"Effect of Segmental Baffles at Different Orientation on the Performances of Single Pass Shell and Tube Heat Exchanger"

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Abstract

In present work, experimentation of single pass, counter flow shell and tube heat exchanger containing segmental baffles at different orientations has been conducted to calculate some parameters (heat transfer rate and pressure drop) at different Reynolds number in laminar flow. In the present work, an attempt has been made to study the effect of increase in Reynolds number at different angular orientation "θ" of the baffles. The range of "θ" vary from 0° to 45° (i.e 0°, 15°, 30° and 45°) and Reynolds number ranges from 500 to 2000 (i.e 500, 1000, 1500 and 2000).

A prototype model of shell and tube type heat exchanger has been fabricated to carry out the experiments. The experiments were performed to determine the effect of baffle orientation on the performance of shell and tube heat exchanger. Water is taken as the working fluid used in both shell and tubes. The objective of the present work is to predict the variation of heat transfer rate, LMTD, heat transfer coefficient, and pressure drop to the shell side with change in range of Reynolds number at different baffle orientations.

Based on the experimental result it has been observed that the angular orientation of baffles and the Reynolds number effects the heat transfer rate and pressure drop in the shell and tube heat exchanger. The heat transfer rate increases up to 30° angular orientation of the baffles and after that there is a drop in heat transfer rate at θ = 45°. The pressure drop to the shell sides decreases continuously from 0° to 45° which helps in reducing the pumping cost of the shell and tube heat exchanger.

Keywords: Shell and Tube heat Exchanger, Heat Transfer Rate, Heat Transfer Coefficient, Pressure Drop, Baffles.

Introduction

A heat exchanger is a device built for efficient heat transfer from one medium to another in order to carry and process energy. They are widely used in petroleum refineries, chemical plants, petrochemical plants, natural gas processing, air-conditioning, refrigeration, and automotive applications. The most commonly used type of heat exchanger is the shell and tube heat exchanger. It is essential to mention that a heat exchanger is not only an apparatus for transferring heat from one medium to another, but is at the same time a pressure and/or containment vessel. In addition to heating up or cooling down fluids in just a single phase, shell and tube heat exchangers can be used either to heat a liquid to evaporate (or boil) it or used as condensers to condense a vapor back to a liquid.

To increase the heat transfer rate in shell and tube type heat exchanger the segmental baffles are introduced inside the cover pipe. The flow arrangement is counter flow as it is more efficient than parallel flow arrangement. One of the most important parts in shell and tube heat exchangers are the baffles. Baffles serve mainly two functions:

- Fixing of the tubes in the proper position during assembly and prevention of tube vibration caused by flow-induced eddies.
- Guidance of the shell-side flow across the tube field, increasing the velocity and the heat transfer coefficient.

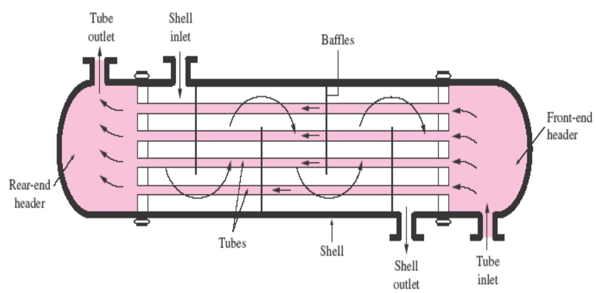

Figure: 1 Different Parts of Shell and Tube Heat Exchanger.

Proposed Work

- In present work, experimentation of single pass, counter flow shell and tube heat exchanger containing segmental baffles at different orientations has been conducted to calculate some parameters (heat transfer rate and pressure drop) at different Reynolds number in laminar flow.

- A prototype model of shell and tube type heat exchanger has been fabricated to carry out the experiments

- Water is taken as the working fluid used in both shell and tubes.

- The flow arrangement used in analysis is counter flow as it is more efficient than parallel flow arrangement.

