Thermal behavior of super critical CO2 in plate heat exchanger with different configuration of plate

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ABSTRACT

The four types of configurations of plate have been used i.e. wavy, tapered, dimpled and bubbled shape. An optimized model of plate heat exchanger has been developed as stated configurations of plate heat exchanger. The simulations have been performed at a different fluid temperature i.e. 10^0C, 15^0C, 20^0C, that is the temperature of super critical CO2 flowing between plate heat exchanger of different channel shape with Reynolds number ranging between 2000 - 3500.

Keywords: Plate Heat Exchanger, Reynolds Number, Bernoulli equation, Heat Exchanger, Pressure Drop.

1. Introduction

- **Why plate heat exchanger**

The plate heat exchanger (PHE) is a specialized design well suited to transferring heat between medium- and low-pressure fluids. Welded, semi-welded and brazed heat exchangers are used for heat exchange between high-pressure fluids or where a more compact product is required.

- **Design and operation technique of plate heat exchangers**

The primary objective within the design of plate heat exchangers is the estimation of the Minimum heat transfer region required for a given heat obligation as this is an critical element to Estimate the general price of designing the plate heat exchanger. Inside the previous segment of This work become discussed in short the exceptional sorts of plate heat exchangers that are used For extraordinary programs in the manufacturing industries but on account that one design principle and Methodology is used for all of them consequently we are going to considerably use the gasketed plate heat exchanger as our case have a look at in this research, the gasketed plate heat exchanger become defined briefly to Include a sequence of square corrugated metal or alloy plates, which might be sealed through gaskets and clamped firmly together in a body with the resource of bolts. The touch of the fluid circulate with the corrugated plate reasons a turbulent go with the flow, which will increase heat transfer between the hot and bloodless fluid streams respectively. Moreover, the recent and bloodless fluid streams flows inside and out the corrugated plate through the round ports positioned in each corner of the plate. The gaskets are well interlocked and embedded within the plates, which facilitates to direct the fluid flow. In practice, a single unit of plate heat exchangers can deplete to 700 plates, which gives a total heat transfer location of approximately 2500m^2

Material used for plate design

The substances used within the fabrication of the plates in plate heat exchangers are specially Chrome steel, aluminium, titanium, hastelloy, incoloy, tantalum, monel and nickel based Alloy are typically used. To attain an efficient heat transfer area which all through design it is an crucial element to estimate the price of designing the plate heat exchanger. The plate Material should be intently checked to be like minded with the fluid stream as a way to avoid Fouling and untimely harm of the gadget, for you to incur extra renovation value as Well as low output ultimately Furthermore, the material selection for plate heat exchangers also depends on the heat Obligation, mode of heat transfer and the kind of fluid move as stated in advance which has to Be compatible with the plate material. The primary issue that determines the selection of The plate fabric is the compatibility of the fluid and heat responsibility, the manufactures selection of Material also can be considered as a element.

- **Advantages of plate heat exchangers**

The effect of plate heat exchangers are several due to their compact design whereby the components may be easily disassembled for inspection, cleaning and Renovation. The power of the design makes it possible to adjust or rearrange the heat transfer vicinity throughout optimization for an expected load or heat duty trade, which may be finished by way of altering the plate length, corrugation patterns, and the pass association respectively. A short contrast between the shell-tube exchangers and plate heat exchangers indicates that fouling may be decreased from 25 to 10 % when a plate heat exchanger is used because the high shear fees, stresses, excessive turbulent glide sample and proper mixing are all attributed to the plate corrugation styles in plate heat exchangers. Plate heat exchangers typically have a high Heat transfer coefficient (W/m2K) due to the fact the plates are Very thin with large surface place and due to the activities taking region at the fluid Boundary layers, which ends up in reaching a small hydraulic diameter flow passage. Fouling is at a discounted fee as compared to shell-tube exchangers, go with the flow association are Commonly counter waft that aids the method temperature to attain as much as 1°C and a better Heat transfer coefficient (W/m2K) is done because of the absence of bypass and leakages. Furthermore, this minimizes the design fee and due to the compact design, the equipment May be transportable so one can occupy less space. Thermal overall performance is commonly high which favors strict temperature control that is fantastic when using heat sensitive Materials because this will optimize the excellence of the product.

