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Comparative Analysis of Conventional and Helical Baffles in Heat Exchanger

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***Abstract*: In a shell-and-tube heat exchanger, the pressure drop is reduced and the heat transfer and the heat transfer-to-pressure-drop ratio are both improved by angling the baffle up to the point where the pressure drop is smallest. However, this study uses computational methods to analyse shell-and-tube heat exchangers. Producing a fast and easy-to-use computer programme for heat transfer calculations is a key part of this process. An examination of a shell-and-tube heat exchanger's shell has been completed. Kern's method is applied to the standard segmental baffle heat exchanger with constant flow rates on the shell side and variable flow rates in the volume. Heat exchangers with a 25% baffle cut have been built using Kern's method (fixed). Compared to segmental baffle heat exchangers, helical baffle heat exchangers are shown to have a higher ratio of heat transfer coefficient per unit pressure drop in this method's thermal analysis.**

***Keywords*: Pressure drop, heat transfer, ratio of heat transfer, shell and tube type heat exchanger and pressure drop, computer programme, Kern' method.**

1. Introduction

For quite some time, heat exchangers have been crucial to the functioning of a number of different systems over their entire lifespans. A heat exchanger is a device used to transfer heat from one medium to another for the purposes of transportation and processing of energy. It is common practise to cool one medium while heating the other. The automobile, HVAC/R, chemical, petrochemical, natural-gas processing, and oil-refining industries all make heavy use of them.

The radiator of a car is a prototypical heat exchanger since it moves air through a closed loop of heated water (engine coolant).

There are two principal varieties of heat exchangers:

- Direct contact heat exchanger in which both heat-exchanging medium are in direct touch with one another.
- Heat exchanger with indirect contact in which the two mediums are separated by a wall through which heat is transported so they never mix.

Shell and tube heat exchangers are indirect contact heat exchangers because one of the fluids passes through a series of tubes. Shell fluid is contained within the shell. Typically cylindrical with a circular cross-section, shells of various shapes are utilised for specific applications.

A. Desirable Heat Exchanger Characteristics

The desirable characteristics of a heat exchanger are maximizing heat transfer performance while minimizing operational and capital expenditures, and minimizing pressure drop. The performance of helical baffle heat exchangers has been particularly impressive in circumstances when the heat transfer coefficient in the shell side is controlled or there is a low pressure drop. It is also highly effective when heat exchangers are anticipated to be subjected to vibration.

A continuous helix-shaped baffle running the length of the shell and tube heat exchanger can also be used to create a helical flow channel for the shell-side fluid.

B. Considerations for the Design and Analytical Model

A heat exchanger's numerous design considerations include the selection of working fluid, construction of an analytical model, analytical considerations and assumptions, technique, input parameters required, and computed parameters.

The advancements in shell-and-tube heat exchangers are centred on the improvement of pressure drop and heat transfer efficiency.

With single segmental baffles, the majority of the pressure loss is lost when changing the flow direction.

This type of baffle arrangement also results in additional unfavourable effects, such as dead spots or dead zones of recirculation, which can increase fouling, high leakage flow that bypasses the heat transfer surface, resulting in a lower heat transfer efficiency, and large cross flow, which not only reduces the mean temperature difference but can also cause damage to the tube.

2. Literature Survey

This survey was conducted with the following purpose in mind:

- Determine the segmental baffles of heat exchangers.
- Pressure drop calculations are used to identify the helical baffles in heat exchangers for heat transmission.

This is applicable to the present investigation.

Sandeep K. Patel and Alkesh M. Mavani have investigated the characteristics of heat exchanger design, which is the method of specifying a design. Designing the shell-and-tube

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heat exchanger, the most common type of liquid-to-liquid heat exchanger, entails calculating heat transfer area and pressure drops, as well as determining whether the assumed design meets all requirements.

B. T. Lebele-Alawa and Victor Egwanwo shell and tube heat exchanger outlet temperatures and overall heat transfer coefficients were determined for three different heat exchanger designs in industry using only first-order governing equations. According to their findings, the tube side had output temperature variations of 0.53%, 0.11%, and 5.10%, while the shell side gave 0.76, 0.4, and 0.74, showing a high efficiency in thermal energy transfer.

B. Prabhakara Rao, P. Krishna Kumar, and Sarit K. Das Instead of offering an experimental analysis, have developed a simulation tool.

They have completed a structural study of a shell-and-tube type heat exchanger using the Finite Element Method and ANSYS, as well as a comparative analysis of the structural analysis with experimental data, which demonstrates more accurate failure of material and site of failure.

