

## LAMPIRAN B

### Perancangan Reaktor (R-01)

Fungsi : Tempat terjadinya reaksi hidrodealkilasi pembentukan benzena

Laju alir massa : 36000,3051 kg/jam

Q pendingin :

Tekanan : 25 atm

Temperatur : 600 °C

(Analysis, Synthesis and Design of Chemical Processes by Richard

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Baile and Friend)

Densitas Campuran :

$$\rho_{campuran} = \rho_i \cdot X_i$$

$$\rho_i = \frac{BM_i \times P}{R \times T}$$

P = 25 atm

T = 873 K

R = 0,0821 L.atm/mol.K

(Berdasarkan laju alir masuk Reaktor)

| Komponen | $n_i$     | fraksi mol $i$ | BM      | $\rho_i$           | $\rho_{camp.}$        |
|----------|-----------|----------------|---------|--------------------|-----------------------|
| (i)      | (mol/jam) | ( $X_i$ )      | (g/mol) | gr/dm <sup>3</sup> | (gr/dm <sup>3</sup> ) |
| Benzena  | 718,8     | 0,000332808    | 78      | 27,21              | 0,0090546             |
| Toluena  | 304096,8  | 0,140798201    | 92      | 32,09              | 4,5182218             |
| Hidrogen | 1550893,6 | 0,71807079     | 2       | 0,698              | 0,5009333             |
| Metana   | 304096,8  | 0,140798201    | 16      | 5,581              | 0,7857777             |
| Total    | 2159806   | 1              |         |                    | 5,8139873             |

$$\rho = \frac{m}{V} \quad V = \frac{m}{\rho}$$

Densitas Campuran : 5,813987329 gr/dm<sup>3</sup>

Volumetrik Rate (V) : 6192016,436 dm<sup>3</sup>/jam

### I. Spesifikasi Katalis

Jenis Katalis : Chromia Alumina (Al<sub>2</sub>O<sub>3</sub>-Cr<sub>2</sub>O<sub>3</sub>)

Diameter Katalis : 3,1 mm

Panjang : 3 mm (US Patent 378388)

GHSV : 815 /jam

Bentuk : Pellet

Porositas : 0,8

Densitas : 0,78 gr/cm<sup>3</sup>

II. Volume Katalis = 7111321,944 gr = 7111,321944 kg

$$GHSV = \frac{\text{Volumetrik rate gas}}{\text{Volume katalis (volume reaktor)}}$$

$$\text{Volume Katalis} = \frac{\text{Volumetrik rate gas}}{GHSV}$$

$$\text{Volumetrik rate gas} = 6192016,436 \text{ dm}^3/\text{jam}$$

$$\text{GHSV} = 815 \text{ /jam}$$

$$\text{Volume katalis} = 7597,56618 \text{ dm}^3$$

$$\text{Faktor keamanan 20\%} = 9117,079416 \text{ dm}^3 = 9117079,416 \text{ cm}^3$$

$$\text{II. Jumlah Tube (Nt) 1 in} = 0,0254 \text{ m}$$

$$1 \text{ ft} = 0,305 \text{ m}$$

$$\text{jumlah tube (Nt)} = \frac{\text{Volume katalis}}{(1 - X) \times (0,25\pi ID^2 L)}$$

Spesifikasi tube : (Tabel 10. Kern)

(pendekatan) OD (in) = 1,5

BWG = 18

ID (in) = 1,4 = 0,03556 m

Flow area per tube = 1,54 (in<sup>2</sup>)

Surface per lin = 0,3925 (ft<sup>2</sup>/ft)

$$\text{Volume Katalis} = 7597,56618 \text{ dm}^3 = 7,59756618 \text{ m}^3$$

$$X = 0,8$$

$$ID = 0,03556 \text{ m}$$

$$L \text{ (panjang tube)} = 1180 \text{ in} = 29,972 \text{ m}$$

$$Nt = 1276,837446$$

$$Nt = 1330 \text{ (mengikuti standar Tabel 9. Kern)}$$

Shell ID (in) = 39  
 2-P = 1330 tube  
 Tube OD (in) = 0,75 (3/4) (Tabel 9 Kern)  
 1 in square pitch

