PLATE HEAT EXCHANGER

Course Project

Cl455: Design Lab

by

Saavi Yadav
(170020003)

Submitted to:

Prof. Kannan Moudgalya

Department of Chemical Engineering
Indian Institute of Technology Bombay
Mumbai 400076 (India)

16 December, 2020

REPORT

Introduction:-

A plate heat exchanger is a type of heat exchanger that uses metal plates to transfer heat between two fluids. This has a major advantage over a conventional heat exchanger in that the fluids are exposed to a much larger surface area because the fluids are spread out over the plates. This facilitates the transfer of heat, and greatly increases the speed of the temperature change.

The concept behind a heat exchanger is the use of pipes or other containment vessels to heat or cool one fluid by transferring heat between it and another fluid. In most cases, the exchanger consists of a coiled pipe containing one fluid that passes through a chamber containing another fluid. The walls of the pipe are usually made of metal, or another substance with a high thermal conductivity, to facilitate the interchange, whereas the outer casing of the larger chamber is made of a plastic or coated with thermal insulation, to discourage heat from escaping from the exchanger.

Variables defined:-

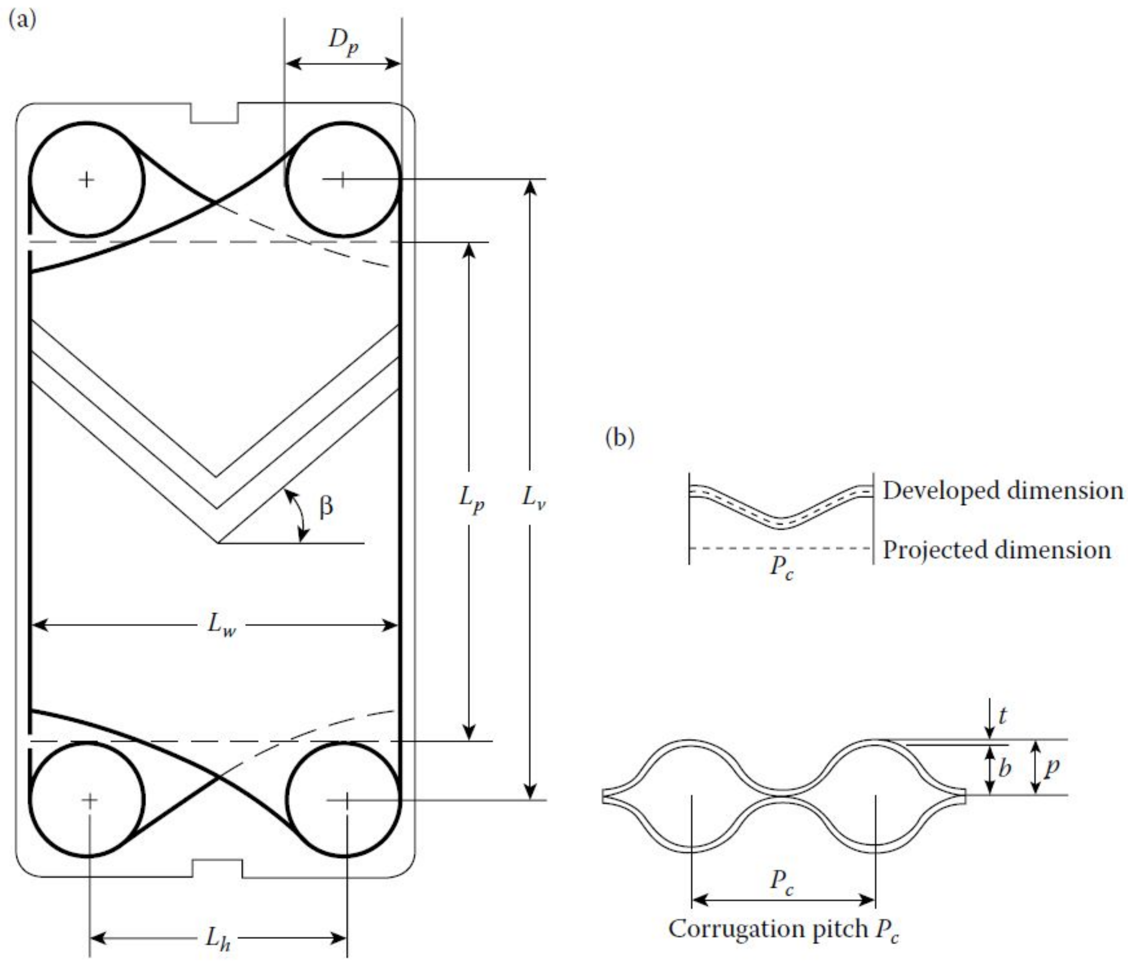
1) Concurrent = 1 (if flow is concurrent otherwise enter 0)
2) plateDataGiven = 1 (if plate data is specified by user else default values are used)
3) verticalPortDistance = Lv (m)
4) compressedPlateLength = Lc (m)
5) horizontalPortDistance = Lh (m)
6) effectiveChannelWidth = Lw (m)
7) numberOfPlates = N
8) noOfPasses = 1
9) effectiveArea = A1 (m^2)
10) plateThickness = t (m)
11) k = 17.5 (Plate Conductivity, W/m.K)
12) isUGiven = 0 (if U has to be calculated using Nu otherwise specify 1 and provide value below)
13) UTheo (W/m2. K)

