

LAMPIRAN

REAKTOR (R)

Tugas : Mereaksikan diethanol amine menjadi morpholine dengan katalis oleum

dengan kecepatan umpan = 100.000 Kg/jam

Jenis : Reaktor Alir Tangki Berpengaduk

Kondisi Operasi : Tekanan : 10 atm

Suhu : 190 °C

NERACA MASSA :

Umpan total masuk :

$$\text{C}_4\text{H}_{11}\text{NO}_2 = 155,0903 \text{ Kgmol/j} = 16284,4824 \text{ Kg/j}$$

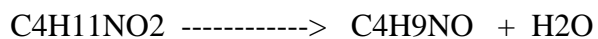
$$\text{H}_2\text{O} = 9,1383 \text{ Kgmol/j} = 164,4897 \text{ Kg/j}$$

$$\text{H}_2\text{SO}_4 = 218,8720 \text{ Kgmol/j} = 21449,4590 \text{ Kg/j}$$

$$\text{SO}_3 = 67,0296 \text{ Kgmol/j} = 5362,3647 \text{ Kg/j}$$

$$\text{Jumlah} = 450,1302 \text{ Kgmol/j} = 43260,7969 \text{ Kg/j}$$

Reaksi yang terjadi :



Konversi : 0,95

Hasil reaksi :

$$\text{C}_4\text{H}_{11}\text{NO}_2 = 7,7545 \text{ Kgmol/j} = 814,2241 \text{ Kg/j}$$

$$\text{H}_2\text{O} = 89,4445 \text{ Kgmol/j} = 1610,0020 \text{ Kg/j}$$

$$\text{H}_2\text{SO}_4 = 285,9016 \text{ Kgmol/j} = 28018,3555 \text{ Kg/j}$$

$$\text{C}_4\text{H}_9\text{NO} = 147,3358 \text{ Kgmol/j} = 12818,2139 \text{ Kg/j}$$

$$\text{Jumlah} = 530,4364 \text{ Kgmol/j} = 43260,7969 \text{ Kg/j}$$

NERACA PANAS

Diketahui Cp rata-rata untuk masing-masing komponen

sebagai berikut :

$$cp \text{ C}_4\text{H}_{11}\text{NO}_2 = 32,62 \text{ Kcal/kmol K}$$

$$cp \text{ H}_2\text{O} = (92,05 - 0,03995 T - 2,1103\text{E-}04 T^2 + 5,3469\text{E-}07 T^3) / 4,2 \text{ Kcal/kmol K}$$

$$cp \text{ H}_2\text{SO}_4 = (26,00 + 0,70337 T - 0,0013856 T^2 + 1,0342\text{E-}06 T^3) / 4,2 \text{ Kcal/kmol K}$$

$$cp \text{ SO}_3 = 12,21 \text{ Kcal/kmol K}$$

$$cp \text{ C}_4\text{H}_9\text{NO} = 39,24 \text{ Kcal/kmol K}$$

Enthalpi Umpan Masuk Diethanolamine

Suhu Umpan masuk Reaktor = 190,0 °C

Suhu referensi = 25 °C

Komponen	M	cp dT	H = m cp dT
C ₄ H ₁₁ NO ₂	10.500,0000	9823,4207	398479,816
H ₂ O	106,0606	4136,4284	5649,534
Jumlah			404129,350

Enthalpi Umpan masuk (H1) = 404129,350 Kj/jam

Enthalpi Umpan Masuk Asam Sulfat dan Oleum

Suhu Umpan masuk Reaktor = 190,0 °C

Suhu referensi = 25 °C

Komponen	M	cp dT	H = m cp dT
H ₂ SO ₄	4867,711	7298,227	592094,401
SO ₃	4,873	4136,428	1119,728
Jumlah	4872,584		593214,128

Enthalpi Umpan masuk (H2) = 593214,128 Kj/jam

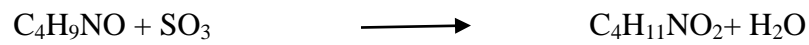
Enthalpi Hasil Reaksi

Suhu hasil reaksi keluar Reaktor = 190,0 °C

Suhu referensi = 25 °C

Komponen	M	cp dT	H = m cp dT
C ₄ H ₉ NO	851,850	9823,421	139467,935
H ₂ O	504,302	4136,428	115889,451
C ₄ H ₁₁ NO ₂	2689,411	11329,360	298718,640
H ₂ SO ₄	11,926	7904,480	961,918
Jumlah	7343,193		954701,666