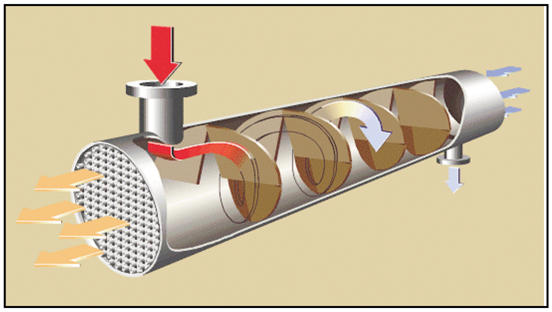

Fig. 1. Schematic view of the Helical Baffle heat exchanger

3. Leakage and Bypass Clearances

i. Baffle clearance from tube (δ_{bt}) = 0.0004 m.
ii. Shell clearance from baffle (δ_{bs}) = 0.001 m
iii. Bundle clearance to Shell (δ_{bd}) = 0.01428 m.

A. Data for Input

Table 1
Shell side

S. No.	Characteristic	Representation	Significance
1	Fluid on Shell side		Water
2	Volume stream rate	($\dot{Q}_s$)	40 to 80 lpm.
3	Shell side Mass flow rate	($\dot{m}_s$)	0.6 kg/sec
4	ID of Shell	(D_{is})	0.153 m
5	Length of Shell	(L_s)	1.123 m
6	Pitch for Tube	(P_t)	0.0225 m
7	Number of passes		1
8	Fixed Baffle cut	L_{bch}	25%
9	Baffle pitch	(L_b)	0.060 m
10	Nozzle ID of Shell side		0.023 m
11	Mean Bulk Temperature	(MBT)	30 ˚C
12	Angle of Baffle	(Degree)	0° to 40°

Table 2
Tube side

S. No.	Characteristic	Representation	Significance
1	Fluid on Tube side		Water
2	Volume stream rate	($\dot{Q}_t$)	40 to 80 lpm.
3	Tube side Mass stream rate	($\dot{m}_t$)	0.6 kg/sec
4	Tube OD	(D_{ot})	0.153 m
5	Thickness of Tube		1.123 m
7	Tube side nozzle ID		1
8	Mean Bulk Temperature	(MBT)	30 ˚C

B. 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^2sec

Table 3
Properties of fluid

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

Table 4
Details value of Heat Exchanger

S.No.	Parameter	Seg. Baffle Heat Exchanger	In Degree					
			10	20	30	40	50	60
1	C'	0.0105	0.0105	0.0105	0.0105	0.0105	0.0105	0.0105
2	L_b	0.06	0.0847	0.174	0.2775	0.4	0.573	0.832
3	A_s	0.004284	0.00605	0.012	0.0198	0.02856	0.0409	0.0594
4	D_E	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
6	N_b	17	13	7	4	3	2	2

Table 5
Volume Flow Rate (Qs) = $0.00067m^3/sec$ (40lpm)

S.No.	Parameter	Seg. Baffle Heat Exchanger	In Degree					
			10	20	30	40	50	60
1	V_{max}	0.16	0.11	0.053	0.033	0.023	0.016	0.011
2	Re	6470.4	4581.46	2219.5	1399.2	962.74	677.85	466.41
3	α_o	1156.33	956.55	642.09	498.18	405.59	334.41	272.25
4	Mf	140.05	99.16	48.04	30.28	20.84	14.67	10.09
5	f	0.07	0.07	0.08	0.11	0.12	0.13	0.14
6	ΔPs	184.78	68.5	9.85	3.69	1.43	0.61	0.24
7	$\alpha_o/\Delta Ps$	6.2578	13.964	65.1868	135.0081	283.6293	548.2131	1134.375

Table 6
Volume Flow Rate (Qs) = 0.001m^3/sec (60lpm)

S.No.	Parameter	Segmental Baffle Heat Exchanger	10°	20°	30°	40°	50°	60°
1	V_{max}	0.233	0.165	0.08	0.05	0.035	0.024	0.0168
2	Re	9700.75	6868.7	3327.6	2097.77	1443.39	1016.27	699.256
3	α_o	1445.11	1195.2	802.28	622.48	506.77	417.84	340.18
4	Mf	140.056	99.16	48.04	30.28	20.84	14.67	10.09
5	f	0.06	0.06	0.07	0.09	0.1	0.11	0.13
6	ΔPs	158.4	58.72	8.62	3.02	1.2	0.513	0.23
7	$\alpha_o/\Delta Ps$	9.1231	20.354	93.07192	206.1192	422.3083	814.5029	1479.04

Table 7
Volume Flow Rate (Qs) = 0.00133m^3/sec (80lpm)

