	0.25	4.9	Fixed
4	43	80	27	12	0.25	6.3	Little motion
6	56	80	28	17	0.32	7	Small bubble
8	60	80	30	20	0.41	7.4	Bubbles increase
10	61	80	31	27	0.53	7.8	Bubbles increase at surface
12	62	82	32	40	0.72	8.5	Bubbles increase at whole bed
16	68	90	32	40	0.72	8.9	Big bubbles
2	69	82	39	40	0.72	10	Big bubbles
4	70	80	35	41	0.75	11.9	Turbulence continuous
6	66	80	36	50	0.9	18	Turbulence continuous
8	68	82	38	55	0.91	22.5	Turbulence continuous
10	70	80	40	56	0.95	24	Turbulence continuous

Table 2 : Calculate data for fluidized bed heat transfer unit

Flow rate from calibration curve (L/min)	Q (Watt)	ΔT (T_1 -T_2) (K)	h (W/m.K)
7	2.75	57	24.12
9	3	37	40.54
10.5	5.44	24	113.33
12.5	8.2	20	205.00
14.5	14.31	19	376.58
15.6	28.8	20	720.00
18	28.8	22	654.55
40	28.8	13	1107.69
50	30.75	10	1537.50
70	45	14	1607.14
80	50.05	14	1787.50

Figures

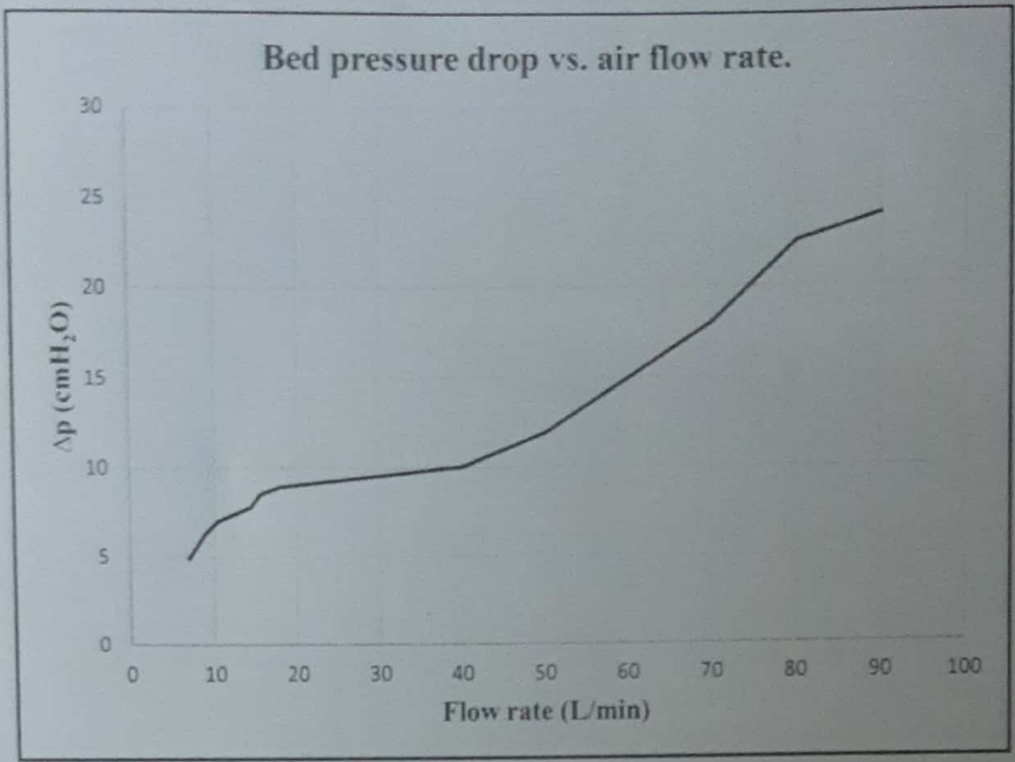

Figure 1 : Bed pressure drop against air flow rate.