Output:-

1) Utheo (W/m2. K)
2) T_out (K)

For points 3-10 the lengths are marked in the diagram below.

Diagram:-



A typical corrugated chevron plate. Image from:- Heat Exchangers _ Selection, Rating, and Thermal Design, Third Edition-CRC Press (2012)

Here, Lv = Vertical port distance
Lh = Horizontal Port Distance
Lw = Effective Channel Width
Lc = Compressed Plate Length
N = no of plates
t = thickness of plate
Dp = Lw - Lh
Pitch (p) = Lc/N
A = effective area

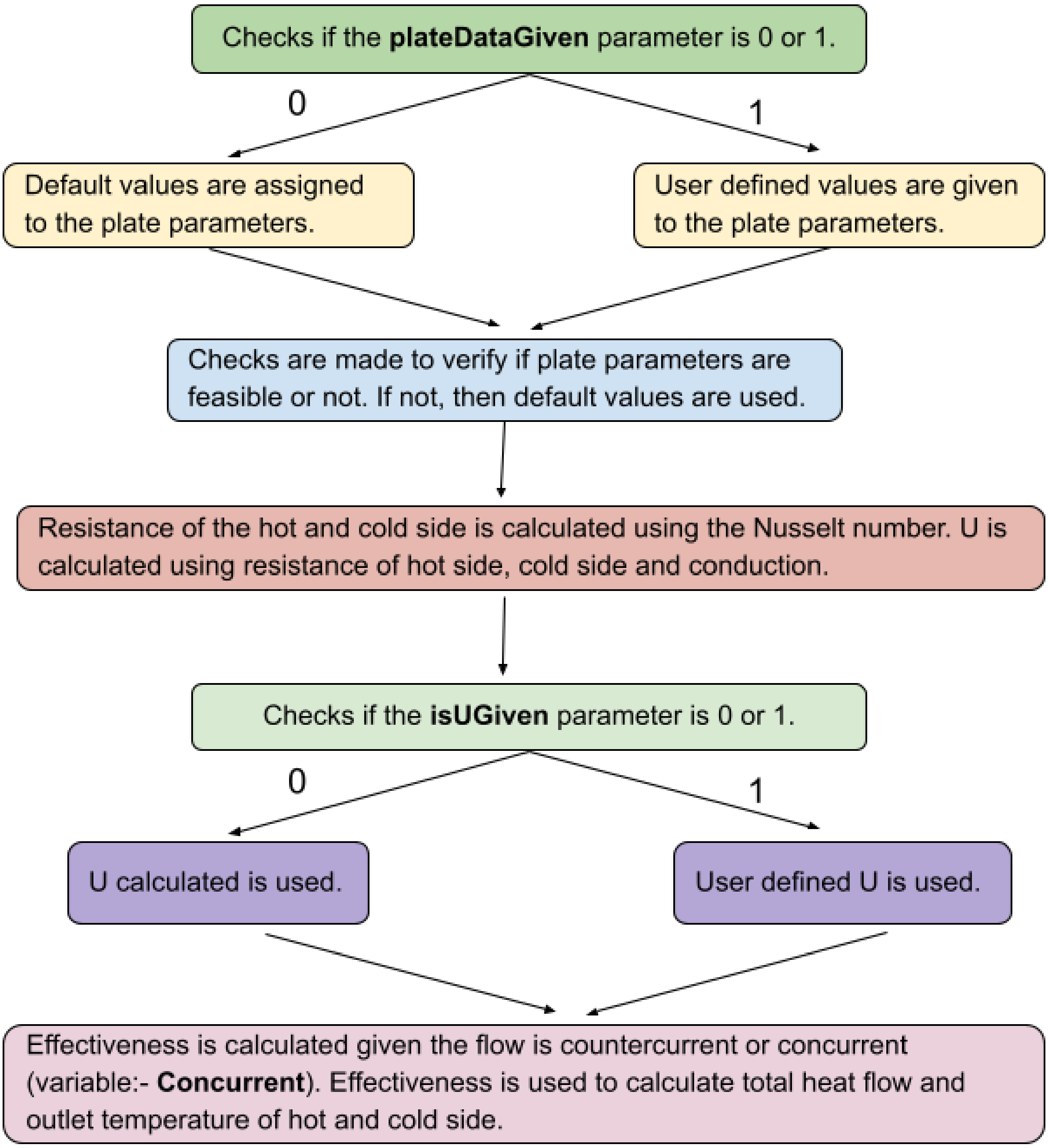
$$\Phi = \frac{developed\ length(A1)}{projected\ length(A1p)}$$