Enthalpi hasil reaksi (H4) = 954701,666Kj/jam

Panas Reaksi :

Dari data Literatur diperoleh :

$$\text{Panas Pembentukan } \text{C}_4\text{H}_9\text{NO} = 5,41 \text{ Kj/kmol}$$

$$\text{Panas Pembentukan } \text{SO}_3 = 11,715 \text{ Kj/kmol}$$

$$\text{Panas Pembentukan } \text{C}_4\text{H}_{11}\text{NO}_2 = 8,88 \text{ Kj/kmol}$$

$$\text{Panas Pembentukan } \text{H}_2\text{O} = 6,002 \text{ Kj/kmol}$$

Panas reaksi pada suhu 25 °C

$$= \text{DHf produk} - \text{DHf reaktan}$$

$$= (\text{DHf } \text{C}_4\text{H}_{11}\text{NO}_2 + \text{DHf } \text{H}_2\text{O}) - (\text{DHf } \text{C}_4\text{H}_9\text{NO} + \text{DHf } \text{SO}_3)$$

$$= (8,88 + 6,002) - (5,41 + 11,715)$$

$$= -2,243 \text{ Kj/kmol}$$

$$\text{Panas reaksi suhu } 80 \text{ °C} = \text{DHr}_0 + \int_{298}^T \text{cp } dT$$

$$= \text{DHr}_0 + \int_{298}^T (\text{Cp produk} - \text{Cp reaktan}) dT$$

dimana :

$$\int_{T_0}^T \text{cp } dT = \int_{298}^T 392,3903 - 451,5309 dT$$

$$= -59,1407 \text{Kj/jam}$$

maka :

Panas reaksi pada suhu 80 °C

$$= \text{DHr0} + \int_{298}^T d \text{ cp dT}$$

$$= -59,1407 + 954701,6659 \text{ KCal/gmol}$$

$$= 43600,5205 \text{ Kj/jam}$$

Jadi :

$$\text{Panas Masuk (H1 + H2 + H3)} = 998361,3270 \text{ Kj/jam}$$

$$\text{Panas Reaksi (Qr)} = 43600,5205 \text{ Kj/jam}$$

Neraca Panas disekitar reaktor :

$$\text{Input - output} = \text{Accumulation}$$

$$\text{Panas Masuk} - (\text{Panas keluar} + \text{panas reaksi} + \text{panas dibuang}) = 0$$

$$(\text{H1} + \text{H2} + \text{H3}) - (\text{H4} + \text{Qr} + \text{Ql}) = 0$$

Panas Yang dikeluarkan (Ql) :

$$(\text{Ql}) = (\text{H1} + \text{H2} + \text{H3}) - (\text{H4} + \text{Qr})$$

$$= 998361,3270 - (954701,666 + 43600,5205)$$

$$= 59,1405 \text{ Kj/jam}$$

Neraca Panas :

Komponen	Input (Kj/jam)	Output (Kj/jam)
Q in	998361,3270	
Q out		954701,67
Q reaksi		43600,5205
subtotal	998361,3270	998302,1864
Q pendingin		59,1407
Total	998361,3270	998361,3270

Perhitungan Volume dan Ukuran Reaktor

Dari data diperoleh :

Densitas $C_4H_{11}NO_2$ = 725,3978 Kg/m³

Densitas H_2O = 975,6407 Kg/m³

Densitas CH_3COOH = 983,7055 Kg/m³

Densitas C_4H_9NO = 808,2536 Kg/m³

Densitas SO_3 = 1764,6882 Kg/m³

Dari data percobaan patent dapat ditentukan konstanta kecepatanreaksi untuk kondisi operasi $T = 80^\circ C$ dan tekanan Atmosferis

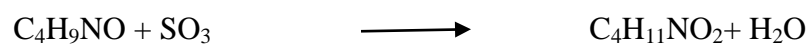
Volume cairan :

Komponen	massa kg	densitas	Volume
C ₄ H ₉ NO	860,322757	725,397854	624076,282
H ₂ O	509,318476	975,640716	496911,842
C ₄ H ₁₁ NO ₂	3318,38778	983,70559	3264316,6
H ₂ SO ₄	2716,16185	808,253699	2195347,86
C ₄ H ₉ NO	12,0445186	1764,6882	21254,8198
JUMLAH			6601907,41