Heat Transfer

Heat transfer is a technological to predict that research the strength transfer between two our bodies due to temperature difference. In concept, thermal electricity is associated with the kinetics energy of molecules on a microscopic scale.

When material's temperature will increase, the thermal agitation of its constituent molecules will boom. Then the regions which include more molecular kinetic power will bypass this strength to regions with much less kinetic electricity. So while an item or fluid is at one of a kind temperature than its surroundings, the heat transfer will occur in one of this way that the body and the surroundings attain thermal equilibrium applications the plate-fin heat exchanger is suitable for use over a huge variety of temperatures and pressures for gas-fuel, gasoline-liquid and multi-section responsibilities. They are used in a selection of programs. They are particularly hired in the discipline of cryogenics for separation and liquefaction of air, natural gas processing and liquefaction, manufacturing of petrochemicals and big refrigeration systems. The exchangers which are used for cryogenic air separation and LPG fractionation are the biggest and maximum complex units of the plate fin kind and a single unit may be of numerous meters in period. Brazed aluminum plate fin exchangers are extensively used inside the aerospace industry due to their low weight to extent ratio and compactness. They are getting used specially in environment manipulate gadget of the plane, avionics cooling, hydraulic oil cooling and gas heating. Making heat exchangers as compact as feasible has been an everlasting demand in automobile and air con industries as both are area aware. In the car quarter they may be used for making the radiators. The different miscellaneous packages are:

- Fuel cells
- Process heat exchangers
- Heat recovery plants
- Pollution control systems
- Fuel processing and conditioning plants
- Ethylene and propylene production plants
- Plate fin heat transfer surfaces

Plate fin heat transfer surfaces

The plate fin exchangers are in particular hired for liquid-to-gasoline and gas-to-fuel packages. Due to the low Heat transfer coefficient (W/m2K)s in gas flows, prolonged surfaces are normally hired in plate-fin heat exchangers. By the use of particularly configured extended surfaces, Heat transfer coefficient (W/m2K)s can also be improved. While such unique floor geometries provide lots better Heat transfer coefficient (W/m2K)s than simple prolonged surfaces, but on the identical time, the strain drop penalties are also excessive, although they may no longer be excessive sufficient to negate the thermal benefits.

1.9 Heat exchanger

Heat exchangers are one of the mainly used devices inside the technique industries. Heat Exchangers are used to transfer heat between two manner streams. You possibly can recognise their utilization that any system which contain cooling, heating, condensation, boiling or evaporation will require a heat exchanger for this motive. Technique fluids, normally are heated or cooled before the manner or undergo a segment alternate. Exceptional heat exchangers are named according To their application. For instance, heat exchangers getting used to condense are referred to as Condensers, further heat exchanger for boiling functions are called boilers. Overall performance And efficiency of heat exchangers are measured via the amount of heat transfer using Least region of heat transfer and Pressure Drop (Pa). An extra better presentation of its performance is accomplished through calculating over all Heat transfer coefficient (W/m2K). Strain drop and location required for a sure quantity of heat transfer, affords a perception about the capital fee and energy Requirements of a heat exchanger. Generally, there is a lot of literature and Theories to design a heat exchanger according to the necessities.

- **Material properties**

Properties	Water - liquid	Steel
Density, ρ	1000 Kg/m^3	7850 Kg/m^3
Thermal Conductivity, K	0.606W/m-K	50.2 W/m-K
Specific Heat, C_p	4.2176 J/Kg-K	510 J/Kg-K

RESULTS

- **Frictional Pressure Drop -**

The frictional pressure drop is determined by pressure difference from FLUENT solver at flow zone between plates, the density of super critical CO2 with hydraulic diameter is evaluated using formula shown below.

$$f = \frac{\rho D_h}{2G^2 L}\Delta P_{fric} V = \frac{m}{\rho.W.H}$$

Table 5.1 Validation of Frictional Pressure Drop obtained from numerical simulation.

