"Performance Evaluation Of A Helical Baffle Heat Exchanger"

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Abstract

This paper analyzes the conventional segmental baffle heat exchanger using the Kern method with varied shell side flow rates and volume flow rate. This method used in design of heat exchangers with a baffle cut of 25%. It predicts heat transfer coefficient, pressure drop of single segmental and helical baffle heat exchanger. This method gives us clear idea that the rate of heat transfer coefficient is maximum in segmental baffle heat exchanger and it decreases as the helical angle increases. This decides the optimum helix angle for helical baffle heat exchanger. The helical baffle angle in the heat exchanger eliminates principle shortcomings caused by shell side zigzag flow induced by conventional baffle arrangement. The flow pattern in the shell side of the heat exchanger with continuous helical baffle was forced to rotational & helical due to geometry of continuous helical baffles, which results in significance increase in heat transfer coefficient per unit pressure drop in the heat exchanger. The pressure drop varies drastically with baffle inclination angle and shell-side Reynolds number. The variation of the pressure drop is large for small inclination angle and it is increases as the helical angle increases.

1 Introduction

Heat exchangers have always been an important part to the life-cycle and operations of many systems. A heat exchanger is a device built for efficient heat transfer from one medium to another in order to carry and process energy. Typically one medium is cooled while the other is heated. They are widely used in petroleum refineries, chemical plants, petrochemical plants, natural gas processing, Air conditioning, refrigeration and automotive applications. One common example of a heat exchanger is the radiator in a car, in which it transfers heat from the water (hot engine-cooling fluid) in the radiator to the air passing through the radiator.

There are two main types of heat exchangers: -
· **Direct contact heat exchanger** where both media between which heat is exchanged are in direct contact with each other.
· **Indirect contact heat exchanger** where both media are separated by a wall through which heat is transferred so that they never mix.

Shell and tube type heat exchanger is an indirect contact type heat exchanger as it consists of a series of tubes, through which one of the fluids runs. The shell is a container for the shell fluid. Usually, it is cylindrical in shape with a circular cross section, although shells of different shapes are used in specific applications

Sandeep K. Patel, Professor Alkesh M. Mavani (2012) has studied the characteristics of heat exchanger design is the procedure of specifying a design. Heat transfer area and pressure drops and check the assumed design satisfies all requirement or not and to design the shell and tube heat exchanger which is the majority type of liquid –to- liquid heat exchanger.

B.T.Lebele-Alawa, Victor Egwanwo (2012) have calculated outlet temperatures of both shell and tube heat exchanger and overall heat transfer coefficients for three different industrial heat exchangers by basic governing equations and concluded that the deviations in outlet temperatures for the tube were 0.53%, 0.11% and 5.10% while the shell side gave 0.76%, 0.47% and 0.74% which indicate high efficiency in thermal energy transfer.

B. Prabhakara Rao, P. Krishna Kumar, Sarit K. Das (2010) has provided a simulation tool rather than providing and experimental analysis. They have performed a structural analysis by using Finite Element Method using ANSYS of shell and tube type heat exchanger and also the comparative analysis of the structural analysis with experimental analysis have also carried out which shows better accuracy accurate failure of material and location of failure.

1.1 Desirable features of heat exchanger

The desirable features of the heat exchanger is to obtain maximum heat transfer performance at the lowest possible operating and capital costs, lower the pressure drop. Helical baffle heat exchangers have shown very effective performance especially for the cases in which the heat transfer coefficient in shell side is controlled or low pressure drop. It can also be very effective, where heat exchangers are predicted to be faced with vibration condition. Helical flow path of the shell-side fluid can also be achieved by a continuous helix shaped baffle running throughout the length of the shell and tube heat exchanger.

The Helix-changer design provides:-
1. Enhanced heat transfer performance/ shell-side pressure drop ratio.
2. Reduced fouling characteristics.
3. Effective protection from flow-induced tube vibrations.
4. Lower capital costs, reduced operating costs, lower maintenance costs and consequently, significant lower total life cycle costs.

1.2 Design Consideration and Analytical Model

The various design considerations of a heat exchanger are: selection of working fluid, development of analytical model, analytical consideration and assumptions, procedure, input parameters required, computed parameters. The developments for shell and tube heat exchangers focus on better results for lower pressure drop and for higher heat transfer co-efficient. With single segmental baffles, most of the overall pressure drop is wasted in changing the direction of flow.