Menentukan Konstanta Kecepatan Reaksi

Konstanta kecepatan reaksi ditentukan berdasarkan teori analisis data dengan persamaan reaksi :

Reaksi



$$\text{Konversi } X_A = 0,65$$

$$(1 - X_A) = 0,35$$

maka

$$\text{C}_4\text{H}_9\text{NO} = n_{A0} (1 - X_A)$$

$$= 40,5643 * 0,35$$

$$\begin{aligned}
 &= 14,1975 \quad \text{Kmol/jam} \\
 \text{SO}_3 &= n_{\text{Bo}} - n_{\text{Ao}} \text{ XA} \\
 &= 81,1285 - 40,5643 * 0,65 \\
 &= 54,7618 \quad \text{Kmol/jam} \\
 \text{C}_4\text{H}_{11}\text{NO}_2 &= 26,3667 \quad \text{Kmol/jam} \\
 \text{H}_2\text{O} &= 26,3667 \quad \text{Kmol/jam}
 \end{aligned}$$

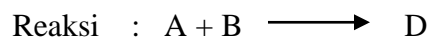
sehingga :

Konstanta kecepatan reaksi :

$$\begin{aligned}
 K_c &= 1,57748\text{E}+13 * \text{EXP}(-8881,918657 / T) \\
 &= 2,2309\text{E}+13 * \text{EXP}(-8881,918657 / 353) \\
 &= 263,6883 \text{ lt}/(\text{Kgmol jam})
 \end{aligned}$$

Anggapan :

- Volume cairan selama reaksi tetap
- Bisa dianggap isothermal karena cairan dalam tangki mixed flow
- Reaksi orde dua



dengan $-r_a = -\frac{dC_A}{dt} = k * C_A * C_B$

Volume cairan :

Komponen	massa kg	densitas	Volume
C ₄ H ₉ NO	860,322757	725,397854	624076,282
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SO ₃	12,0445186	1764,6882	21254,8198
JUMLAH			6601907,41

Kondisi Awal :

$$\text{Konsentrasi awal C}_4\text{H}_9\text{NO} = 0,005217 \text{ grmol/lt}$$

$$\text{Konsentrasi awal SO}_3 = 0,010434 \text{ grmol/lt}$$

$$\text{Perbandingan konsentrasi} = 2,000000$$

maka diperoleh volume reaktor dengan volume:

$$\text{Konversi Reaktor (Xa)} = 0,65$$

Volume cairan dalam reaktor :

$$F_v, x_a$$

$$V = \frac{F_v, x_a}{k * C_{Ao} (1 - x_a)(M - x_a)}$$

$$k * C_{Ao} (1 - x_a)(M - x_a)$$

$$19168,1085 * 0,650$$

$$= \frac{\quad}{\quad}$$

$$263,6883 * 0,005217 * (1 - 0,650) * (2,000 - 0,650)$$

$$= 135 \text{ liter}$$

Over Design : 20 %

$$\text{Volume reaktor} = (100/80) * 21701,8409 \text{ lt}$$

$$= 27127,3011 \text{ lt}$$

$$\text{Dipakai Volume reaktor} = 27,127 \text{ m}^3$$

Menghitung ukuran reaktor :

Reaktor berbentuk silinder tegak dengan perbandingan H : D = 1 : 1

$$V_t = \frac{\pi * D^2 * (h/d) * D}{4} + \frac{\pi}{12} D^2 * D$$

Atau :

$$\text{diameter (D)} = \left[\frac{V_t}{\pi/4 * (h/d) + \pi/12} \right]^{1/3}$$

$$\text{diameter (D)} = \left[\frac{27,127}{\pi/4 * 1. + \pi/12} \right]^{1/3}$$

$$= 2,86 \text{ m}$$

$$\text{Tinggi (H)} = 1 * 2,86$$

$$= 2,86 \text{ m}$$

diperoleh ukuran Reaktor :

$$\text{diameter} = 2,86 \text{ m}$$

$$\text{tinggi} = 2,86 \text{ m}$$

$$\begin{aligned} \text{Volume cairan dalam head} &= (1/2) * (\pi/12) * 27,89 \text{ m}^3 \\ &= 3,65 \text{ m}^3 \end{aligned}$$

$$\begin{aligned} \text{Volume cairan dibadan Reaktor} &= 21,7018 \text{ m}^3 - 3,64 \text{ m}^3 \\ &= 18,05 \text{ m}^3 \end{aligned}$$

$$\begin{aligned} \text{Tinggi cairan dibadan Reaktor} &= (4 * 18,05) / (3,14 * (2,85^2)) \text{ m} \\ &= 2,82 \text{ m} \end{aligned}$$