Validation Results					
Reynolds No.	Frictional Pressure Drop (Pa) at (10 ⁰ C)	Frictional Pressure Drop (Pa) at (15 ⁰ C)	Frictional Pressure Drop (Pa) at (20 ⁰ C)	Heat transfer coefficient (W/m^2K)	Effectiveness
200	583	596.83	612.88	103.85	0.12
250	767.44	785.32	856.45	108.33	0.14
300	963.52	994.58	1052.45	110.58	0.16
350	1163	1178.32	1193.56	112.47	0.17

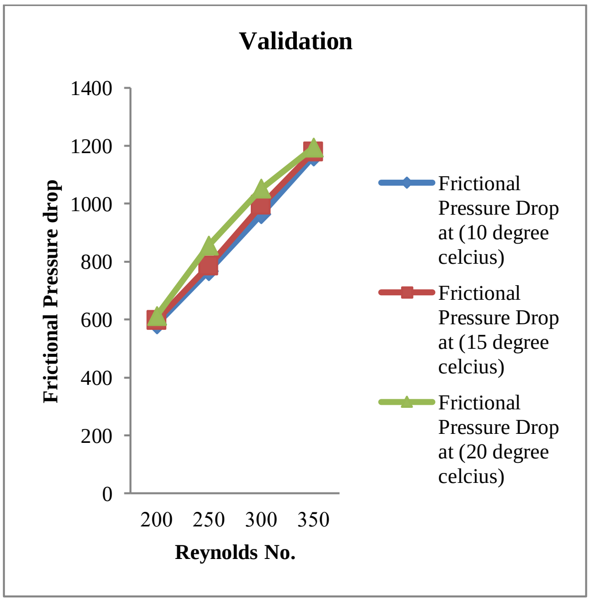

Figure 3: Variation of Reynolds number and frictional Pressure Drop (Pa) for different operating temperature of fluid.

- **Inlet port Pressure Drop**

The inlet pressure drop is determined by pressure difference from FLUENT solver at flow zone between plates, the density of water with number of flow channels is evaluated using formula shown below.

$$\Delta P_{port,in,lw} = (504.5 + 6.81 \times \alpha) \times \left(\frac{1}{2}\rho U_{ch}^{2}\right) \times Re^{-0.387} \times N_{ch}^{0.225}$$

Table No. 5.2 Validation of Inlet port Pressure Drop obtained from numerical simulation.

Validation Results					
Reynolds No.	**Inlet port Pressure Drop (Pa) at (10 ⁰ C)**	**Inlet port Pressure Drop (Pa) at (15 ⁰ C)**	**Inlet port Pressure Drop (Pa) at (20 ⁰ C)**	**Heat transfer coefficient (W/m2K)**	**Effectiveness**
200	162.85	173.59	188.44	106.52	0.17
250	183.66	186.25	212.66	109.69	0.19
300	236.89	241.88	248.45	112.86	0.21
350	248.66	253.89	257.96	114.33	0.22

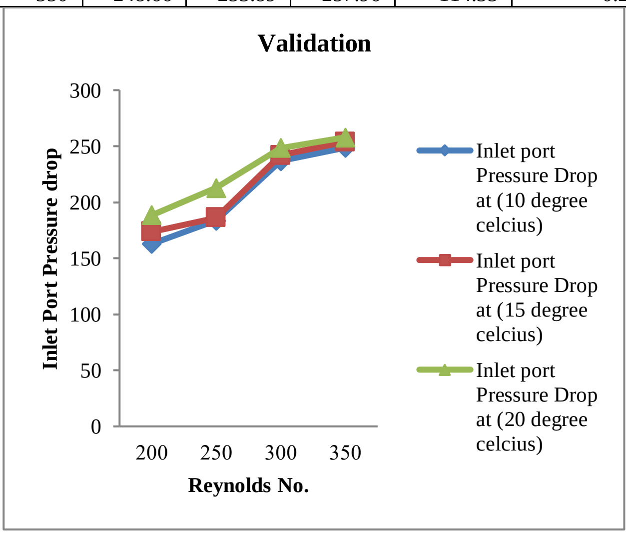

Figure 4: Variation of Reynolds number and inlet port Pressure Drop for different operating temperature of fluid.

