LAMPIRAN

7.1 Tahapan Perhitungan Perancangan Heat Exchanger

1. mencari Q (beban panas) dari neraca panas

2. menentukan Δt

   Δt LMTD = $\frac{(T_1-t_2)-(T_2-t_1)}{ln\frac{(T_1-t_2)}{(T_2-t_1)}}$

   Δt = Δt LMTD x FT

   a. untuk 1-2 exchanger FT > 0,75. jika FT pada 1-2 Exchanger < 0,75 maka gunakan 2-4 Exchanger.

   b. Untuk 2-4 exchanger FT > 0,9 untuk removable longitudinal baffle. FT 0,85 untuk welded longitudinal baffle.

   c. FT dihitung karena di dalam tube terjdi perubahan arah aliran. Sebagai contoh untuk 1-2 exchanger, lewatan merupakan gabungan antara aliran searah dan lawan arah. Dengan demikian dalam 1-2 exchanger tersebut jika dihitung LMTD untuk counter current maka harus dihitung faktor koreksi FT nya.

3. Assumsikan UD sementara dari Tabel 8 Kern, 1965. Lalu hitung area heat transfer A dengan persamaan :

   A = $\frac{Q}{U_D.\Delta t}$

   A > 200 ft^2 gunakan shell & tube

   A < 100 ft^2 gunakan double pipe

   Tentukan klasifikasi tube dari Tabel 10 Kern, 1965

   L = 6, 8, 12, 16, 20 ft (pelatihan pegawai PT. PUSRI) BWG, OD, a"

4. Tentukan jumlah tube

Nt = $\frac{A}{a''.L}$

5. Koreksi UD

6. Temperatur kalorik

a. Temperatur rata-rata fluida yang terlibat dalam pertukaran panas

b. Dihitung untuk fluida dengan viskositas > 1 Cp.

Tc = T2 + Fc(T1-T2)

tc = t1 + Fc(t2-t1)

1. menghitung flow area luas penampang yang tegak lurus arah aliran.

   a. shell :

   C' = PT – OD

   B = maksimum = IDshell (pers. 11.3 Kern, 1965, hal 226) Minimum = IDshell/5 (pers. 11.4 Kern, 1965, hal 226)

   as = $\frac{ID \times C' \times B}{144 \times P_T}$

   b. tube :

   at = $\frac{Nt \times a't}{11 \times n}$

2. menghitung mass velocity (G)

   shell :

   Gs = $\frac{W}{a_s}$

   tube :

   Gt = $\frac{W}{a_t}$

3. menghitung bilangan reynold

shell :

De = ... in (fig. 28, Kern)

Res = $\frac{D_e \, x \, G_S}{\mu}$

tube :

D = ... in (Tabel 10, Kern)

Ret = $\frac{D \quad x \, G_t}{\mu}$

menentukan heat transfer factor, JH

shell :

Nilai JH untuk shell didapat dari figure 28 Kern

tube :

Nilai JH untuk tube didapat dari figure 24 kern

11. menentukan termal function

$(\frac{C.\mu}{k})^{\frac{1}{3}}$

12. menentukan hi & ho

film koefisien hi & ho adalah suatu ukuran aliran panas per unit permukaan dan unit perbedaan temperatur yang mengindikasikan laju perpindahan panas.

shell :

ho / ϕS = J_H x $\frac{k}{D_e}$ x $(\frac{C.\mu}{k})^{\frac{1}{3}}$

tube :

$ho / \phi_t = J_H \times \frac{k}{D_e} \; x \; (\frac{C.\mu}{k})^{\frac{1}{3}}$

13. menentukan hio

$h_{io} / \phi_t = h_i / \phi_t \times \frac{ID}{OD}$

14. temperatur dinding tw

$tw = t_c + \frac{\frac{ho}{\phi S}}{\frac{hio}{\phi t}+\frac{ho}{\phi S}} \times (T_C - t_w)$

15. koefisien hi dan hio terkoreksi pada temperatur dinding tw

Shell :

