The University of Jordan

School of Engineering

Chemical Engineering Department

Chemical Engineering Laboratory (1) 0915361

Experiment Number (8)

Fluidized bed Heat transfer unit

Type of the report: full report

Instructor: prof. Ahmad Abu Yaghy

Performing Date: 8-8-2022

Submitting Date :22-8-2022

Name	Id Number
Laila Alameri	
Noor Ghassan	
Saja Alqaisi	
Sara Albanna	

Abstract

Two stream meters are used in this experiment setup, and one of the flow meters has a range that is roughly equivalent to one-tenth that of the other. Also, it includes a glass cylinder through which air can be passed. the objective of the analysis is to calculate the heat transfer coefficient and study the effect of air velocity on pressure drop through the fluidized bed. Our main result was:

1. There is a direct relation between air flow and heat transfer coefficient, the heat transfer coefficient increases as the air flow rate increases.

2. There is an inverse relation between air flow and temperature difference, when the Air flow rate increases the temperature difference between bed and heater decreases.

3.we found that after a certain point fluid start flowing inside the bed after increasing air velocity to a certain value (fluidization).

Table of content

Table of tables

Table of figure

Introduction

A solid particle matter (often found in a holding vessel) will behave like a fluid when the proper conditions are present, which is a physical phenomenon known as a fluidized bed. Pumping pressurized fluid into the particles is the typical method for creating a fluidized bed. The resulting medium then exhibits numerous qualities and traits common to regular fluids, including the capacity to float freely in a gravity-driven system or to be pumped utilizing fluid technologies.

Fluidization is the resultant phenomena. Fluidized beds can be used for a variety of processes, including solids separation, fluid catalytic cracking, fluidized bed combustion, heat or mass transfer, and interface modification, such as coating solid objects. Fluidized beds are also used in certain chemical reactors and for solids separation.

Fluidized bed activities are highly beneficial in heat transfer because of their improved rate of heat transfer compared to conventional methods. Examples of fluidized bed processes are catalytic petroleum processes.

Theory

The bed can be thought of as exhibiting the fluid behavior predicted by Archimedes' principle since an object with a density greater than the bed will sink, but an object with a density smaller than the bed will float. Objects with various densities relative to the bed can be made to sink or float by changing either the fluid or solid fraction because the "density" of the bed, which is the solid volume fraction of the suspension, can be changed by changing the fluid fraction.

Because fluidized bed activities have a higher rate of heat transfer than traditional methods, they are very helpful in transferring heat. Catalytic petroleum processes, ion exchange water treatment, and separation are a few examples of fluidized bed processes.

Both methods can be used to determine the heat transfer coefficient (fixed and fluidized bed) using the following equation:

$Q = h * A * (T_2 - T_1)$

Where:

Q: heat input ($Q = I * V$).

h: heat transfer coefficient.

A: Surface area of the heating element.

T_1: temperature of the bed.

T_2: temperature of the heating element.

Apparatus

A fluidized bed is made of a fluid-solid mixture with fluid-like characteristics. Because of this, the top of the bed is essentially horizontal, which is like hydrostatic behavior. A single bulk density can be used to describe the bed, which is thought of as a heterogeneous mixture of fluid and solid.

Comparing fluidized beds to packed beds, the interaction of the solid particles with the fluidization medium (a gas or a liquid) is significantly increased. This behavior in fluidized combustion beds promotes efficient thermal transport both within the system and between the bed and its container. The bed can have a large heat capacity while maintaining a homogeneous temperature field, similar to how effective heat transfer allows for thermal uniformity like that of a well-mixed gas.

Application:

High amounts of interaction between gases and solids are promoted using fluidized beds in technical processes. Modern process and chemical engineering rely heavily on a certain set of fundamental features that can be used in a fluidized bed. These properties include: extremely high fluid-solid interaction surface area per unit bed volume, The fluid and scattered solid phase are moving at high relative velocities., high amounts of particle phase intermixing, collisions between particles and against walls on a regular basis.

