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Study of construction and geometry parameter for selection shell and tube heat exchanger

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Abstract: The transfer of heat to and from process fluids is an essential part of most chemical and petroleum industries. The most commonly used type of heat-transfer equipment is the ubiquitous shell and tube heat exchanger, Choices are usually a compromise among process design requirements, optimum thermal performance, allowable pressure drop, ease of maintenance, and cost. For the best overall exchanger performance, designers must take into account a wide variety of specific condition and constraints; development of general recommendations is therefore impossible. However, the following brief discussion can help reconcile structural code-oriented specifications, as represented by TEMA standards and strictly thermal design-oriented specification. In this paper for a given heat exchanger, study of the effect of key parameters like baffle spacing, tube outer diameter and tube thickness, tube passes, tube pitch and tube layout in a Shell and tube heat exchanger with single segmental baffles and staggered tubes. A numerical code is developed by Bell- Delaware method for the thermal performance of shell and tube type heat exchanger. An Experiment had been conducted on existing heat exchanger (Ammonia Product Heater, IFFCO KALOL) for Ammonia process plant for validation of Numerical model and HTRI software for parametric analysis. After verification of the code, parametric analysis is carried out in the present study. Above parametric analysis is also carried out with standard software (HTRi software).

Keywords: fluids, HTRI, TEMA, heat exchanger, ubiquitous shell, Shell

I Introduction

Transfer of heat from one fluid to another is an important operation for most of the chemical industries. The most common application of heat transfer is in designing of heat transfer equipment for exchanging heat from one fluid to another fluid. Such devices for efficient transfer of heat are generally called Heat Exchanger. Heat exchangers are normally classified depending on the transfer process occurring in them.

1.1 TYPE OF HEAT EXCHANGER

The types of heat exchanger used in the chemical process and other industries are listed below:

- Double-pipe exchanger
- Shell and tube exchangers
- Plate and frame exchangers (plate heat exchangers)
- Plate-fin exchangers
- Spiral heat exchangers
- Air cooled: coolers and condensers and
- Direct contact: cooling and quenching.

1.2 WHY SHELL AND TUBE HEAT EXCAHNGER?

Shell and tube heat exchanger as they developed through the year are the most widely used types of heat exchanger because of their rugged construction and the greater variations and operating condition that can be accommodated, in particular:

- No phase changes, condensation and boiling in horizontal or vertical side, depend on best operating conditions.
- Pressure range from vacuum to very high values.
- Permissible pressure drop can be varying within a wide range and the design can be adjusted independently for each fluid because of a variety of shell flow types and tube bundle arrangement.
- Thermal stresses can be accommodating rather inexpensively.
- Size range from very small to extremely larger (5000m2).
- Positive separation of fluids can be obtained.
- A great variety of material can be used, accommodating demands for low construction cost as well as corrosion resistance and high pressure/temperature requirement. And

- Tube bundle can be removed for cleaning or repair.

Before beginning the thermal design of an exchange, designers must be aware of the following construction specification:

- Shell and bundle types
- Baffle type (segmental, double segmental, etc.)
- Tube type, material, diameter, thickness, and length
- Tube layout and pitch
- Tube pass arrangement
- Leakage and bypass dimension (baffle-to—shell, tube-to-baffle, bundle-to-shell, and tube partitions)
- Nozzle arrangement and diameters
- Minimum end-baffle spacing

Choices are usually a compromise among process design requirements, optimum thermal performance, allowable pressure drop, ease of maintenance, and cost. For the best overall exchanger performance, designers must take into account a wide variety of specific condition and constraints; development of general recommendations is therefore impossible. However, the following brief discussion can help reconcile structural code-oriented specifications, as represented by TEMA standards and strictly thermal design-oriented specification.