- **Outlet port Pressure Drop (Pa)**

Validation Results					
Reynolds No.	**Outlet port Pressure Drop (Pa) at (10 ⁰ C)**	**Outlet port Pressure Drop (Pa) at (15 ⁰ C)**	**Outlet port Pressure Drop (Pa) at (20 ⁰ C)**	**Heat transfer coefficient (W/m²K)**	**Effectiveness**
200	158.33	163.78	180.25	109.25	0.19
250	169.88	185.45	196.65	111.66	0.20
300	209.66	220.65	230.45	115.88	0.23
350	229.52	235.69	243.66	118.65	0.24

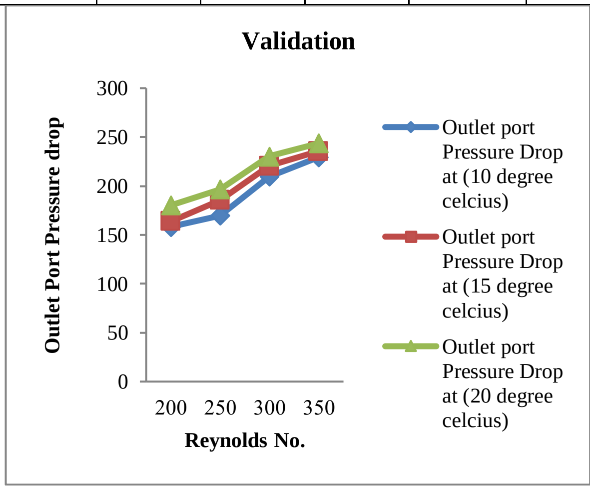

Figure 5: Variation of Reynolds number and outlet port Pressure Drop for different operating temperature of fluid.

- **Frictional Pressure Drop (Pa) characteristics (Bubbled Plate heat exchanger)**

Below shown table represents the values of frictional Pressure Drop (Pa) obtained from numerical simulation for different values of operating temperature of fluid and Reynolds number (Re).

$$\varepsilon = \frac{C_h(T_{hi} - T_{ho})}{C_{min}(T_{hi} - T_{co})} = \frac{25.9875(80-76)}{25.8835(80-71.5)} = 0.47$$

Reynolds No.	**C_h**	**T_{hi}**	**T_{ho}**	**C_{min}**	**T_{hi}**	**T_{co}**	**Q1**	**Q2**	**Effectiveness**
200	25.9875	80	76	25.8835	80	71.5	103.95	220.0098	0.472479061
250	25.9875	80	76	25.8835	80	72.5	103.95	194.1263	0.535476269
300	25.9875	80	76	25.8835	80	73.4	103.95	170.8311	0.60849576
350	25.98	80	76	25.88	80	74.6	103.95	595.3205	0.636385

Table 1: frictional Pressure Drop (Pa) obtained from numerical simulation for bubbled Plate heat exchanger.

Bubbled Plate					
Reynolds No.	**Frictional Pressure Drop (Pa) at (10 ⁰ C)**	**Frictional Pressure Drop (Pa) at (15 ⁰ C)**	**Frictional Pressure Drop (Pa) at (20 ⁰ C)**	**Heat transfer coefficient (W/m2K)**	**Effectiveness**
200	816.78	863.77	874.69	167.58	0.47
250	863.98	883.59	899.74	172.42	0.53
300	898.77	908.66	933.54	176.68	0.60
350	918.25	923.65	996.88	180.35	0.63

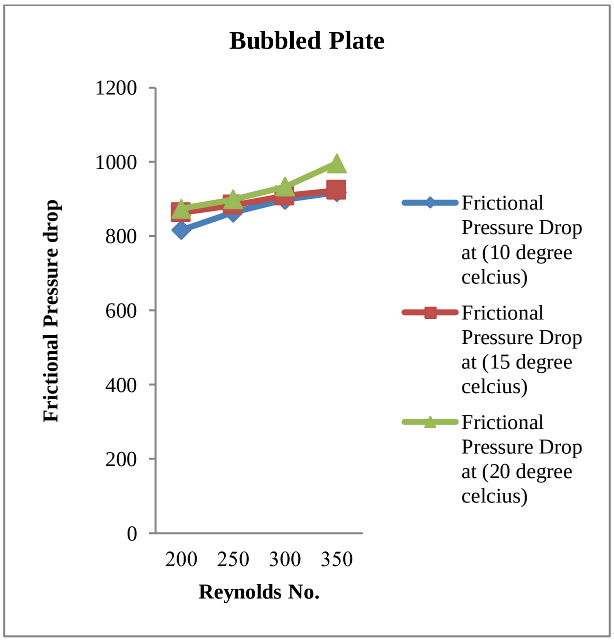

Figure 6: Variation of Reynolds number and frictional Pressure Drop (Pa) for different operating temperature of fluid in bubbled plate heat exchanger.