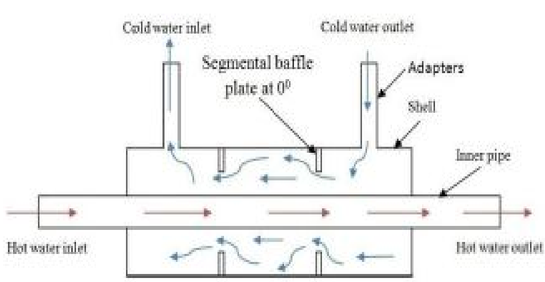

Figure: 2 Shell & Tube Heat Exchanger Containing Segmental Baffles at 0°.

- In the present work, an attempt has been made to study the effect of increase in Reynold number at different angular orientation "θ" of the baffles. The range of "θ" vary from 0° to 45° (i.e 0°, 15°, 30° and 45°) and Reynold number ranges from 500 to 2000 (i.e 500, 1000, 1500 and 2000).

Components and Specifications Used for Setup

The components used in the experimental setup of Shell and Tube Heat Exchanger and their specification are tabulated in table:

Table: 1 Components and Specifications used for Setup

S. No.	Component Name	Specification	Quantity
1	Shell outer diameter	180 mm	
2	Shell inner diameter	170 mm	
3	Thickness of shell	5 mm	
4	Tube outer diameter	19 mm	
5	Tube inner diameter	17 mm	
6	Thickness of tube	1 mm	
7	Length of tube	320 mm	
8	Number of tubes		10
9	Number of baffles		4
10	Number of pumps	220/240 V AC 50 Hz, Ph-1,3 5W	2
11	Electronic Regulator	6 Amp 240V AC	2
12	Electrical water heater	230 V AC 50 HZ 1000W	1
	Measuring Devices		
13	Digital thermometer		1
14	U-Tube manometer		1
15	Beaker	2 lit.	1

Experimental Setup

The different key components of the shell and tube heat exchanger with their measuring devices are shown in Figure: 3.

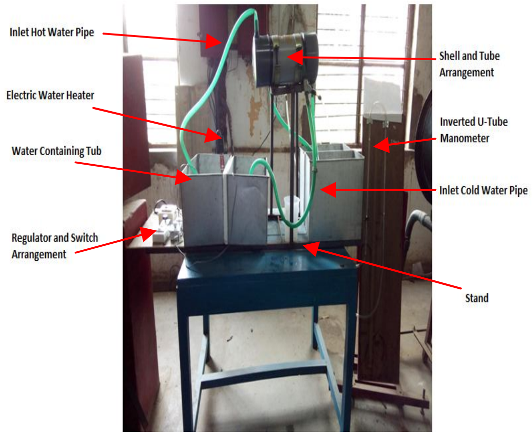

Figure: 3. Experimental Setup Photograph of Shell and Tube Heat Exchanger.

FORMULAE:

Sr.No.	PARAMETERS	DATA REDUCTION
1.	Total heat transfer rate	$Q = U\ A\ \theta m$
2.	Logarithmic mean temperature difference, LMTD	$\theta_m = \frac{\theta_1 - \theta_2}{\ln\left(\frac{\theta_1}{\theta_2}\right)}$
3.	Overall heat transfer coefficient (1)Inner surface (2) Outer surface	$U_i = \frac{1}{\frac{1}{h_i}+R_{fi}+\frac{r_i}{k}ln\left(\frac{r_o}{r_i}\right)+\left(\frac{r_i}{r_o}\right)R_{fo}+\left(\frac{r_i}{r_o}\right)\frac{1}{h_o}}$ $U_0 = \frac{1}{\left(\frac{r_o}{r_i}\right)\frac{1}{h_i}+\left(\frac{r_o}{r_i}\right)R_{fi}+\left(\frac{r_o}{k}\right)ln\left(\frac{r_o}{r_i}\right)+R_{fo}+\frac{1}{h_o}}$
4.	Heat transfer coefficient	$h = \frac{mc_p\Delta t}{\pi DL\theta_m}$
5.	Reynold number	$Re = \frac{\rho VD}{\mu}$
6.	Mass flow rate	$m = A\times V \times \rho$
7.	Pressure drop	$\Delta P = g\times H \times (\rho_h - \rho_l)$