1.3 CLASSIFICATION OF HEAT EXCHANGERS (TEMA)

Amongst of all type of exchangers, shell and tube exchangers are most commonly used heat exchange equipment. Classification of heat exchanger in Figure 1.2 and common types of shell and tube exchangers are:

Fixed tube-sheet exchanger (non-removable tube bundle): The simplest and cheapest type of shell and tube exchanger is with fixed tube sheet design. In this type of exchangers the tube sheet is welded to the shell and no relative movement between the shell and tube bundle is possible (Figure 1.3).

Removable tube bundle: Tube bundle may be removed for ease of cleaning and replacement. Removable tube bundle exchangers further can be categorized in floating-head and U-tube exchanger.

- Floating-head exchanger: It consists of a stationery tube sheet which is clamped with the shell flange. At the opposite end of the bundle, the tubes may expand into a freely riding floating-head or floating tube sheet. A floating head cover is bolted to the tube sheet and the entire bundle can be removed for cleaning and inspection of the interior. This type of exchanger is shown in Figure 1.4.
- U-tube exchanger: This type of exchangers consists of tubes which are bent in the form of a ‘U’ and rolled back into the tube sheet shown in the Figure 1.5. This means that it will omit some tubes at the centre of the tube bundle depending on the tube arrangement. The tubes can expand freely towards the ‘U’ bend end.

The different operational and constructional advantages and limitations depending on applications of shell and tube exchangers are summarized in Table 1.1. TEMA and IS: 4503-1967 (India) standards provide the guidelines for the mechanical design of unfired shell and tube heat exchangers.

A Figures

A Figures

Mass velocity is the ratio of flow rate of shell side to cross flow area between two baffles. From Equation 5.3 velocity directly proportionally on flow rate and inversely proportionally on density and Cross flow area. Assume flow rate and density remain constant, so that velocity inversely proportionally Cross flow area. Therefore baffle spacing increase between two baffles, cross flow area shell side will be increase and decrease in shell side velocity. Baffle spacing does not giving consequence on tube side velocity therefore velocity of tube side remain constant. Velocity of window depends on the shell side velocity, when shell side velocity increase at same time widow velocity increase and vice versa because mass flow rate in cross flow and window remain equal.