S.No.	**Parameter**	**Segmental Baffle Heat Exchanger**	**10°**	**20°**	**30°**	**40°**	**50°**	**60°**
1	V_{max}	0.31	0.219	0.106	0.067	0.046	0.032	0.022
2	Re	12902	9135.46	4425.7	2790.03	1926.93	1356.73	933.51
3	α_o	1690.51	1398.16	938.53	728.18	594.063	489.81	398.77
4	Mf	140.05	99.16	48.04	30.28	20.84	14.67	10.09
5	f	0.05	0.055	0.06	0.08	0.09	0.11	0.12
6	ΔPs	132	53.82	7.38	2.69	1.08	0.51	0.21
7	$\alpha_o/\Delta Ps$	12.8068	25.978	127.1720	270.6988	550.0583	960.4117	1898.904

- Specific Heat (Cp), KJ/KgK
- Thermal Conductivity (K), W/m-K
- Density (ρ), kg/m^3

4. Observation Table and Calculation

The table 4, 5, 6, and 7 shows the observations.

5. Results and Discussions

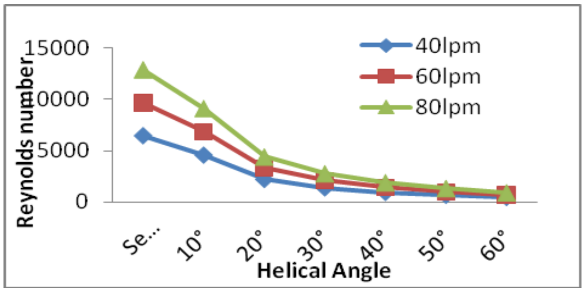

Fig. 2. Graph plot between Reynolds number and helical angle

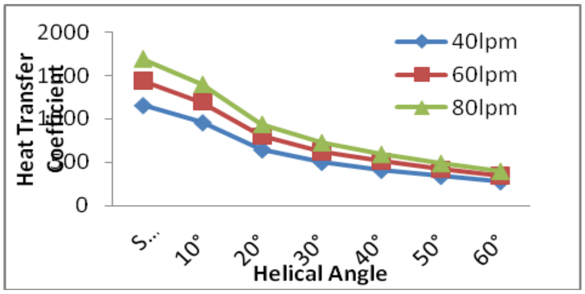

Fig. 3. Graph plot between heat transfer co-efficient and helical angle

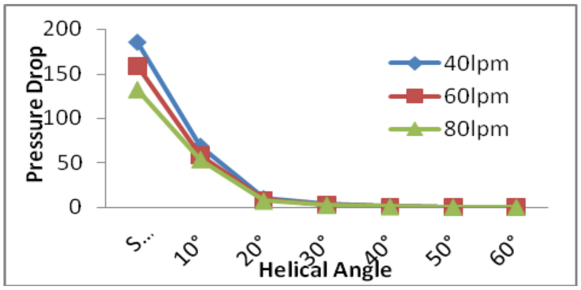

Fig. 4. Graph plot between pressure drop and helical angle

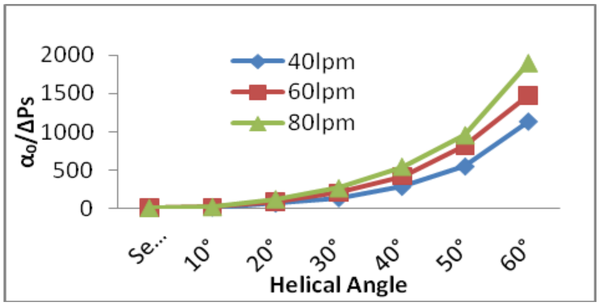

Fig. 5. Graph plot between ratio of heat transfer and pressure drop and helical angle

6. Conclusion

An analytical model has been built to evaluate the thermal analysis of a segmental baffle and helical baffle heat exchanger, and a comparative analysis of the thermal parameters of segmental and helical angles has been performed. The model examines the rate of heat transfer and pressure drop of segmental and helical baffle heat exchangers, respectively. Derived computationally from 0° to 60° tilt angle for the baffle. The following paragraphs provide a summary of the key findings and conclusions derived from this inquiry.

- The use of helical baffles in heat exchangers decreases shell-side pressure loss, pumping cost, size, weight, fouling, etc. when compared to segmental baffles in new installations.
- The helix-changer type of heat exchangers can reduce capital costs as well as operating and maintenance costs, hence enhancing the dependability and availability of process equipment in a cost-efficient manner.
- The ratios of heat transfer coefficient to pressure drop for helical baffle heat exchangers are greater than those of typical segmental heat exchangers.
- The conclusion is that shell-and-tube heat exchangers with a 35° baffle inclination angle operate better than those with segmental and helical baffle inclination angles.

7. Future Scope

a) The study can be conducted utilizing different fluids in the shell side heat exchanger, including isopropanol, isobutane, and other fluids, as well as one side fluid and the other side air.

b) The effects of interstitial materials and coatings at the interface of tube and fin on heat transfer can be the focus of the study.

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