Result and Discussion:

In present work, experimentation of single pass, counter flow shell and tube heat exchanger containing segmental baffles at different orientations has been conducted to calculate some parameters (heat transfer rate and pressure drop) at different Reynolds number in laminar flow. In the present work, an attempt has been made to study the effect of increase in Reynolds number at different angular orientation "θ" of the baffles. The range of "θ" vary from 0° to 45° (i.e. 0°, 15°, 30° and 45°) and Reynolds number ranges from 500 to 2000 (i.e. 500, 1000, 1500 and 2000).

A prototype model of shell and tube type heat exchanger has been fabricated to carry out the experiments. This experimental setup had been placed on the ground of the heat and mass transfer lab, Department of Mechanical Engineering, Jabalpur Engineering College, Jabalpur (M.P). The experiments were performed to determine the effect of baffle orientation on the performance of shell and tube heat exchanger. Water is taken as the working fluid used in both shell and tubes. The objective of the present work is to predict the variation of heat transfer rate, LMTD, heat transfer coefficient, and pressure drop to the shell side with change in range of Reynolds number at different baffle orientations.

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- In the experiment, we have recorded the inlet and outlet temperature of hot and cold fluid at different Reynolds number with different angle of orientation of Baffle plates (i.e 0 °, 15 °, 30 ° and 45 °) one by one.

- With the help of these measuring parameters we have to calculate the variation of heat transfer rate, LMTD, heat transfer coefficient, and pressure drop to the shell sides of the heat exchanger. Mathematical calculations are done in the earlier section.

- From the next pages the no of tables are presented after which the graphs are plotted to see the effect of various parameters with respect to each other.

Tables for Different Baffle Orientations:-

Table: 1 Different Performance Assessment when Baffle Orientation at θ = 0°

For θ = 0°

Re	T_{h1}	T_{c1}	T_{h2}	T_{c2}	θ_m	h_i	h_o	U_o	Q	Δp
500	69	28	65.1	43.6	30.88	972.05	512.74	283.06	1668.69	220.72
1000	69	28	63.3	39.4	32.36	1355.7	1213.01	480.67	2969.39	382.59
1500	69	28	62.4	36.8	33.28	1526.38	1365.71	527.48	3351.17	603.31
2000	69	28	62.2	34.8	34.2	1530.32	1369.23	528.52	3450.63	941.7

Table: 2 Different Performance Assessment when Baffle Orientation at θ = 15°

For θ = 15°										
Re	T_{h1}	T_{c1}	T_{h2}	T_{c2}	θ_m	h_i	h_o	U_o	Q	Δp
500	69	28	64.8	44.8	30.06	1075.53	962.18	398.27	2285.5	191.29
1000	69	28	63.1	39.8	32.05	1416.86	1267.72	497.73	3045.31	353.16
1500	69	28	62.1	37.17	32.95	1611.75	1437.38	549.32	3455.36	559.17
2000	69	28	61.9	35.1	33.9	1611.99	1442.3	550.08	3559.88	897.61

Table: 3 Different Performance Assessment when Baffle Orientation at θ =30°

For θ = 30°										
Re	T_{h1}	T_{c1}	T_{h2}	T_{c2}	θ_m	h_i	h_o	U_o	Q	Δp
500	69	28	64.4	46.4	28.95	1222.96	1094.23	442.53	2445.7	147.15
1000	69	28	62.9	40.2	31.75	1478.83	1323.07	514.66	3119.44	309.01
1500	69	28	61.5	37.97	32.24	1790.48	1597.2	594.77	3660.62	500.31
2000	69	28	61.4	35.6	33.4	1751.34	1566.99	585.68	3734.36	824.04