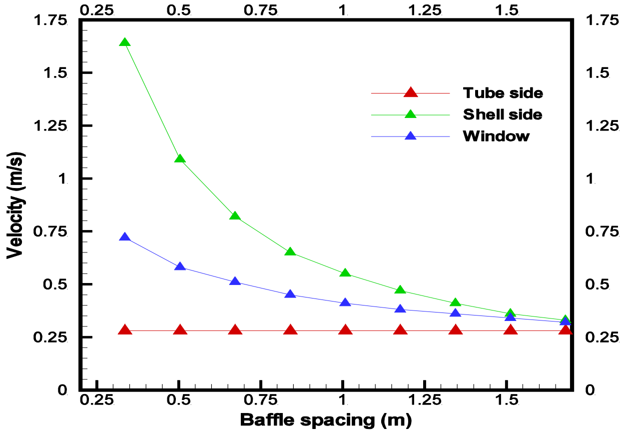


Fig. 1 Effect of Baffle spacing on Velocity

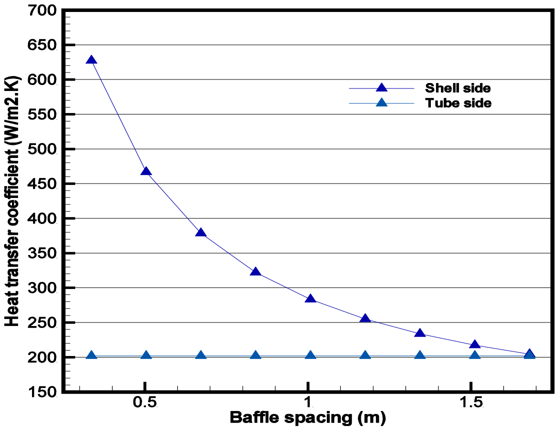


Fig 2 Effect of Baffle spacing on Heat transfer coefficient

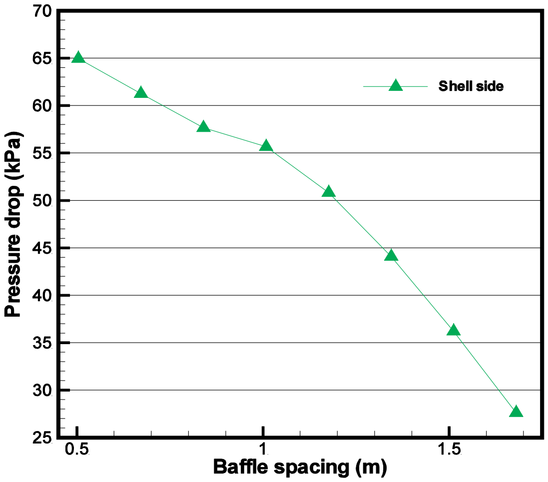


Fig.4 Effect of Baffle spacing on Pressure drop

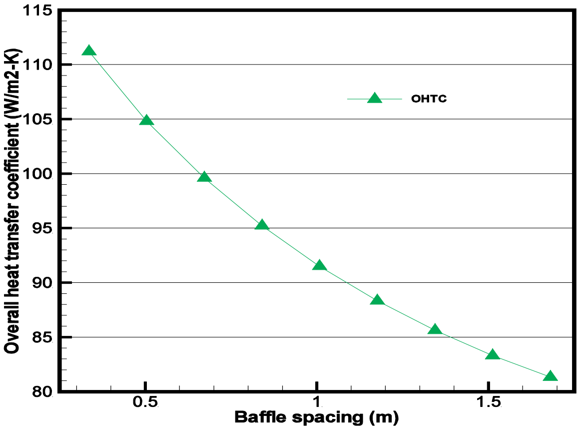


Fig.3 Effect of Baffle spacing on Overall Heat transfer coefficient

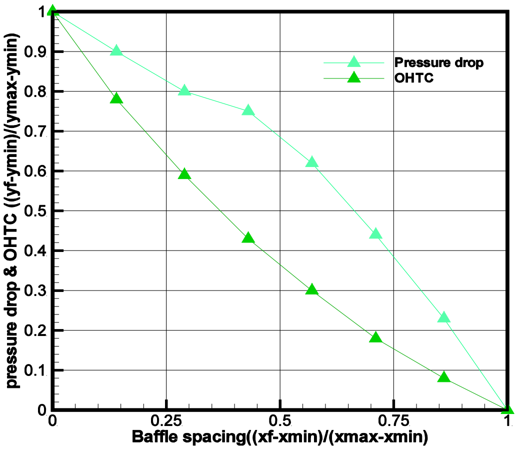


Fig.5 Conclusion based on baffle spacing

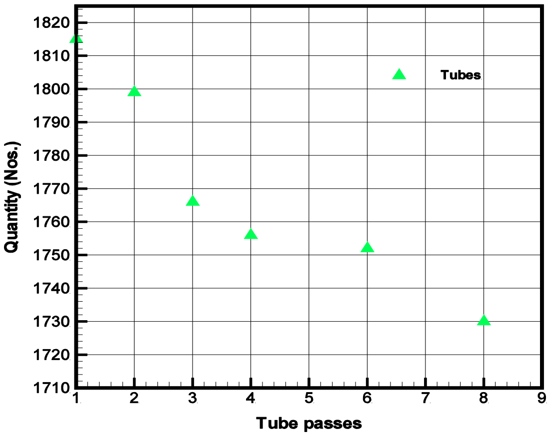


Fig .6 Effect of tube passes on Tube quantity

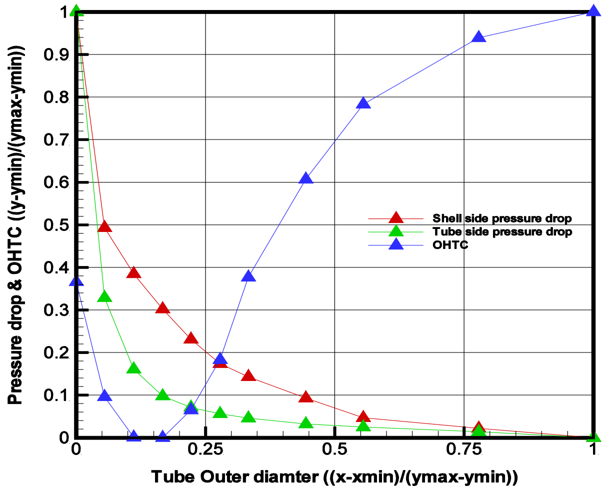


Fig .7 Conclusion based on tube outer diameter

B. TABLE

Table 1 Comparison between experimental data, HTRI software and numerical model

	Shell side(kPa)	Tubeside (kPa)	U (W/m2_C)
