ISSN 2229-5518

"Thermal analysis of Conventional and Helical baffle in heat exchanger"

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Abstract: An attempt made to decrease the pressure drop and to increase the heat transfer and the ratio of heat transfer and pressure drop in shell and tube type heat exchanger by tilting the baffle angle up to which we get the minimum pressure drop. This study however, considers shell and tube type heat exchanger with the aid of computer programming. It involves developing a simple user-friendly computer programme for the heat transfer calculations and ensures that the computational time is kept minimal. Analysis has been done in shell and tube type heat exchanger at shell side. It analyzes the conventional segmental baffle heat exchanger using the Kern's method with fixed shell side flow rates and varied volume flow rate. Since Kern' method used in design of heat exchangers with a baffle cut of 25% (fixed). The thermal analysis of helical baffle heat exchanger using this method give us clear idea that the ratio of heat transfer coefficient per unit pressure drop is maximum in helical baffle heat exchanger as compared to segmental baffle heat exchanger.

Keywords: Shell and tube heat exchanger, helical angle, pressure drop, heat transfer, ratio of heat transfer and pressure drop, Kern's method, baffle cut of 25%, computer programme.

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.

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2. LITERATURE SURVEY

This survey has been carried out with the following objective:

- To identify some of the segmental baffle of heat exchangers.
- To identify the helical baffles in heat exchangers for heat transfer, pressure drop calculations this can be used in the present study.

Sandeep K. Patel, Professor Alkesh M. Mavani 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 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 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

1.2 DESIGN CONSIDERATION AND ANALYTICAL MODEL

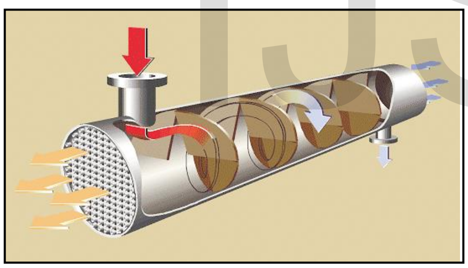

Figure 1.1 Schematic view of the Helical Baffle Heat Exchanger

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 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.

2. 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.

2.1 INPUT DATA

SHELL SIDE

S. No.	Quantity	Symbol	Value
1	Shell side fluid		Water
2	Volume flow rate	($\dot{Q}_s$)	40 to 80 lpm.
3	Shell side Mass flow rate	($\dot{m}_s$)	0.6 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	Baffle angle	(Degree)	0° to 40°

TUBE SIDE

S. No.	Quantity	Symbol	Value
1	Tube side fluid		Water
2	Volume flow rate	($\dot{Q}_t$)	40 to 80 lpm.
3	Tube side Mass flow rate	($\dot{m}_t$)	0.6 kg/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

2.2 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

2.3 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
- Specific Heat (Cp), KJ/KgK
- Thermal Conductivity (K), W/m-K
- Density (ϱ), kg/m^3

3. Observation Table and Calculation

3.1 Details value of Heat Exchanger

S.No	Parameter	Segemental Baffle Heat Exchanger	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

3.2 Volume Flow Rate (Qs) = 0.00067m^3/sec (40lpm)

S.No.	Parameter	Segemental Baffle Heat Exchanger	10°	20°	30°	40°	50°	60°
1	Vmax	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_0	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	α_0/ΔPs	6.25787422	13.96423	65.18680	135.0081	283.6293	548.2131	1134.375

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

S.No.	Parameter	Segemental Baffle Heat Exchanger	10°	20°	30°	40°	50°	60°
1	Vmax	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_0	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	α_0/ΔPs	9.12316919	20.35422	93.07192	206.1192	422.3083	814.5029	1479.043

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

S.No.	Parameter	Segemental Baffle Heat Exchanger	10°	20°	30°	40°	50°	60°
1	Vmax	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_0	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	α_0/ΔPs	12.8068394	25.97844	127.1720	270.6988	550.0583	960.4117	1898.904