$\phi_S = (\frac{\mu}{\mu w})^{0,14}$

$ho = (\frac{ho}{\phi S}) \times \phi_S$

Tube :

$\Phi t = (\frac{\mu}{\mu w})^{0,14}$

$hi = (\frac{hi}{\phi t}) \times \phi_t$

$hio = (\frac{hio}{\phi t}) \times \phi_t$

16. Uc (koefisien perpindahan panas menyeluruh saat bersih)

$Uc = \frac{hio \; x \; ho}{hio + ho}$

17. Rd

$Rd = \frac{Ut - UD}{Ut \; x \; UD}$

18. ΔP

shell :

f = ……. (Fig. 29 Kern, 1965) N+1 = 12.L/B

$\Delta Ps = \frac{f \; x \; Gs^2 \; x \; Ds \; x \; (N+1)}{5.22.10^{10} \; x \; D \; x \; s \; x \; \Phi t}$

Tube :

f = ...

ΔPt = $\frac{f \ x \ Gt^2 \ x \ L \ x \ n}{5.22.10^{10} \ x \ D \ x \ s \ x \ \Phi t}$

ΔPr = $\left[\frac{4n \ x \ v^2}{s \ x \ 2g}\right]$

ΔPtube = ΔPt + ΔPr

7.2 Perhitungan Perancangan Heat Exchanger

Shell side		Tube side		Temperatur :	
IDs	= 10 in	IDt	= 0,62 in	Th1 = 81 ^OC =	177,8 ^OF
B	= 7	ODt	= ¾	Th2 = 77 ^OC =	170,6 ^OF
Baffle space	= 6 in	BWG	= 16	Th1 = 4 ^OC =	7,2 ^OF
Passes	= 1	pitch	= triangular	Th2 = 25 ^OC =	77 ^OF
Pt	= 0,9375	passes = 2		Tc2 = 33 ^OC =	91,4 ^OF
C	= 0, 99 (fig. 2 Kern)	C	= 0,98 (fig2 Kern)	ΔTc = 8 ^OC =	14,4 ^OF
de	= 0,045833333 ft	Nt	= 12		

Shell

1) Heat Balance :

Q = AU ΔTLMTD

= 232988,87 Btu/jam

A = 7080 cm^2

0,708 m^2

7,618 ft^2

U = 340 btu/jam ft^2 ^oF

ΔTLMTD = (Th1-Tc2)-(Th2-Tc1)/(ln(Th1-Tc2)/(Th2-Tc1))

= 89,952 ^oF

Q shell = W x C(Th1-Th2)

W shell = Q/C(Th1-Th2)

= 342630,69 / (0,99 x 7,2 ^oF)

= 48068,28 lb/jam

Q tube = W x C(Th1-Th2)

W tube = Q/C(Th1-Th2)

= 232988,87/ (0,98 x 14,4 ^{o}F)

= 32686,43 lb/jam

2) Δt =

Hot fluid		cold fluid	Diff
177.8	Higher Temp	77	100.8
170.6	Lower Temp	91.4	79.2
7.2	Differences	14.4	21.6

L = 1 m

= 3,2808399 ft

= 39,370079 in

LMTD = 89,952 ^{o}F

R $= \frac{7,2}{14,4}$

= 0,5

S $= \frac{14,4}{177,8 - 91,4}$

= 0,167

Ft = 0,98 (Fig 18 Kern)

Δt = Ft x ΔTLMTD

= 0,98 x 89,952 ^{o}F

= 88,153 ^{o}F

Shell

3) Hot Fluid; shell side, water

4) As = ID x C'B / 144Pt

dengan C' = Pt – OD

= 0,9375 – ¾

= 0,188 in

B = L/b

$= \frac{39{,}370079\ \text{in}}{6\ in}$

= 7

As = ID x C'B / 144Pt

= 10 in x 0,188 x (7 / 144) x 0,9375

= 0,091 ft^2

5) Gs = W/as

= 32686,43 lb/jam / 0,091 ft^2

= 358661,651 lb/jam ft^2

6) At Ta = (Th1 +Th2) /2

= (177,8 ^oF + 170,6 ^oF) / 2

= 174,2 ^oF

Tube

3) Cold Fluid; tube side, water

4) a't = 0,302 in^2 (table 10 Kern)

at = Ntxa't / 144xn

= 12 x (0,302 in^2 /144) x 2

= 0,0503 ft^2

5) Gt = w/at

= 16509,98 lb/jam/ 0,0503 ft^2

= 328012,89 lb/jamft^2

vel, v = Gt/3600$_\varrho$

= 328012,89 lb/jam /

(3600 X62,5)