This kind of baffle arrangement also leads to more undesirable effects such as dead spots or dead zones of recirculation which can cause increased fouling, high leakage flow that bypass heat transfer surface giving rise to lesser heat transfer co-efficient, and large cross flow which not only reduces the mean temperature difference but can even damage the tube.

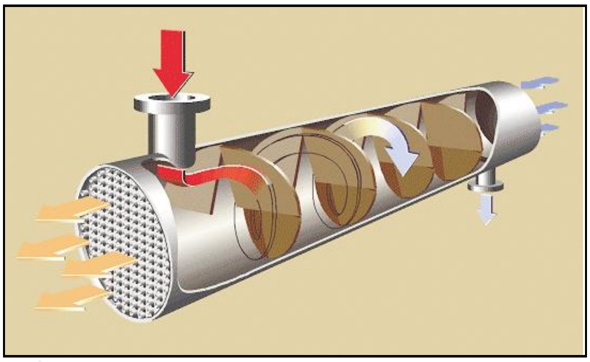


Figure 1.1 Schematic view of the Helical Baffle Heat Exchanger

1.3 Baffle spacing

Baffle spacing is the centerline-to centerline distance between adjacent baffles. It is the most vital parameter in STHE design. The TEMA standards specify the minimum baffle spacing as one fifth of the shell inside diameter or 2 in., whichever is greater. Closer spacing will result in poor bundle penetration by the shell side fluid and difficulty in mechanically cleaning the outsides of the tubes.

1.4 Segmental Cut Baffles

- Optimal baffle spacing is somewhere between 40% - 60% of the shell diameter.
- Baffle cut of 25%-35% is usually recommended.

2 Problem Formulation

Conventional shell and tube heat exchangers with segmental baffles having low heat transfer co-efficient due to the segmental baffle arrangement causing high leakage flow by-passing the heat transfer surface and high pressure drop that posses a big problem for industries as the pumping costs increases. The hydrodynamic studies testing the heat transfer (mean temperature difference) and the pressure drop; with the help of research facilities and industrial equipment have shown much better performance of helical baffle heat exchangers as compared to the conventional ones. This results in relatively high value of shell side heat transfer coefficient, low pressure drop, and low shell side fouling.

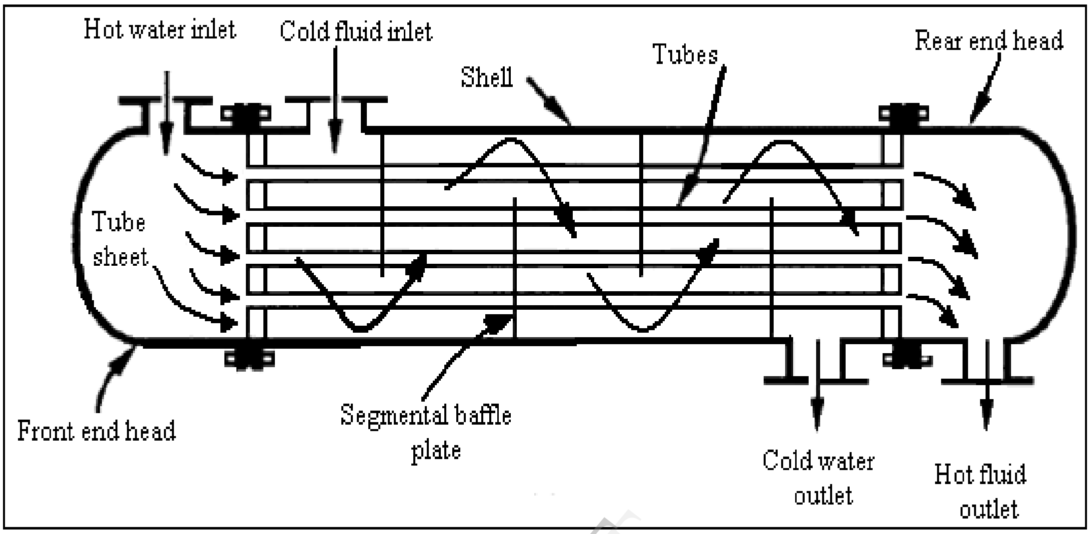


Figure 2.1 Heat Exchanger Analyses

Input Data

At shell side

S. No.	Quantity	Symbol	Value
1	Shell side fluid		Water
2	Volume flow rate	($\dot{Q}_s$)	40 lpm.
3	Shell side Mass flow rate	($\dot{m}_s$)	1 kg/sec
4	Shell ID	(D_{is})	0.153 m
5	Shell length	(L_s)	1.123 m
6	Tube pitch	(P_t)	0.0225 m
7	No. of passes		1
8	Baffle cut (Fixed)	L_{bch}	25%
9	Baffle pitch	(L_b)	0.060 m
10	Shell side nozzle ID		0.023 m
11	Mean Bulk Temperature	(MBT)	30 ˚C
12	Shell side Mass velocity / mass flux	($\dot{M}_f$)	kg / (m^2s)