Experiment	3.573	2.536	919.723
HTRI software	3.403	2.381	923.000
Numerical	3.060	1.841	785.151

Table 2 Process data

Process data	Shellside	Tubeside
Flow rate (kg/hr)	47351	75003
Density (kg/m3)	602.74	626.34
Heat capacity (J/kg .K)	5052	4778
Viscosity (cp)	0.472	0.15415
Thermal conductivity (W /m.K)	0.4722	0.5077
Inlet temperature (°C)	39.5	5.6
Outlet temperature (°C)	17.2	20

IV Conclusions

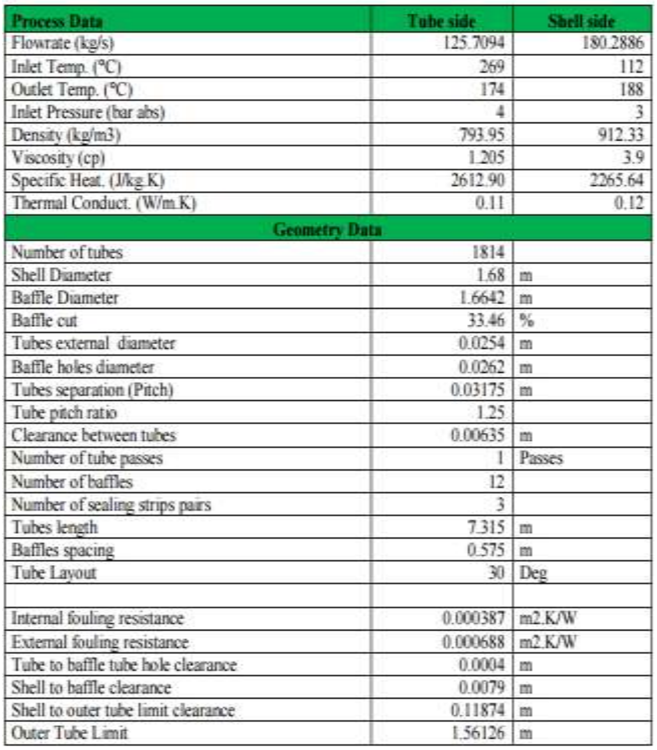
The effect of various parameters like baffle spacing, tube outer diameter and tube thickness, tube passes, tube pitch and tube layout on shell and tube heat exchanger has been investigated experimentally using a numerical model and HTRi software. Based on the results of this experimental investigation following conclusions can be made:

