Optimization of Single Pass Shell and Tube Heat Exchanger by Experimental Approach under Different Baffle Orientation

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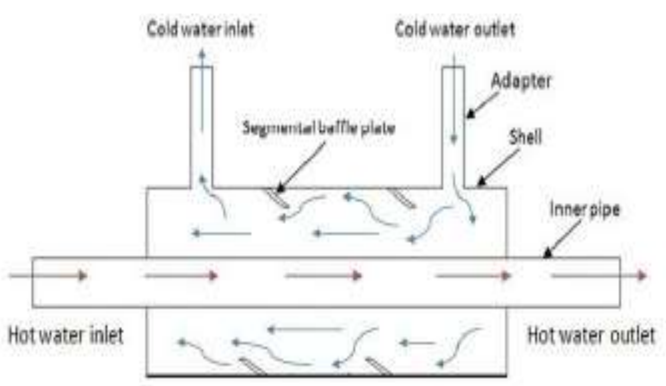
Abstract: **In this study, the experimental analysis was performed on the shell & tube type heat exchanger containing segmental baffles at different orientations. In the current work four angular orientations (ɵ) 0˚, 15˚, 30˚ and 45˚ of the baffles were analyzed for the Reynolds number range 500-2000. It was observed that with increase of Reynolds number from 500 to 2000 at 0˚ angular orientation. There was increase in heat transfer rate and pressure drop. But when we increased the angle of orientation at particular reynold number, heat transfer rate increases upto 30˚ and after that it start decreases and pressure drop decreases continuously from 0˚ to 45˚.**

Keywords**: shell-and-tube heat exchanger, lmtd, heat transfer coefficient, reynold number, heat transfer rate, pressure drop.**

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, and 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. 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 used in analysis is counter flow as it is more efficient than parallel flow arrangement. The different orientation of baffles in heat exchanger is given below:



The shell and tube heat exchanger provides a comparatively large ratio of heat transfer area to volume and weight (up to 1000 m^2/m^3) [Hesselgreaves, 2001]. It provides this surface in a form which is relatively easy to construct in a wide range of sizes (Figure 1.1 and 1.2) and which is mechanically rugged enough to withstand shop fabrication stress, shipping and field erection stress, and normal operating conditions [Palen, 1986; Driedger, 1996; Wolverine, 2001]. There are many modifications of the basic configuration which can be used to solve special problems. [Saundres, 1988; Wolverine, 2001]. 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.

Figure 1: shell and tube heat exchanger made by Addison Fabricators Inc., Addison, Alabama, USA (8000 tubes/90 tonnes).

Baffles

One of the most important parts in shell and tube heat exchangers is 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.
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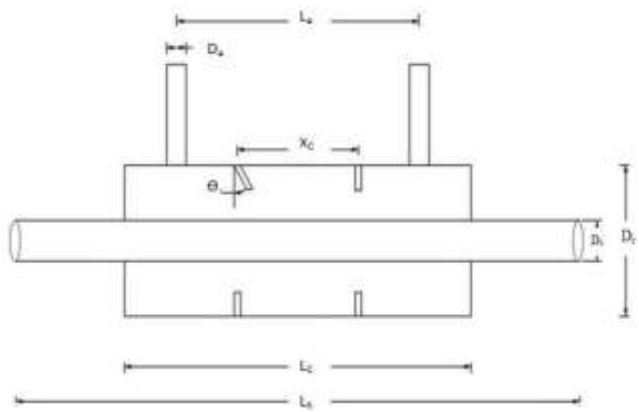
The most common baffle shape is single segmental as shown in Figure 3. The segmental baffle cut must be less than half of the shell inside diameter in order to ensure that adjacent baffles overlap at least one full baffle tube row.

TEST SPECIMEN

A variety of different strategies are available to improve the performance of shell and tube type heat exchanger as discussed by S.P.Walde [16]. The present paper mainly attempts to study the different effects in shell and tube heat exchanger by increasing Reynolds number with segmental baffles at different **angular** orientations (ϴ) 0˚, 15˚, 30˚ and 45˚ over pipe. The model is situated with four segmental baffles. The various dimensions used in heat exchanger are shown in fig.2. The working fluid used is de-ionized water. The material used for design of model is galvanized iron. The geometric parameters of shell and tube heat exchanger are given in table 1:



Dimensions used in heat exchanger

3. RESULTS AND DISCUSSION

In the present study, different cases were studied to understand the heat transfer coefficient, heat transfer rate and pressure drop of shell and tube type heat exchanger having hot water and cold water inlets. Performance comparison and other details are also considered.