L (in) = 1180

Laju alir umpan dalam tube masuk / jumlah tube = Feed =  
 4655,651456 dm<sup>3</sup>/jam

III. Tebal Tube

$$tebal\ tube = \frac{P_{design} \times (r\ tube)}{f \times e - (0,6P_{design})} + C$$

P design = P operasi + P hidrostatik (psi)

P operasi = 25 atm

P hidrostatik = ρ.g.tinggi cairan

= 1707716,917 gr/m.s<sup>2</sup>

= 1707,716917 kg/m.s<sup>2</sup>

= 1707,716917 Pa

= 0,016853856 atm

tinggi cairan = 1180 in

= 29,972 m

ρcampuran = 5,813987329 gr/dm<sup>3</sup>

= 5813,987329 gr/m<sup>3</sup>

g = 9,8 m/s

P design = 25,01685386 atm

$$1 \text{ atm} = 101325 \text{ Pa}$$

$$\text{Faktor Keamanan } 20\% = 30,02022463 \text{ atm}$$

Bahan yang digunakan adalah stainless steel SA-167 grade 11 tipe 316

$$\begin{aligned} \text{Allowable stress (f)} &= 8500 \text{ psia} \\ &= 1112 \text{ F} = 600 \text{ }^\circ\text{C} \\ &\text{(item 4, allowable stress p.342)} \end{aligned}$$

$$P_{\text{design}} = 30,02022463 \text{ atm} = 441,4738916 \text{ psi}$$

$$r_{\text{tube}} = \frac{\text{Tube OD(in)}}{2} = 0,375 \text{ in}$$

$$f = 8500 \text{ psia} = 578 \text{ (1 psia = 0,068 atm)}$$

$$\text{effisiensi penyambungan} = 0,8 \text{ atm}$$

$$C \text{ (faktor korosi)} = 0,0125 \text{ in/tahun} = 0,125 \text{ in}$$

$$\text{tebal tube} = \frac{P_{\text{design}} \times (r_{\text{tube}} \text{ (OD)})}{f \times e - (0,6P_{\text{design}})} + C$$

$$\text{tebal tube} = 0,150332789 \text{ in} = 0,1875 \text{ in}$$

(mengikuti standar tabel 5.6 brownell young)

$$\text{ID tube} = \text{OD} - 2 \text{ (tebal tube)} = 0,375 \text{ in}$$

$$\text{ID tube} = 0,375 \text{ in}$$

#### IV. Diameter Shell

$$\text{ID shell} = 300 \text{ in} = 7,62 \text{ m}$$

#### V. Tebal Shell

$$\begin{aligned} \text{tebal shell} &= 10,25811579 \text{ in} \\ &= 1,5 \text{ in (mengikuti standar} \\ &\text{ tabel 5.6 brownell young)} \end{aligned}$$

$$\begin{aligned} \text{OD shell} &= \text{ID shell} + 2 (\text{tebal shell}) \\ &= 300 + 3 \end{aligned}$$

$$\text{OD shell} = 303 \text{ in}$$

VI. Tebal Head

$$\begin{aligned} \text{Tebal Head} &= \frac{(P_{\text{design}} \times \text{radius of crown} \times W)}{((2 \times f \times e) - (0,2 \times P_{\text{design}}))} \end{aligned}$$

$$r = 42$$

$$i_{cr} = 3,75 \text{ } 3 \frac{3}{4} \text{ (Tabel 5.7 Brownell young)}$$

$$W = \frac{1}{4} \times ((3 + (r/i_{cr}))^{0,5})$$

$$\text{Torispherical head (Flanged and dishead head)} = 0,942072184$$

$$f = 578 \text{ atm}$$

$$e = 0,8$$

$$P_{\text{design}} = 25,01685386 \text{ atm}$$

$$\text{Tebal Head} = 1,076153814 \text{ in}$$

$$\text{Tebal Head standar} = 1,125 \text{ in} = 1 \frac{1}{8}$$

(Tabel 5.6 Brownell Young)