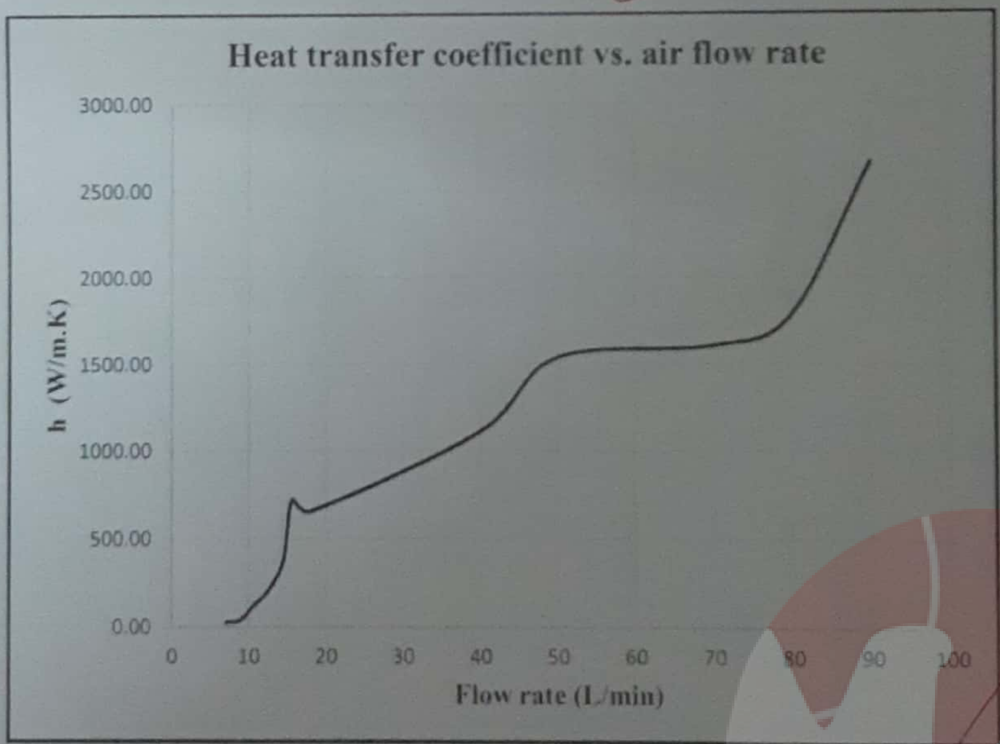

Figure 2 : Heat transfer coefficient against the air flow rate

Discussion

Figure 1 showed that increases the fluid flow rate increases the pressure drop because when the flow increases, the velocity and friction increase, so the pressure drop increases.

The results showed that the fluidization head increases as the water inlet superficial velocity increases. As well as when the water inlet superficial velocity increases, the average solid phase temperature increases due to the increase in the turbulent inside the bed, which contribute in the convection and conduction process inside the bed.

Figure 2 it was verified that the heat transfer coefficient increases with the increase in the solid particle mass flow rate because when the fluidization velocity increases, heat transfer coefficients for the surfaces in contact with the fluidized bed also increase, due to the increase of heat transfer by particle contacts.

When the bed is fluidized with liquids, we have the case of the "homogenous" fluidization. Gas fluidization leads to so-called "heterogenous" fluidization. At gas velocities just above the minimum fluidization velocity, bubbles form, small bubbles would first appear on the material's surface inside the bed when the air flow was increased. These bubbles moved up the material as the air flow increased, from the bottom to the top. When the air flow speed is increased to a high level, large air bubbles start to form that can penetrate deeply into the bed and work to mix the material inside it.

It was also illustrated that the water bubbles in the bed higher areas were bigger than the rest of the bed and more radially elongated, meanwhile the water bubbles in the bed lower areas were smaller and radially regularly distributed. This proposed that as water bubbles moved up the bed tended to coalesce.

As the velocity increases, the head of fluidization increases with respect to the initial particle head. It was observed from the profile of solid phase volume fraction that a lower concentration of particles is found in the regions close to the walls, demonstrating that the water bubbles as they move up the bed tend to be push to the sides of the bed.

Conclusion

By conducting the experiment on different flow rates of air, it was concluded that:

- Increasing fluid flow rate leads to an increase in pressure drop.
- Pressure drop in the bed is almost stationary at low flow rate, but at high flow rate the fluid reaches the minimal fluidization velocity, and the particles begin to move and separate from one another that means the bed is fluidized.
- Increasing fluid flow rate leads to an increase in heat transfer coefficient.
- At higher velocity, bubbles are formed and tend to occur, the bed is often referred to as a boiling bed.

References

1) Chemical engineering laboratory "1" (0915361); University of Jordan; faculty of engineering and Technology; Department of Chemical engineering.

2) Incropera, (2011), Fundamentals of Heat and Mass Transfer, John Wiley & Sons, Inc..

Appendix

- **Sample of calculation; taking the 1st raw from Table 2:**

1) **From raw data table:**

→ $V = 11\ V$

→ $I = 0.25\ A$

→ Surface area (A) = $20\ cm^2 = 0.002\ m^2$

2) **ΔT**

$\Delta T = T_1 - T_2 = 85 - 25 = 57\ °C = 57\ K$

3) **Heat input**

$Q = V\,I = 11 \times 0.25 = 2.75\ W$

4) **Heat transfer coefficient**

$$h = \frac{Q}{A \,.\, \Delta T} = \frac{2.75}{0.002 \times 57} = 24.12\ W/m.K$$