Table: 4 Different Performance Assessment when Baffle Orientation at θ = 45°

For θ = 45°										
Re	T_{h1}	T_{c1}	T_{h2}	T_{c2}	θ_m	h_i	h_o	U_o	Q	Δp
500	69	28	64.6	45.6	29.5	1147.98	1027.14	420.29	2366.89	103
1000	69	28	63	40	31.9	1447.65	1295.26	506.17	3082.46	250.15
1500	69	28	61.8	37.57	32.6	1699.88	1516.19	572.02	3559.89	426.73
2000	69	28	61.6	35.4	33.6	1695.1	1516.67	571.49	3665.69	735.75

Graphs between Different Parameters:-

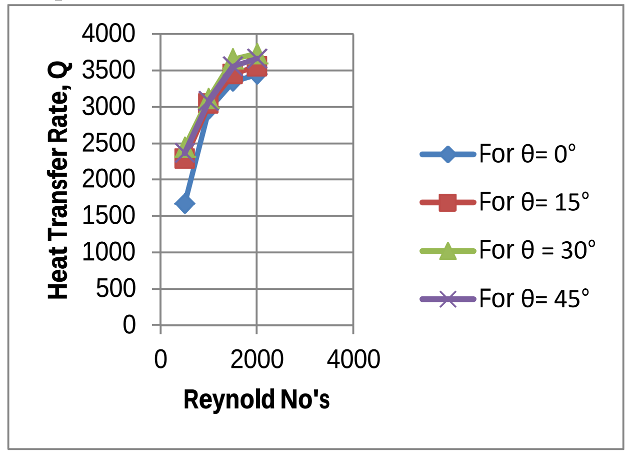

Figure: 4 Performance Assessment of Heat Transfer Rate Vs Reynolds number.

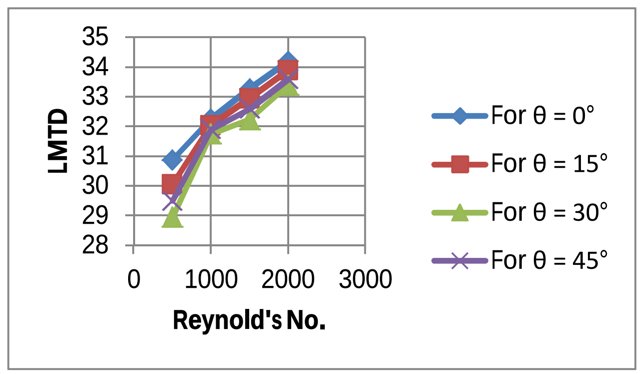

Figure: 5 Performance Assessment of LMTD Vs Reynolds number.

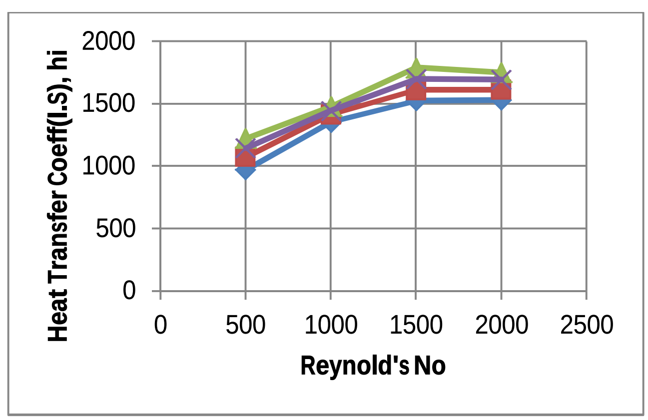

Figure: 6 Performance Assessment of Heat Transfer Coefficient (Inner Side) Vs Reynolds Number.