= 1,458 ft/sec

6) At ta = (Tc1+Tc2) / 2

= (77 °F + 91,4 °F) / 2

= 84,2 °F

µ = ((0,95.2,42)+(0,8.2,42))/2

= 0,8712 lb/jamft

= 2,118 lb/jamft (fig. 14)

µ = ((0,35.2,42)+(0,37.2,42))/2

= 0,8712 lb/jamft

Ds = IDs/12

= 10 in / 12

= 0,833 ft

Res = (Ds x Gs) / µ

= (0,833 ft x 358661,651 lb/jam ft^2) / 0,8712 lb/jam ft

= 343072,439 (Turbulen)

7) jH = 380 (fig 28 Kern)

8) At Ta = 174,2 °F

c = 1 Btu/lb °F

k = 0.898 Btu/(jam)(ft2)(°F/ft) (Tabel 4 Kern)

$(c\mu/k)^{(1/3)}$ = $(0,99 \times 0,8712/0,898)^{(1/3)}$

= 0,98664

9) ho = jH x k/de x $(c\mu/k)^{(1/3)}$

=380x0,898 Btu/(jam)(ft^2)(°F) / (0,045833333 ft) x 0,98664)

= 90552,580 Btu/jam $ft^{2o}F$

7) D = IDt/12

= 0,62/12

= 0,052 ft

8) Ret = D x Gt/μ

= 0,052 ft x 328012,89 lb/$jamft^2$ / 2,118lb/jamft

= 8003,4629 (laminar)

9) hi = 415 Btu/jam (ft2) (°F) (fig 25 kern)

10) hio = hi x ID/OD

= 415 Btu/jam (ft2) (°F) x (0,62 in / ¾)

= 343,067

13) Clean overall (Uc) = hio x ho/hio + ho

= (343,067 x 90552,580) / (343,067 + 90552,580)

= 341,772 Btu/(jam)(ft^2)(°F)

14) Rd = Uc-UD / UcxUD

= (341,772 – 340) / (341,772 x 340)

= 0,00002 (hr))(ft^2)(°F) / Btu

Summary		
90552,580	h outside	343,067
Uc		341,772
U_D		340
Rd Calculated		0.00002
Rd Required		0.001

Pressure Drop

Shell

1) Res = 343072,4395

f = 0.001 ft/in^2

2) No. of crosses, N + 1 = 12L/B

= 12 x 6,56167979

= 78,74

Ds = 10/12

= 0,833 ft

3) ΔPs = (f x Gs^2 x Ds x (N+1)) / (5,22 x 10^{10} x Ds x Ǿs)

= ((0,001 x $(358661,651)^2$ x 0,833 x 78,74)) / (5,22 x 10^{10} x 0,833 x 1)

= 0,194 psi

Tube

1) Ret = 8003,462882

= 0,00015 ft^2 / in^2

2) ΔPt = (f x Gt^2 x L x n) / (5,22 x 10^{10} x Ds x Ǿt)

= ((0,00015 x $(328012,89)^2$ x 1 x 2) / (5,22 x 10^{10} x 0,052 x 1)

= 0,012 psi

3) Gt = 328012,89 lb/jamft^2

$V^2/2G'$ = 0,03

4) ΔPr = 4 n/s ($v^2/2G'$)

= 4 x (2/1) x 0,03

= 0,24 psi

ΔPT = $\Delta Pt + \Delta Pr$

= 0,012+ 0,24

= 0,252 psi