A1p = Lp*Lw
Lp = Lv - Dp
Mean channel spacing, b = p − t

Hydraulic Diameter, $Dh = \frac{4 \times channel\ flow\ area(Ac)}{Wetted\ Perimeter} = \frac{2 \times b}{\Phi}$

Number of channels per pass, Ncp =(Nt-1)/(2*Np)
Reh = (Mass velocity*Dh)/viscosity
Nu = (H*Dh)/k = $0.3 * (Re)^{0.663} * (Pr)^{1/3} * (\mu)^{0.17}$
1/U = 1/Hc + 1/Hh + t/k
where k = conductivity of plate

Flowchart:-



Checks if the **plateDataGiven** parameter is 0 or 1.
0
1
Default values are assigned to the plate parameters.
User defined values are given to the plate parameters.
Checks are made to verify if plate parameters are feasible or not. If not, then default values are used.
Resistance of the hot and cold side is calculated using the Nusselt number. U is calculated using resistance of hot side, cold side and conduction.
Checks if the **isUGiven** parameter is 0 or 1.
0
1
U calculated is used.
User defined U is used.
Effectiveness is calculated given the flow is countercurrent or concurrent (variable:- **Concurrent**). Effectiveness is used to calculate total heat flow and outlet temperature of hot and cold side.

Example problem:-

Cold water will be heated by a wastewater stream. The cold water with a flow rate of 140 kg/s enters the gasketed-plate heat exchanger at 22°C and will be heated to 42°C. The wastewater has the same flow rate entering at 65°C and leaving at 45°C. The maximum permissible pressure drop for each stream is 50 psi.