4. Results and Discussions

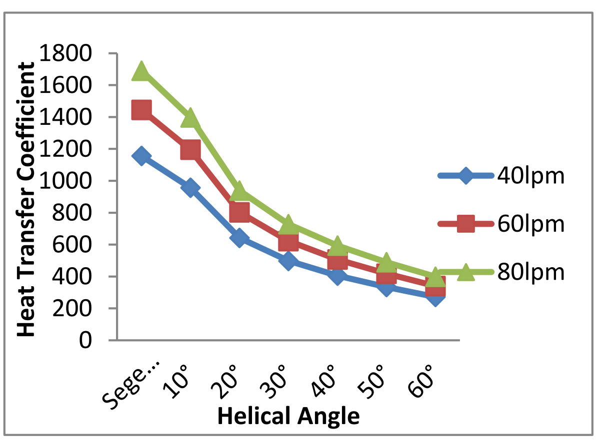

Figure 4.1 Graph plot between heat transfer co-efficient and helical angle

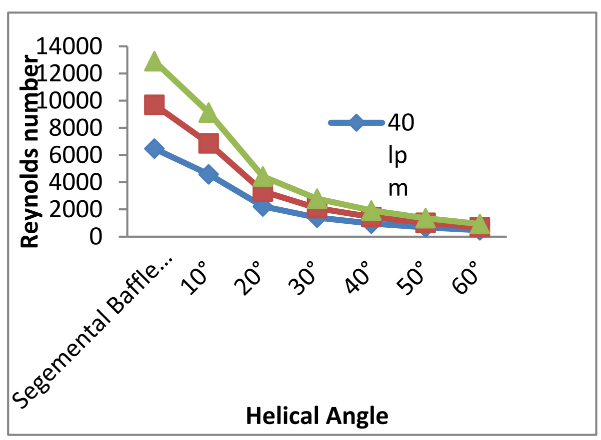

Figure 4.2 Graph plot between Reynolds number and helical angle

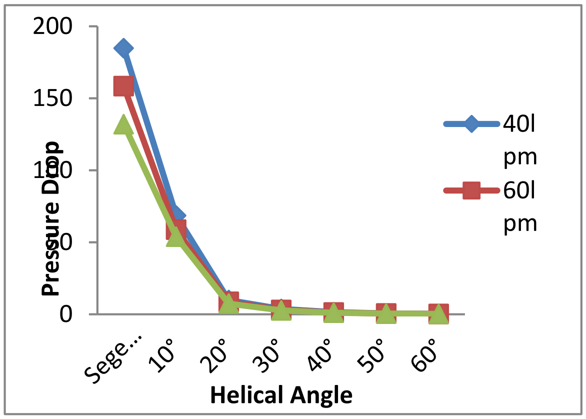

Figure 4.3 Graph plot between pressure drop and helical angle

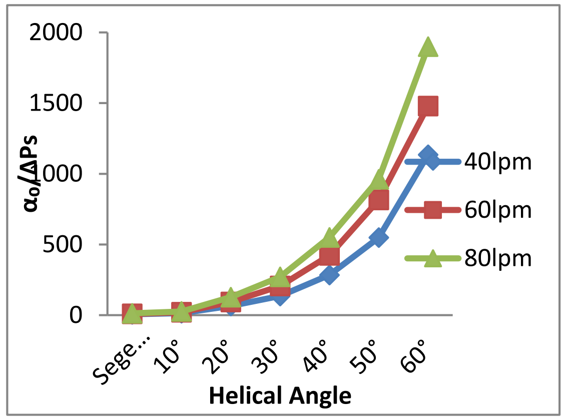

Figure 4.4 Graph plot between ratio of heat transfer and pressure drop and helical angle

5. Conclusion

An analytical model has been developed to evaluate thermal analysis of a segmental baffle and helical baffle heat exchanger as well as the comparative analysis between the thermal parameters between segmental and helical angle has been carried out. 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 0° to 60° tilt angle for the baffle. The significant observations and conclusions obtained from the present investigation are summarized in the following paragraphs.

- 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 helix-changer 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.
- For the helical baffle heat exchangers, the ratios of heat transfer coefficient to pressure drop are higher than those of a conventional segmental heat exchanger.
- It is concluded that shell-and-tube heat exchanger with 35° baffle inclination angle results in better performance compared to segmental baffle and helical inclination angles.

6. 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.

7. References

[1]. Sandeep K. Patel, Professor Alkesh M. Mavani "Shell & Tube Heat Exchanger Thermal Design with Optimization of Mass Flow Rate and Baffle Spacing" International Journal of Advanced Engineering Research and Studies IJAERS/Vol. II/ Issue I/Oct.-Dec.,2012/130-135.

[2]. B.T.Lebele-Alawa, Victor Egwanwo "Numerical Analysis of the Heat Transfer in Heat Exchangers" International Journal of Applied Science and Technology Vol. 2 No. 4; April 2012 page no. 60-64.

[3]. A.O. Adelaja, S. J. Ojolo and M. G. Sobamowo "Computer Aided Analysis of Thermal and Mechanical Design of Shell and Tube Heat Exchangers Advanced Materials Research" Trans Tech Publications, Switzerland Vol. 367 (2012) pp 731-737.

[4]. Ahmed F. Khudheyer and Mahmoud Sh. Mahmoud "Numerical Analysis of Fin-Tube Plate Heat Exchanger by using CFD Technique" ARPN Journal of Engineering and Applied Sciences Volume 6, No. 7, July 2011Sepehr Sanaye, Hassan Hajabdollahi "Multi-objective optimization of shell and tube heat exchanger", Applied Thermal Engineering 30 (2010) 1937-1945.

[5]. B. Prabhakara Rao, P. Krishna Kumar, Sarit K. Das "Comparative Study of Vertical Heat Exchanger Using Finite Element Method" International Journal of Heat and Mass Transfer, Volume 53, Issue 13-14 June 2010,page 2877-2884.

[6]. Qiuwang Wang, Guidong Chen, Min Zeng, Qiuyang Chen, Botao Peng, Dongjie Zhang, Laqin Luo "Shell-side heat transfer enhancement for shell-and-tube heat exchangers by helical baffles" Chemical Engineering Transactions Volume 21, 2010.