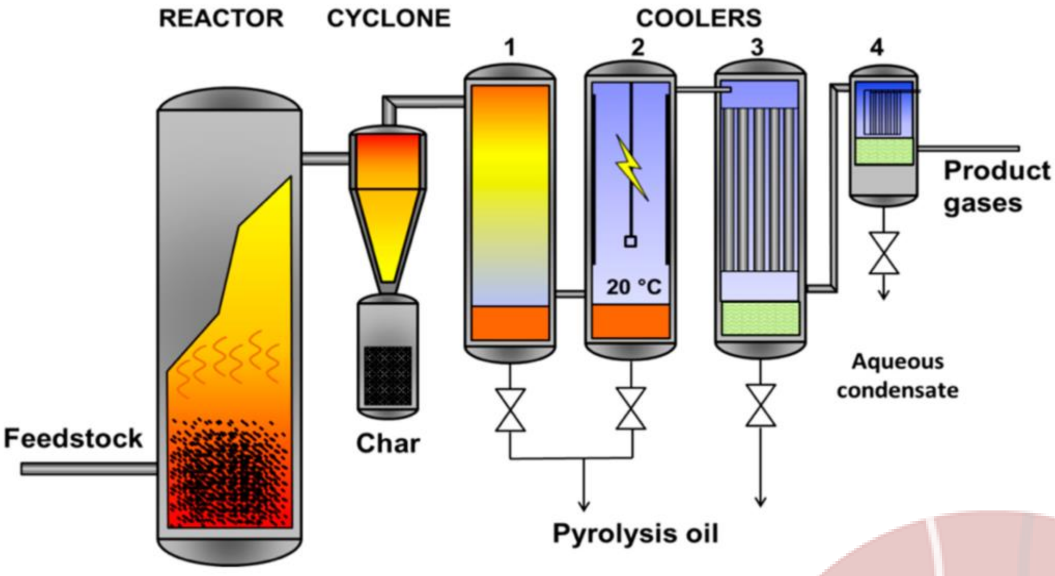

Figure (1): main parts of fluidized heat transfer unit

A fluidized bed is a bed of particles that has been continuously fluidized by an upward flow of gas. A vertical cylindrical tube with a perforated distributor plate at the lowest point typically makes up the process. The tube is filled with a particulate material (often sand), and gas flows upward from the distributor plate. If the gas is moving at a very slow speed, it will just flow around the particles and exit at the top. In this situation, we have a permanent bed. If the gas flow rate keeps rising, at some point the upward force on each particle will be equal to its weight. The particle is suspended in this case, and the gas rate is referred to as the minimum fluidization rate. Any additional speed boost generates gas bubbles that swiftly move upward within the system. It is frequently referred to as a bubbling fluidized bed. Figure below depicts a fluidized bed that is bubbling.

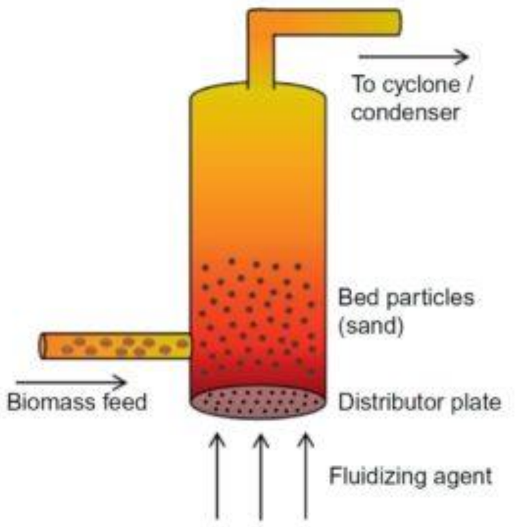

Figure (2): bubbling in fluidized bed

The bubbling fluidized bed has many essential qualities, including the fact that the particles move incredibly quickly, encouraging intelligent intermixture and consistent conditions throughout the bed, making heat transfer extremely efficient and temperature control simple.

This system has had successful commercial use and scaling it up is simple. The brief duration of the vapors, specifically for rapid pyrolysis, is only regulated by varying the gas rate.

Procedure:

1. initially, we fully opened the air bleed control valve and switched on the blower.
2. Secondly, we completely immersed the heating element inside bed.
3. Thirdly, we adjusted the variance to maintain the heating element by thermostat to be controlled at predetermined temperature, at the same time we closed the control valve gradually to induce air through the bed causing the increase of pressure across the bed.
4. Finally, after temperature was stabilized, we recorded the data of our experiments (the air flow rate, bed pressure drop, air and element temperatures, voltage and current at each flow rate.

Result:

Table (1): Raw data for fluidize bed heat transfer unit

flow rate (scale)	T_1 (◦C) Bed temp	T_2 (◦C) Heater Temp.	T_3 (◦C) Air Temp.	Voltage (V)	Current (A)	Δ p (cm H_2O)	Observation
2	38	104	34	10	0.25	5	Fixed
4	54	96	35	10	0.25	6	little motion
6	78	102	38	20	0.48	7	small bubble
8	79	104	38	10	0.58	7.5	bubbles increase
10	78	98	40	30	0.65	8	bubbles increase at surface
12	80	98	42	30	0.65	8.5	bubbles increase at whole bed
14	82	98	42	30	0.65	8.5	big bubbles
16	82	100	44	30	0.65	9	big bubbles
18	82	96	44	29	0.65	9	Turbulence continuous
2	81	98	48	35	0.75	10.5	Turbulence continuous
4	82	94	48	40	0.83	10.5	Turbulence continuous
6	84	94	48	45	0.9	15.5	Turbulence continuous
8	83	94	48	45	0.9	18.5	Turbulence continuous
10	82	94	48	55	1	22.5	Turbulence continuous

