CHEMICAL ENGINEERING DESIGN & SAFETY

CHE 4253

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Heat Exchanger Design

Shell & Tube Exchangers

Heat Exchangers - Typical design procedure
(FROM CHE 3123)

1) Define duty: heat transfer rate, flows, temperatures.
2) Collect required physical properties (ρ, μ, k).
3) Decide on the type of exchanger.
4) Select a trial value for *U*. ⇐ What value???
5) Calculate the mean temperature difference, ΔT_m
6) Calculate area required.
7) Decide on the exchanger layout. ⇐ What criteria???
8) Calculate individual coefficients.
9) Calculate *U*. If significant difference from step (4), substitute in (4) and repeat.
10) Calculate the pressure drop. If it is not satisfactory, back to (7) or (4) or (3).
11) Optimise: repeat (4) to (10) to determine cheapest solution (usually smaller area). ⇐ Repeat HOW?

NAÏVE APPROACH

EXHAUSTIVE ENUMERATION

Make combinations of selected values of

- Tube Diameters
- Tube length
- Tube Pitch and clearance
- Baffles
- Tube passes
- Split Flow arrangement
- Shell Diameter

NAÏVE APPROACH

Standard Values of the Discrete Design Variables

Variable	Values
Outer tube diameter (m)	0.019, 0.025, 0.032, 0.038, 0.051
Tube length (m)	1.220,1.829,2.439, 3.049, 3.659, 4.877, 6.098
Number of baffles	1, 2, … , 20
Number of tube passes	1, 2, 4, 6
Tube pitch ratio,	1.25, 1.33, 1.50
Shell diameter (m)	0.787, 0.838, 0.889, 0.940,0. 991, 1.067, 1.143, 1.219, 1.372, 1.524
Tube layout	square, triangular

NAÏVE APPROACH

Design Data

	Hot stream	Cold stream
Fluid	Crude oil	Cooling water
Stream allocation	Shell side	Tube side
Mass flow rate (kg/s)	110	228.8
Inlet temperature (ºC)	90	30
Outlet temperature (ºC)	50	40
Fouling factor (m^2K/W)	0.0002	0.0004
Allowable pressure drop (kPa)	100	100
Flow velocity bounds (m/s)	[1.0 3.0]	[0.5 2.0]

Properties of the Streams

	Hot stream	Cold stream
Density (kg/m^3)	786.4	995
Heat capacity (J/(kg·K))	2177	4187
Viscosity (Pa·s)	$1.89 \cdot 10^{-3}$	$0.72 \cdot 10^{-3}$
Thermal conductivity (W/(m·K))	0.122	0.59

NAÏVE APPROACH

Heat Exchanger Design Results (Using Kern Design Method)

Area (m^2)	624
Outer tube diameter (m)	0.019
Tube length (m)	4.9
Number of baffles	7
Number of tube passes	4
Tube pitch ratio	1.25
Shell diameter (m)	1.219
Tube layout	triangular
Total number of tubes	2139
Baffle spacing (m)	0.610
Tube pitch (m)	0.024

Shell-side flow velocity (m/s)	0.94
Tube-side flow velocity (m/s)	2.2
Shell-side heat transfer h (W/m^2K)	1163
Tube-side heat transfer h(W/m^2K)	9206
Overall heat transfer U (W/m^2K)	584
Shell-side pressure drop (kPa)	84.9
Tube-side pressure drop (kPa)	91.9

We will compare!!!!!!!

NAÏVE APPROACH

EXHAUSTIVE ENUMERATION IN EXCEL

Tube diameter	do	
Tube Length	L	
Tube pitch	Tp; triangle=0, square=1	
# of Baffles	Nb	
# tubes per pass	Ntp	
Tube passes	Tp	
Tube bundle diameter	Db	
Shell diameter	Ds	

do	L	Tp	Nb	Ntp	Tp	Db	Ds	….	ht	hs	Ucalc	Areq=Q/(Ucalc*ΔTml)	A=pi*do*L*Tp*Ntp	

Data
(one combination per file)

Calculated values
Use corresponding formulas based on stream flows, properties and geometry given by data.

Feasible Exchanger
A> Areq

Best Solution: Lower feasible A