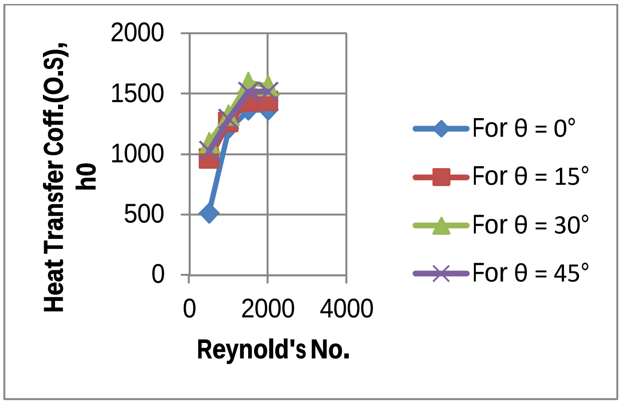

Figure: 7 Performance Assessment of Heat Transfer Coefficient (Outer Side) Vs Reynolds Number.

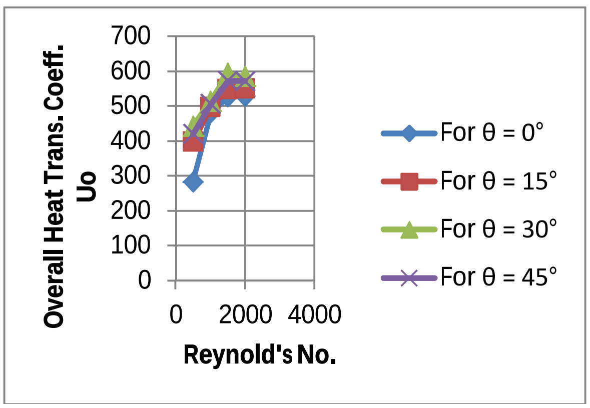

Figure: 8 Performance Assessment of Overall Heat Transfer Coefficient Vs Reynolds Number.

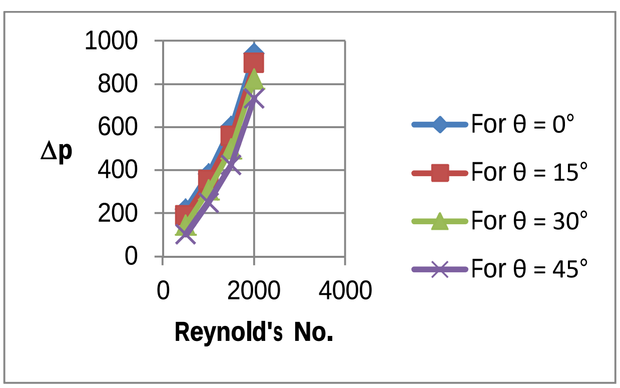

Figure: 9 Performance Assessment of Pressure Drop Vs Reynolds Number.

Conclusion

In present work, experimentation of single pass, counter flow shell and tube heat exchanger containing segmental baffles at different orientations has been conducted to calculate some parameters (heat transfer rate and pressure drop) at different Reynolds number in laminar flow. In the present work, an attempt has been made to study the effect of increase in Reynolds number at different angular orientation "θ" of the baffles. The range of "θ" vary from 0° to 45° (i.e 0°, 15°, 30° and 45°) and Reynolds number ranges from 500 to 2000 (i.e 500, 1000, 1500 and 2000.

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Nomenclature:

Q	Total heat transfer rate (w)
U	Overall heat transfer coefficient (w/m^2°C)
A	Heat transfer area (m^2)
θ_m	Logarithmic mean temperature difference, LMTD (°C)
H	Coefficient of convective heat transfer (w/m^2°C)
D_o	Outer diameter of tube (m)
D_i	Inner diameter of tube (m)
L	Length of tube (m)
V	Velocity of water (m/s)
M	Mass flow rate of water (kg/s)
P	Density of water (kg/m^3)
μ	Dynamic viscosity of water (n-s/m^2)

C_P	Specific heat of water (j/kg℃)
R_f	Fouling factor (m^2℃/w)
T	Temperature of water (℃)
K	Thermal conductivity (w/m℃)
ΔP	Pressure drop (n/m^2)
G	Acceleration due to gravity (m/s^2)
H	Difference in fluid(turpentine oil) level (m)
ρ_h	Density of heavy fluid, water (kg/m^3)
ρ_l	Density of light fluid, turpentine oil (kg/m^3)

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