Inlet port Pressure Drop (Pa) characteristics (bubbled plate heat exchanger)

Table No. 2: inlet port Pressure Drop (Pa) obtained from numerical simulation for bubbled plate heat exchanger.

Bubbled Plate					
Reynolds No.	Inlet port Pressure Drop (Pa) at (10 ⁰ C)	Inlet port Pressure Drop (Pa) at (15 ⁰ C)	Inlet port Pressure Drop (Pa) at (20 ⁰ C)	Heat transfer coefficient (W/m2K)	Effectiveness
200	768.55	777.77	798.25	169.85	0.49
250	785.66	814.44	844.22	176.65	0.58
300	825.45	831.65	897.66	182.45	0.68
350	868.66	876.96	924.44	187.72	0.73

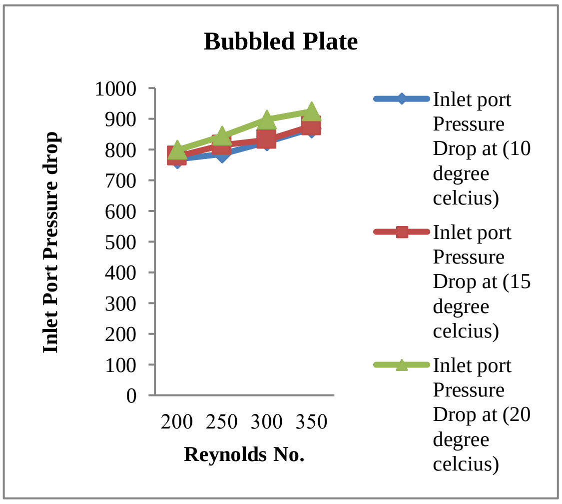

Figure 7: Variation of Reynolds number and inlet port Pressure Drop (Pa) for different operating temperature of fluid in bubbled plate heat exchanger.

Outlet port Pressure Drop (Pa) characteristics (bubbled plate heat exchanger)

Table No. 3: outlet port Pressure Drop (Pa) obtained from numerical simulation in bubbled plate heat exchanger.

Bubbled Plate					
Reynolds No.	Outlet port Pressure Drop (Pa) at (10 ⁰ C)	Outlet port Pressure Drop (Pa) at (15 ⁰ C)	Outlet port Pressure Drop (Pa) at (20 ⁰ C)	Heat transfer coefficient (W/m2K)	Effectiveness
200	803.33	823.48	848.44	178.69	0.52
250	836.66	846.44	867.33	186.98	0.63
300	857.98	868.99	889.25	196.55	0.72
350	879.99	888.78	1054.66	210.87	0.78

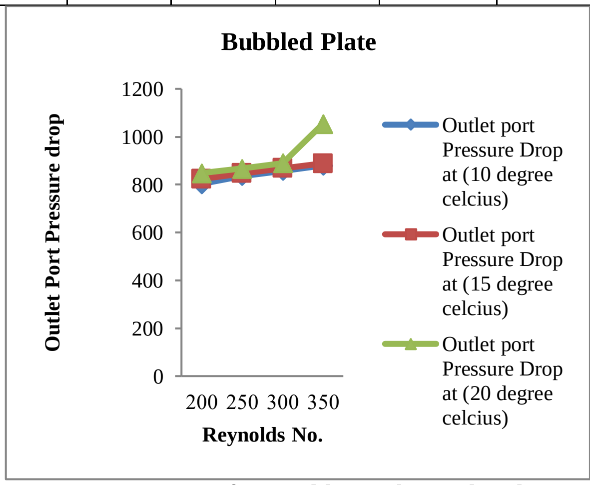

Figure 8: Variation of Reynolds number and outlet port Pressure Drop (Pa) for different operating temperature of fluid in bubbled plate heat exchanger.

CONCLUSION

- Results have best frictional Pressure Drop in plate heat exchanger of bubbled shaped configuration, i.e. 996.88 (PA) and have best inlet Pressure Drop i.e. 924.44 (PA) and outlet Pressure Drop i.e. 1054.66 (PA) at 200C.
- By applying the different shapes in plate of plate heat exchanger the frictional Pressure Drop increases in bubbled shape, thus due to increase in frictional Pressure Drop velocity of flow is increased due to this heat transfer of plate heat exchanger increases.

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