Tube Side

S. No.	Quantity	Symbol	Value
1	Tube side fluid		Water
2	Volume flow rate	($\dot{Q}_t$)	40 lpm.
3	Tube side Mass flow rate	($\dot{m}_t$)	1kg/sec
4	Tube OD	(D_{ot})	0.153 m
5	Tube thickness		1.123 m
7	Tube side nozzle ID		1
8	Mean Bulk Temperature	(MBT)	30 ˚C

Leakage and bypass clearances:

i) Tube to baffle clearance (δ_{bt}) = 0.0004 m.
ii) Baffle to shell clearance (δ_{bs}) = 0.001 m
iii) Shell to bundle clearance (δ_{bd}) = 0.01428 m.

Fluid Properties

S. No.	Property	Symbol	Unit	Cold Water (Shell side)	Hot Water (Tube side)
1	Specific Heat	Cp	KJ/kg-K	4.178	4.178
2	Thermal Conductivity	K	W/m-K	0.615	0.615
3	Viscosity	µ	kg/m-s	0.001	0.001
4	Prandtl's Number	Pr	-	5.42	5.42
5	Density	ρ	kg/m^3	996	996

Step-wise Procedure

The model development involves thermal analysis of two sections of the heat exchanger, which are as follows

- Thermal Analysis of Segemental Baffle Heat Exchanger
- Thermal Analysis of Helical Baffle Heat Exchanger

Input Required

The following are the input parameters at shell side

- Flow rate of hot fluid at shell side, m^3/sec
- Shell Side Mass Flux ($\dot{M}_f$), kg/m^{2}sec
- Mean Bulk temperature, 0C
- Specific Heat (Cp), KJ/KgK
- Thermal Conductivity (K), W/m-K
- Density (ρ), kg/m3

Research Aspects

Research on the helical baffle heat exchanger has forced on two principle areas.

- Hydrodynamic studies on the shell side of the heat exchanger
- Heat transfer coefficient and pressure drop studies.

Use of helical baffles in heat exchanger reduces shell side pressure drop, pumping cost, size, weight, fouling etc. as compare to segmental baffle for new installations. The helical angle heat exchanger type heat exchangers can save capital cost as well as operating and maintenance cost and thus improves the reliability and availability of process plant in a cost effective way. The model evaluates the rate of heat transfer, pressure drop of a segmental baffle as well as for the helical baffle heat exchanger. Computational obtained at 10° to 40° tilt angle for the baffle.

Important Parameters:

The following are the input parameters at shell side:

- Pressure Drop (ΔPs)
- Cross-flow Area
- Helical Baffle pitch angle (ϕ)
- Baffle spacing (Lb)
- Equivalent Diameter (DE)
- Heat transfer coefficient (α_o)

Observation Table and Calculations

Details value of Heat Exchanger

S.No.	Parameter	Segemental Baffle Heat Exchanger	10°	15°	20°	25°	30°	35°	40°
1	C'	0.0105	0.0105	0.0105	0.0105	0.0105	0.0105	0.0105	0.0105
2	L_b	0.06	0.0847	0.1288	0.174	0.224	0.2775	0.336	0.4
3	A_s	0.00428	0.00605	0.0092	0.012	0.01524	0.0198	0.02399	0.02856
4	D_E	0.04171	0.04171	0.04171	0.04171	0.04171	0.04171	0.04171	0.04171
5	P_r	5.42	5.42	5.42	5.42	5.42	5.42	5.42	5.42
6	N_b	17	13	9	7	5	4	4	3

VOLUME FLOW RATE (Qs) = 0.00067m^3/sec (40lpm)