VII. Tinggi head dan volume head

$$\begin{aligned} \text{Thickness (in)} &= 1,125 \text{ in} \\ \text{Sf dipilih} &= 1,5 \quad 1 \frac{1}{2} \text{ in} \\ \text{Icr} &= 2,375 \quad 3 \frac{3}{8} \text{ in} \end{aligned}$$

$$r = 42 \text{ in}$$

$$a = ID/2 = 19,5 \text{ in}$$

$$AB = a - \text{icr} = 17,125 \text{ in}$$

$$BC = r - \text{icr} = 39,625 \text{ in}$$

$$AC = (BC^2 - AB^2)^{0,5} = 35,73338775 \text{ in}$$

$$b = r - AC = 6,266612251 \text{ in}$$

$$\begin{aligned} \text{OA} = \text{Tinggi head} &= \text{th} + b + \text{Sf} \\ &= 1,125 + 6,266612251 + 1,5 \end{aligned}$$

$$\text{Tinggi head} = 8,891612251 \text{ in}$$

$$\text{Tinggi head} = 0,225846951 \text{ m}$$

$$1 \text{ in} = 0,0254 \text{ m}$$

$$\text{Volume head} = 2 \times 0,000076 \times ID^3$$

$$1 \text{ ft} = 0,305 \text{ m}$$

$$= 0,067252511 \text{ m}^3$$

IX. Tinggi reaktor dan volume reaktor

$$\begin{aligned} \text{- Tinggi reaktor} &= \text{Tinggi shell} + 2 \times \text{Tinggi Head} \\ &= 29,972 + 0,451693902 \end{aligned}$$

$$\text{Tinggi reaktor} = 30,4236939 \text{ m}$$

- Volume total reaktor

$$V_t = V_{\text{silinder}} + V_{\text{head}} + 2V_{\text{sf}}$$

$$V_{\text{silinder}} = \frac{1}{4} \times \pi \times \text{ID}_{\text{shell}}^2 \times L$$

$$= 0,881379118 \text{ m}^3$$

$$V_{\text{head}} = 0,067252511 \text{ m}^3$$

$$V_{\text{sf}} = \frac{1}{4} \times \pi \times \text{ID}_{\text{shell}}^2 \times \text{sf}$$

$$= 0,001120397 \text{ m}^3$$

$$2V_{\text{sf}} = 0,002240794 \text{ m}^3$$

$$V_t = 0,950872423 \text{ m}^3$$

|  |   |                            |   |                            |  |
|--|---|----------------------------|---|----------------------------|--|
| Dengan demikian direncanakan reaktor fixed bed dengan spesifikasi :  |   |                            |   |                            |  |
| <i>Shell :</i>   |   |                            |   |                            |  |
| ID   | = | 300 in                     | = | 7,62 m                     |  |
| OD   | = | 303 in                     | = | 7,6962 m                   |  |
| Tebal shell  | = | 1,5 in                     | = | 0,0381 m                   |  |
| <i>Tube :</i>  |   |                            |   |                            |  |
| ID   | = | 0,375 in                   | = | 0,009525 m                 |  |
| OD   | = | 0,75 in                    | = | 0,01905 m                  |  |
| Jumlah tube dengan 6-P   |   |                            | = | 1330 tube                  |  |
| Pitch  | = | 1 in square pitch          | = | 0,0254 m                   |  |
| Panjang tube   | = | 1180 in                    | = | 29,972 m                   |  |
| Tebal tube   | = | 0,1875 in                  | = | 0,0047625 m                |  |
| Tebal head   | = | 1,125 in                   | = | 0,028575 m                 |  |
| Tinggi head  | = | 8,891612251 in             | = | 0,225846951 m              |  |
| Volume head  | = | 0,067252511 m <sup>3</sup> | = | 0,067252511 m <sup>3</sup> |  |
| Tinggi reaktor   | = | 30,4236939 m               | = | 30,4236939 m               |  |
| Volume total reaktor   | = | 0,950872423 m <sup>3</sup> | = | 0,950872423 m <sup>3</sup> |  |
| Bahan yang digunakan adalah stainless steel SA-167 grade 11 tipe 316 |   |                            |   |                            |  |
| Bentuk head <i>Torispherical head (Flanged and dishead head)</i>     |   |                            |   |                            |  |