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

Table no. 1

The variation of LMTD, heat transfer coefficient, heat transfer rate and pressure drop with different Reynolds number at different orientation of baffle plates are shown in the form of tables and graphs.

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

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

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

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

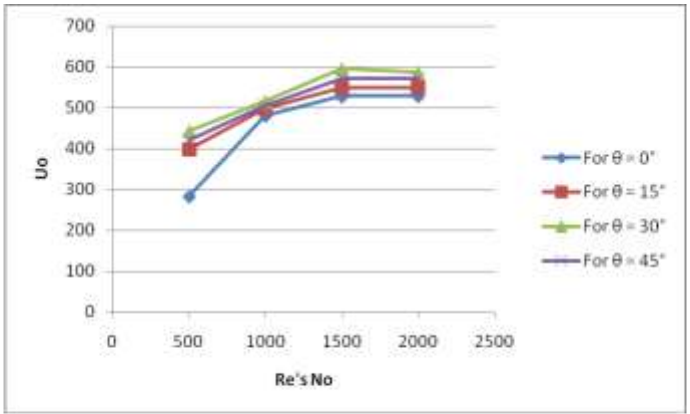


Fig.3 : Graph between Re's no and Uo

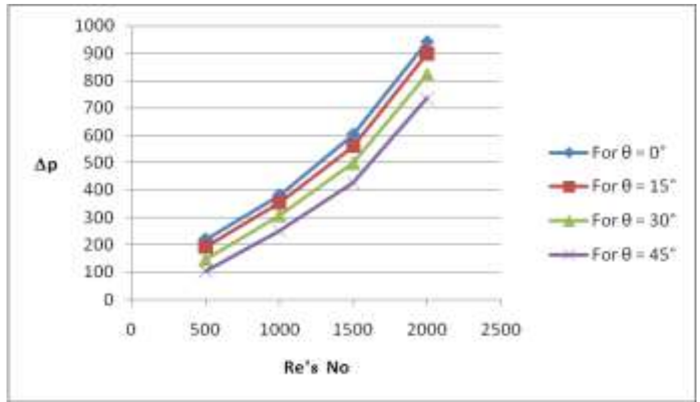


Fig.4 : Graph between Re's no and Δ P

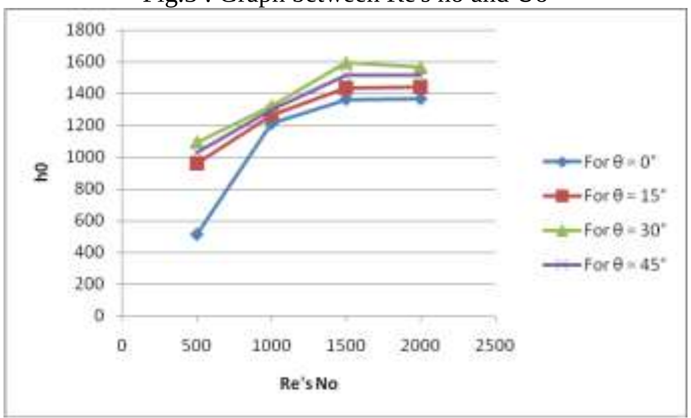


Fig.5 : Graph between Re's no and ho

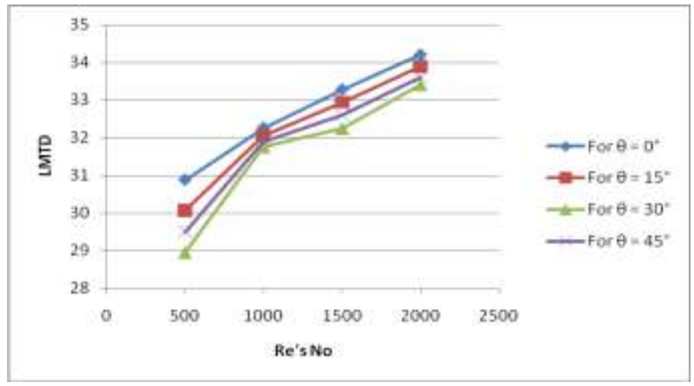


Fig.6 : Graph between Re's no and LMTD

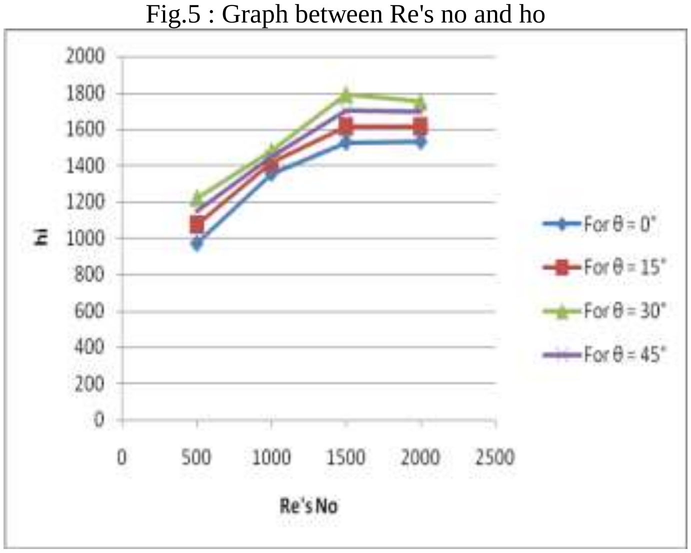


Fig.7 : Graph between Re's no and hi

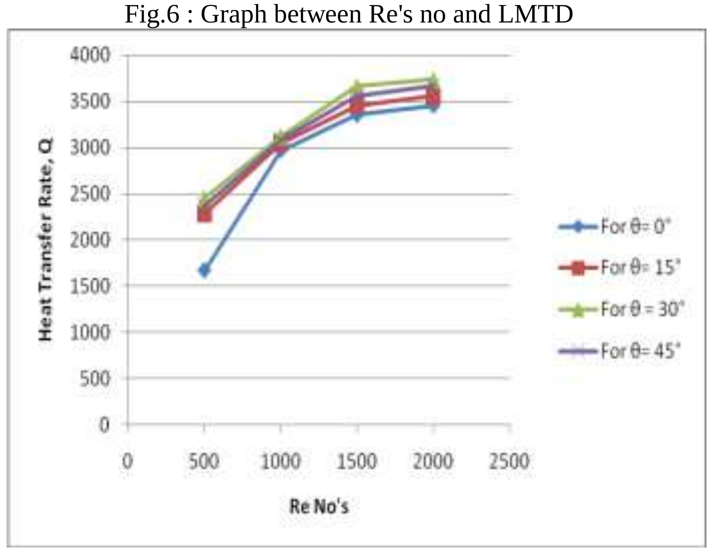


Fig.8 : Graph between Re's no and Q

CONCLUSION

In this paper, experimental study of shell and tube heat exchanger is conducted to calculate the heat transfer coefficient, LMTD, heat transfer rate and pressure drop at different Reynolds number. It is concluded that the increase in Reynolds number has significant impact on different parameters of shell and tube type heat exchanger. The major findings are summarized as follow:

- Based upon the following experimental setup, the effect of baffle orientation on different angle of Shell and Tube Heat Exchanger show that the performance level is increasing upto 30° and after that it starts decreasing. So our experiment shows that 30° baffle orientation gives optimum heat transfer rate.
- The effect of Baffle angle on the performance of pressure drop, i.e decreases continuously from 0° to 45° which helps in reducing the pumping cost.
- The heat transfer cocfficient and LMTD increases with increase in Reynold number in shell and tube heat exchanger for both hot fluid inlet and cold fluid inlet.

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)
ρ	Density of water (kg/m^3)
μ	Dynamic viscosity of water (N-S/m^2)
C_p	Specific heat of water (J/kg°C)
R_f	Fouling factor (m^2°C/W)
t	Temperature of water (°C)
K	Thermal conductivity (W/m°C)
ΔP	Pressure drop (N/m^2)
g	Acceleration due to gravity (m/s^2)
H	Difference in fluid(tarpin) level (m)
ρ_h	Density of heavy fluid, water (kg/m^3)
ρ_l	Density of light fluid, tarpin (kg/m^3)

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