Table (2): calculated data for fluidize bed heat transfer unit

flow rate from calibration curve (L/min)	Q(Watt)	$\Delta T= T_2-T_1$ (◦C)	h (W/m^2. K)
7	2.5	66	18.94
9	2.5	42	29.76
10.5	9.6	24	200.00
12.5	5.8	25	116.00
14.5	19.5	20	487.50
15.5	19.5	18	541.67
17.5	19.5	16	609.38
18	19.5	18	541.67
20.5	18.85	14	673.21
40	26.25	17	772.06
50	33.2	12	1383.33
70	40.5	10	2025.00
80	40.5	11	1840.91
90	55	12	2291.67

Diagrams:

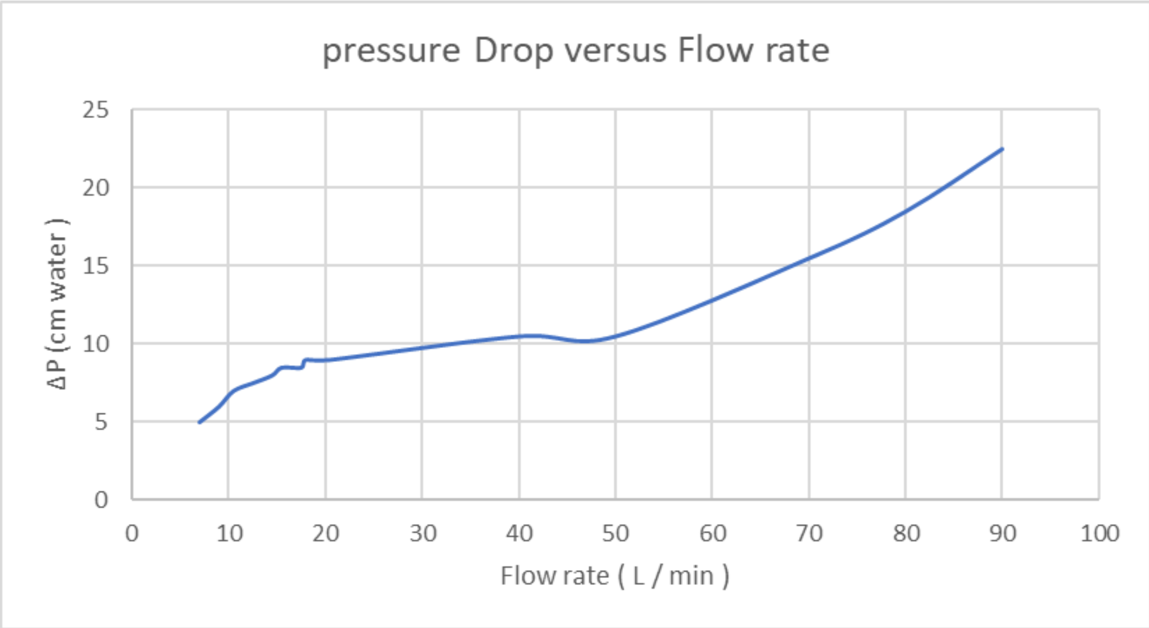

Figure (1): Bed pressure drop vs. flow rate

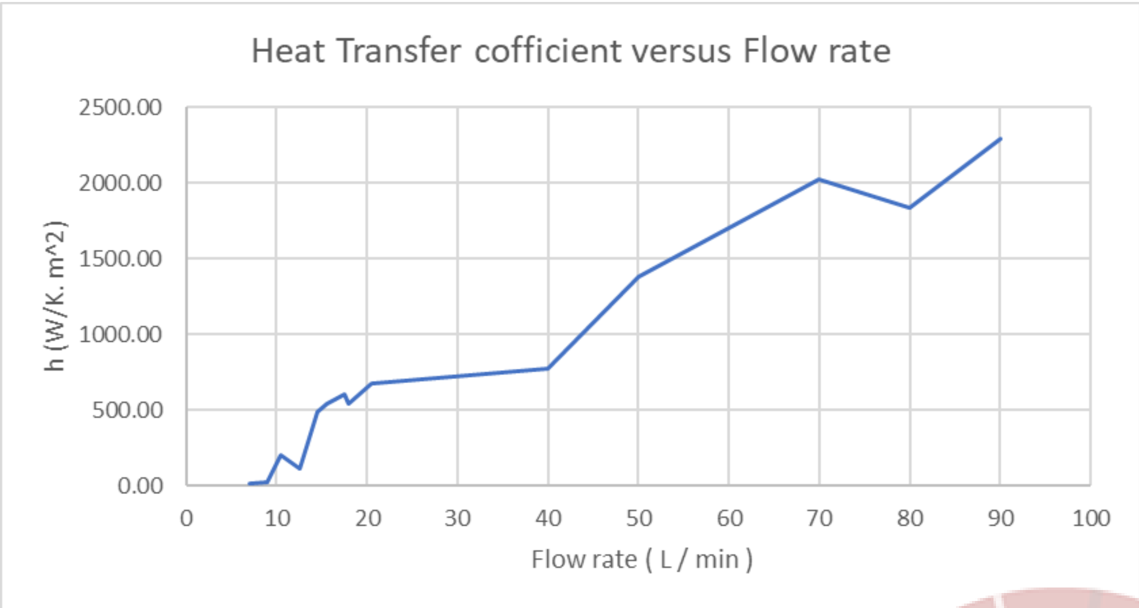

Figure (2): Heat Transfer coefficient vs. Flow rate

Discussion

In this experiment, we will examine how the speed of the air flow affects the change in pressure drop within the bed and the heat transfer coefficient. We will also manipulate the heater's temperature by varying the voltage. 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. We observe that the heat of the heater was almost constant throughout the experiment despite an increase in the voltage, and this is because the increased air flow velocity worked to improve the flow of the material inside the bed while also increasing the pressure drop and the heat transfer coefficient.

The velocity of the fluid affects the heat transfer coefficient (h=q/ (A* delta T) (directly proportional)

- The difference in temperature between the heater and the bed (inversely proportional)

- The heater's ability to distribute heat to the bed (directly proportional)

In this experiment we have increased the air flow rate to study its effect on heat transfer coefficient and on pressure drop. From the result we can discussed the following:

1. Fixed bed region: where a direct linear relation results between the pressure drop & the air flow rate which means that when the air flow rate increases, the pressure drop will increase.

2. Transition region: for intermediate flow rates; when the air flow rate increases the pressure drop increases to reach a maximum point then it starts decreasing.

3. Fluidized bed region: for high flow rates; the pressure drop becomes approximately constant with the increment of the air flow rate.

The porosity of the bed when true fluidization occurs is the minimum porosity for fluidization. If the flow rate of fluid is increased the bed starts to expand and the voidage of the bed increases.