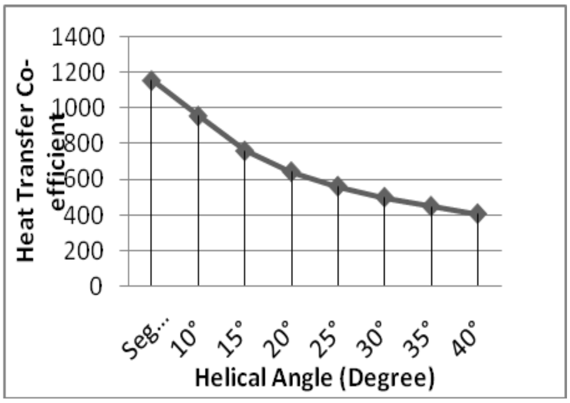
MASS FLOW RATE (Ms) - 1.0 Kg/sec

S.No.	Parameter	Segemental Baffle Heat Exchanger	10°	15°	20°	25°	30°	35°	40°
1	Vmax	0.16	0.11	0.072	0.053	0.0417	0.033	0.027	0.023
2	Re	6470.4	4581.46	3014.88	2219.5	1732.41	1399.2	1153.7	962.74
3	α_0	1156.33	956.55	759.89	642.09	560.29	498.18	448.03	405.59
4	Mf	233.43	165.28	108.76	80.07	62.49	50.48	41.62	34.73
5	f	0.07	0.07	0.08	0.08	0.09	0.11	0.11	0.12
6	ΔPs	513.3	190.28	65.47	27.35	15.28	10.27	6.017	4

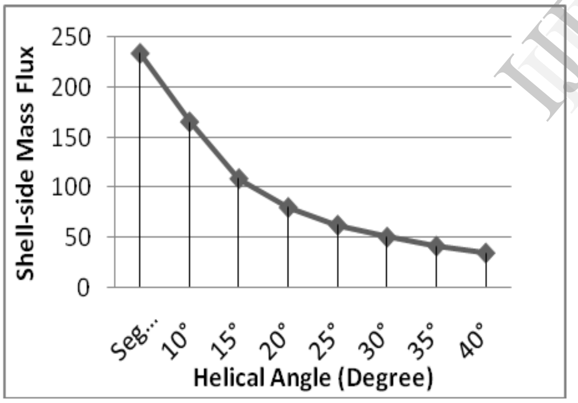
Results and Discussions

Graphical Representation of

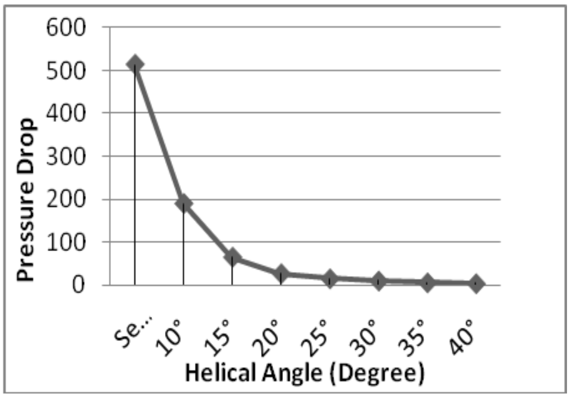
- **Heat Transfer Coefficient and Helical Angle**



- **Shell-side mass flux and Helical Angle**



- **Pressure Drop And Helical Angle**



Conclusion

In the present paper an attempt has been made to modify the existing Kern's Method for continuous helical baffle heat exchanger, which is used for segmental baffle heat exchanger. Results give us clear idea that the helical baffle heat exchanger gives far better results for heat transfer coefficient, pressure drop than the conventional segmental heat exchanger in all the cases of the varying flow rate.

Heat Transfer Co-efficient (α_o) – The rate of heat transfer coefficient in segmental baffle heat exchanger is maximum and it decreases as increase in helical angle and it becomes minimum at helical angle of 40° due to decrease in Reynolds number.

Shell side Mass Flux ($\dot{M}_f$) – In this heat exchanger shell side mass flux ($\dot{M}_f$) is maximum in segmental baffle heat exchanger for different flow rate and it decreases with different helical angle. Also the variation of the mass flux is relatively small after an inclination of 30° helical angle.

Pressure Drop (ΔPs) – It also indicates that the pressure drop (ΔPs) in a helical baffle heat exchanger is lesser as compared to the segmental baffle heat exchanger due to increased cross-flow area, which resulting in lesser mass flux throughout the shell. The variation in pressure drop is approximately after an inclination of 35° helical angle.

Compared to the conventional segmental baffled shell and tube exchanger helical angle heat exchanger offers the following general advantages.

- Increased heat transfer rate/ pressure drop ratio.
- Reduced bypass effects.
- Reduced shell side fouling.
- Prevention of flow induced vibration.

- Reduced maintenance.

Future Scope

- The study can be carried out using different fluid in the shell side heat exchanger such as iso-propane, iso-butane and other fluid and one side fluid and other side air can also be carried out.
- The study can be focused on the effects of interstitial materials and coatings at the interface of tube and fin on heat transfer.

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