The process specifications are as follows:

Items	Hot Fluid	Cold Fluid
Fluids	Wastewater	Cooling water
Flow rates (kg/s)	140	140
Temperature in (°C)	65	22
Maximum permissible pressure drop (psi)	50	50
Total fouling resistance ($m^2 \cdot K/W$)	0.00005	0
Specific heat ($J/kg \cdot K$)	4,183	4,178
Viscosity ($N \cdot s/m^2$)	5.09×10^{-4}	7.66×10^{-4}
Thermal conductivity ($W/m \cdot K$)	0.645	0.617
Density (kg/m^3)	985	995
Prandtl number	3.31	5.19

The constructional data for the proposed plate heat exchanger are:-

Plate Material	SS304
Plate thickness (mm)	0.6
Chevron angle (degrees)	45
Total number of plates	105
Enlargement factor, ϕ	1.25
Number of passes	One pass/one pass
Overall heat transfer coefficient (clean/fouled) $W/m^2 \cdot K$	8,000/4,500
Total effective area (m^2)	110
All port diameters (mm)	200
Compressed plate pack length, L_c, (m)	0.38
Vertical port distance, L_v, (m)	1.55
Horizontal port distance, L_h, (m)	0.43
Effective channel width, L_w, (m)	0.63
Thermal conductivity of the plate material (SS304), $W/m \cdot K$	17.5

Calculations:-

Effective no of plates, Ne = Nt − 2 = 103

Pitch, p = Lc/Nt = 0.38/105 = 0.0036 m

mean channel flow gap, b = 0.0036 − 0.0006 = 0.0030 m

one channel flow area, Ach = b*Lw = 0.0030 × 0.63 = 0.00189 m2

single-plate heat transfer area, A1 = Ae/Ne = 110/103 = 1.067 m2

Dp = Lw - Lh

Lp = Lv - Dp

projected plate area, A1p = Lp* Lw = (1.55 − 0.2) × 0.63 = 0.85m2

Enlargement factor, Φ = 1.067/0.85 = 1.255

Hydraulic/equivalent diameter, Dh = (2*b/ Φ) = 2×0.0030/1.255 = 0.00478 m

Number of channels per pass, Ncp = (Nt-1)/(2*Np) = (105 - 1)/(2*1) = 52

Mass flow rate per channel, vch = 140/52 = 2.6923079 kg/s
Mass velocity, Gch = 2.69/0.00189 = 1415.514 kg/m2 s
Reh = (Gh*Dh)/viscosity_h = (1423.28*0.00478)/5.09*10^-4 = 13,372.58026
Rec = (Gc*Dh)/viscosity_c = (1423.28*0.00478)/7.66*10^-4 = 8885.95738
Nuh = (Hh*Dh)/kh = $0.3 * (Re)^{0.663} * (Pr)^{1/3} * (\mu)^{0.17}$ = 243.0433
Hh = 32600.5287 W/m2 K
Nuc = (Hc*Dh)/kc = $0.3 * (Re)^{0.663} * (Pr)^{1/3} * (\mu)^{0.17}$ = 215.4844
Hc = 27,649.1815 W/m2 K
1/U = 1/Hc + 1/Hh + 0.0006/17.5
U = 9888.507 W/m2 K

Sample Calculations for Tout:-
Cc = massFlow_cold *Cp_cold
Ch = massFlow_hot *Cp_hot
NTU = U*A/Cmin
R = Cmin/Cmax
Pcc = $\frac{1-e^{-NTU(1-R)}}{1-R*e^{-NTU(1-R)}}$ when R != 1 (effectiveness of Countercurrent flow)

= NTU/(NTU+1) when R = 1

Pp = $\frac{1-e^{-NTU(1+R)}}{1+R}$ (effectiveness of Concurrent flow)
Q = effectiveness * Cmin * (Th_in - Tc_in)
Th_out = Th_in - Q/Ch
Tc_out = Tc_in + Q/Cc

For the above example:-
Cc = 584920 J/K
Ch = 585620 J/K
NTU = 1.85963
R = 0.998804
Pp = 0.4881388
Q = 12277453.4144 J
Th_out = 317.185 K
Tc_out = 316.1399 K

Bibliography:-

1) intechopen.com , "*Heat transfer studies and applications* ", https://www.intechopen.com/books/heat-transfer-studies-and-applications/modeling-and-design-of-plate-heat-exchanger
2) Anchasa Pramuanjaroenkij, Hongtan Liu, and S. Kakaç, "*Heat Exchangers _ Selection, Rating, and Thermal Design*", Third Edition-CRC Press (2012)