1. The velocity of fluid and pressure drop on shell side of heat exchanger decrease with increase of baffle spacing.
2. It can be found that shell side convection heat transfer coefficient and OHTC have inverse relationship with baffle spacing. If baffle spacing increase from .336 to 1.68 meter, shell side convection heat transfer coefficient will decrease 3.07 times as much as initial baffles spacing. OHTC will decrease 1.37 times as much as initial baffle spacing.
3. Quantities of tube reduce with increase of tube passes, which will reduce flow area due to this reason Tube side velocity of heat exchanger increase and shell side velocity remain more or less constant.
4. The tube side convection heat transfer coefficient and OHTC have inverse relationship with tube passes. If baffle spacing increase from 1 to 8 passes, tube side convection heat transfer coefficient will increase 9.8 times as much as initial tube passes. OHTC will increase 2.81 times as much as initial tube passes.
5. Quantities of tube reduce with increase of tube pitch, which will reduce flow area due to this reason Tube side velocity of heat exchanger increase and shell side velocity decrease.
6. Pressure drop on shell side of heat exchanger decrease with increase of tube pitch and tube side pressure drop increase with trifling.
7. Heat transfer coefficient of tube side and overall heat transfer coefficient of heat exchanger increase with increase of tube pitch and shell side heat transfer of heat exchanger decrease with increase of tube pitch.
8. Higher quantity of tube in the exchanger at 30° & 60° as compare with 45° and 90° And heat transfer area depends on tube quantity of exchanger. If tube layout change from 45° and 90° to 30° & 60°, tube quantity will increase 15.34 percentage at 45° and 90° and heat transfer area increase by 15.56 percentage.
9. Higher pressure drop in shell side in the exchanger at 30° and lowest pressure drop at 45°.Tube side pressure drop approximate constant in all tube layout.

10. The 30° and 45° patterns give higher heat-transfer rates, but at the expense of a higher pressure drop than the square pattern. Overall heat transfer coefficient of 30° and 60° & 45° and 90° tube layout are same.
11. The tube outer diameter increases from 6.36 to 63.5 mm, corresponding heat transfer area decrease about 11.18 time as much as initial outer tube diameter because OD tube increase the quantity of tube entrapment in the given exchanger reduced. Smaller the outer diameter the heat transfer area available on the tube will be increasing which lead to the smaller size of heat exchanger for given heat duty.
12. Suddenly pressure drop on shell side when tube OD change from 6.36 to 9.525 mm. When the tube outer diameter increases from 6.36 to 63.5 mm, corresponding shell side pressure drop decrease about 5.7 time as much as initial outer tube diameter.
13. Suddenly pressure drop on tube side when tube OD change from 6.36 to 9.525 mm. When the tube outer diameter increases from 6.36 to 63.5 mm corresponding tube side pressure drop decrease about 4 time as much as initial outer tube diameter.
14. The shell side convection heat transfer coefficient has inverse relationship with Tube OD. If tube OD increase from 6.36 to 9.525 mm, shell side convection heat transfer coefficient will decrease 1.65 times as much as initial tube OD and that tube side convection heat transfer coefficient and OHTC decrease initially up to tube OD 12.5 and 15.875 mm after 15.875 mm tube OD tube side convection heat transfer coefficient and OHTC increase.

The methodology as presented in this work is based on Delaware method, which provides good predictions for shell side flow. It has been shown that how the basic algorithm can be applied using Delaware method.

Appendix



Process Data	Tube side	Shell side
Flowrate (kg/s)	125.7094	180.2886
Inlet Temp. (°C)	269	112
Outlet Temp. (°C)	174	188
Inlet Pressure (bar abs)	4	3
Density (kg/m3)	793.95	912.33
Viscosity (cp)	1.205	3.9
Specific Heat. (J/kg.K)	2612.90	2265.64
Thermal Conduct. (W/m.K)	0.11	0.12
Geometry Data		
Number of tubes	1814	
Shell Diameter	1.68	m
Baffle Diameter	1.6642	m
Baffle cut	33.46	%
Tubes external diameter	0.0254	m
Baffle holes diameter	0.0262	m
Tubes separation (Pitch)	0.03175	m
Tube pitch ratio	1.25	
Clearance between tubes	0.00635	m
Number of tube passes	1	Passes
Number of baffles	12	
Number of sealing strips pairs	3	
Tubes length	7.315	m
Baffles spacing	0.575	m
Tube Layout	30	Deg
Internal fouling resistance	0.000387	m2.K/W
External fouling resistance	0.000688	m2.K/W
Tube to baffle tube hole clearance	0.0004	m
Shell to baffle clearance	0.0079	m
Shell to outer tube limit clearance	0.11874	m
Outer Tube Limit	1.56126	m

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