Menghitung tebal shell dan head

Tebal shell :

$$\text{Tekanan design (p)} = 2,19 \text{ psi}$$

$$\text{Allowable stress} = 18750 \text{ psi}$$

$$\text{Efisiensi sambungan} = 0,85$$

$$\text{Faktor korosi} = 0,125 \text{ in}$$

$$\text{Jari-jari Reaktor} = 56,22 \text{ in}$$

$$\begin{aligned} t_{\text{shell}} &= \frac{p \cdot r_i}{S \cdot e - 0,6 \cdot p} + c \\ &= \frac{2,19 \cdot 56,22}{18750 \cdot 0,85 - 0,6 \cdot 22,0} + 0,125 \\ &= 0,1369 \text{ in} \end{aligned}$$

Maka dipilih tebal shell $\frac{3}{16}$ in

Tebal Head :

$$\begin{aligned} th &= \frac{P \cdot r \cdot w}{(2 \cdot S \cdot E) - (0,2 \cdot P)} + C \\ &= 0,1955 \text{ in} \end{aligned}$$

Maka dipilih tebal head $\frac{1}{4}$ in

Menghitung pengaduk dalam Reaktor

Dipilih : Pengaduk type Turbine dengan 6 blade

Jumlah baffle 4 buah

Dari tabel 477, Brown diperoleh :

$$D_i/D_R = 1/3$$

$$E = D_i = 1$$

$$W = D_i/5$$

$$L = D_i/4$$

$$B = D_R/12$$

Diameter Impeler	= 0,95 m
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Tinggi Impeler	= 0,95 m
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Lebar Baffle	= 0,24 m
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Tinggi Zone pegadukan	= 0,19 m
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Jumlah Impeller	= 5 Impeller
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diambil :

z_i/D_i	= 1
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Putaran	= 2,88 rps
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efisiensi	= 70 %
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Tinggi baffle diambil sama dengan tinggi cairan bilangan Reynold dalam Reaktor:

$$Re = \frac{\rho_L N D I^2}{\mu_L}$$

$$5257,68 * 73 * 0,95$$

$$= \frac{\quad}{\quad}$$

$$0,44$$

$$= 824179,6422$$

Dari fig, 477 brown diperoleh

$$P = \frac{N^3 D I^5 \rho N_p}{550 gc}$$

$$(1,21^3) * (0,95/0,3048)^5 * 328,23 * 7$$

$$= \frac{\quad}{\quad}$$

$$550 * 32,2$$

$$= 69,47 \text{ Hp}$$

effisiensi : 70 %

$$P \quad 69,47$$

$$\text{Power} = \frac{\quad}{\quad} = \frac{\quad}{\quad}$$

$$\text{eff} \quad 0,70$$

$$= 99,24 \text{ Hp}$$

Digunakan motor dengan daya = 100 Hp

Spesifikasi Reaktor

Tugas : Mereaksikan Diethanolamine dan Oleum menjadi Morpholine dan Air dengan katalis Asam Sulfat dengan kecepatan umpan = 7343,1935 kg/j

Jenis : Reaktor Alir Tangki Berpengaduk

Kondisi Operasi :

Tekanan : 10 atm

Suhu : 190 °C

Diperoleh ukuran Reaktor :

Diameter = 2,86 m

Tinggi = 3,99 m

Volume cairan dalam head = 3,65 m³

Volume cairan dibadan Reaktor = 18,05 m³

Tinggi cairan dibadan Reaktor = 2,82 m

Dipilih Tebal shell : $\frac{3}{16}$ in

Tebal Head : $\frac{1}{4}$ in

Dipilih : Pengaduk type Turbine dengan 6 blade

Jumlah baffle 4 buah

Diameter Impeler = 0,95 m

Tinggi Impeler = 0,95 m

Lebar Baffle = 0,24 m

Digunakan motor dengan daya = 100 Hp

Tebal Jacket :

Tebal Jacket = 0,24 in

Jenis bahan Isolasi = Stainless steel SA-167

Jenis Bahan Reaktor : Baja Steinless Steel

LAMPIRAN GAMBAR REAKTOR RATB