The heat transfer coefficient depends on:

• The temperature difference between the heater and the bed (inversely proportional).

• The heat transfer from the heater to the bed (directly proportional).

• Velocity of the fluid (directly proportional).

Figure of “Air flow rate Vs. Pressure drop”:

- When Air flow rate increase the Pressure drop increase and still increase to reach fluidizing point

Figure of “Air flow rate Vs. Heat transfer coefficient”:

- When Air flow rate increase the heat transfer coefficient increase

Conclusion

The Pressure decreases as the flow rate increases, the bed becomes more porous (void) with increasing flow rate, boiling beds are those in which bubbles develop more quickly, low flow rates result in an immobile bed, high flow rates achieved in moving particles, the heat transmission coefficient varies proportionally with fluid velocity, when the air flow rate increases (h) increases. air flow rate is directly proportional with the power.

References

1.Website: Wikipedia (2022). Fluidized bed from…

2. Book: Laboratory Manual for Chemical Engineering Laboratory (1) (August -2022). Experiment (8), Fluidized bed heat transfer. The University of Jordan, faculty of engineering and technology, department of chemical engineering.

Appendix

Sample of calculation

Taking the first raw of table (2):

-Surface Area of the heating element = 20cm^2 = 2x103 m^2.

-voltage = 10 V.

-Current = 0.25 A.

1.Tempreutre difference of the system:

Temperature of the bed T_1 = 38 ∘c, Temp of heater T_2 = 104 ∘c

$\Delta T = T_2 - T_1 = 104\text{-}38 = 66$ ∘c.

2.Heat input

Q = V*I= 10 x 0.25 =2.5 W.

3.heat transfer coefficient:

From Newton's Law: $Q = h * A * \Delta T$

$$h = \frac{Q}{A * \Delta T} = \frac{2.5}{2 * 10^{-3} * 66} = 18.94 \frac{W}{m^2 * k}.$$

.

Symbols

Table (3): symbols used in calculations and their meanings.

Symbol	Meaning	Unit
Q	Heat input (Q=I*V).	w
h	Heat transfer coefficient.	W/m^2. K
A	Surface area of the heating element.	m^2
T_1	Temperature of the bed.	°C
T_2	Temperature of the heating element.	°C
T_3	Air Tempe Ture.	°C
ΔT	Temperature difference ($\Delta T = T_2 - T_1$).	°C
Δ p	Bed pressure drop.	cm H_2O
V	Voltage.	V
I	Current.	A