ENP100 - Prosess og produksjon

Øving 9 - Løsningsforslag

Oppgave 1:

a) Oppgitt : $\rho u = \frac{\dot{m}}{A}$

$\rho = \frac{P}{ZRT}$

(Fordi massestrøm, $\dot{m}$ [kg/s] $= u \cdot A \cdot \rho$; $\frac{m}{s} \cdot m^2 = \frac{m^3}{s}$ (= Volumstrøm), ρ ~ kg/m³)

(Fordi reell gass : $pv = ZRT$; $\rho = \frac{1}{v}$) — v: spesifikt volum

Trykktapsledd : $-\frac{dp}{dL} = \frac{1}{2} f_D \cdot \frac{\rho u^2}{D} = \frac{f_D}{2D} \cdot \rho u^2$ — $\frac{f_D}{2D}$: Konstant.

Skriv så $\rho u^2 = \frac{(\rho u)^2}{\rho} = \frac{(\dot{m}/A)^2}{P/ZRT} = \frac{\dot{m}^2 ZRT}{P \cdot A^2}$

Sett inn : $-\frac{dp}{dL} = K \cdot \frac{\dot{m}^2 ZRT}{P A^2}$

Løst mhp. dL : $\underline{\underline{dL = -\frac{A^2}{K \cdot ZRT \cdot \dot{m}^2} \cdot p\,dp}}$

QED

b) Integrer fra $L=0$ til $L=L$; dermed fra $p = p_1$ til $p = p_2$:

$$\int_0^L dL = -\frac{A^2}{K \cdot ZRT \cdot \dot{m}^2} \int_{p_1}^{p_2} p\,dp \rightarrow L = -\frac{A^2}{K \cdot ZRT \cdot \dot{m}^2} \cdot \frac{1}{2}(p_2^2 - p_1^2)$$

Løs mhp. $\dot{m}$

(Snudd fortegnet her, siden $P_1 > P_2$)

$$\dot{m}^2 = \frac{A^2 \cdot (P_1^2 - P_2^2)}{2K \cdot ZRT \cdot L} \Rightarrow \dot{m} = \sqrt{\frac{(P_1^2 - P_2^2) \cdot A^2}{2K\,ZRTL}}$$

Sett inn tall; OBS enheter:

* Gasskonstanten på massebasis:

$$R = \frac{R_0}{M_w} \quad ; \quad R_0 = 8.3144 \text{ J/mol K} \text{ (universell)}$$

$$M_w = \gamma_g \cdot M_{w,luft} = 0.63 \cdot 29 \frac{g}{mol}$$

$$R = \frac{8.3144 \text{ J/mol K}}{0.63 \cdot 29 \text{ g/mol}} = 0.455 \frac{J}{gK} = 455 \frac{J}{kg\,K}$$

* Temperatur i K: $T = 7.3^\circ C + 273.15 = 280.45 K$

$$\dot{m} = \sqrt{\frac{\left[(137 \cdot 10^5)^2 - (85 \cdot 10^5)^2\right] \cdot (0.46 \text{ m}^2)^2}{2 \cdot 0.0065 \frac{1}{m} \cdot 0.94 \cdot 455 \cdot 280.45 \cdot 540000 \text{ m}}}$$

Enhets-sjekk:

$$\frac{\left(\frac{N}{m^2}\right)^2 \cdot m^4}{\frac{1}{m} \cdot \frac{Nm}{kg\,K} \cdot K \cdot m} = \frac{N^2\,kg}{Nm}$$

$$= \frac{kg \cdot m}{s^2} \cdot \frac{kg}{m} = \frac{kg^2}{s^2}$$

$$\rightarrow \dot{m} = \sqrt{29009 \frac{kg^2}{s^2}} = 170.3 \text{ kg/s}$$

c) Weymouth-formelen: Trenger D

$$\rightarrow D = \sqrt{\frac{4A}{\pi}} = \sqrt{\frac{4 \cdot 0.46\ m^2}{\pi}} = \underline{0.765\ m}$$ ($A = 0.46\ m^2$)

Til passende enheter:

$P_1 = 137$ bar $= 13700$ kPa

$P_2 = 85$ bar $= 8500$ "

(eller "som før")

$$q_{sc} = 1.185 \cdot 10^7 \cdot \left(\frac{288.15\ K}{101.325\ kPa}\right) \cdot \sqrt{\frac{(13700^2 - 8500^2) \cdot 0.765^{5.333}}{0.63 \cdot 540000 \cdot 280.45 \cdot 0.94}}$$

$$= 18\,716\,427\ Sm^3/d = \underline{18.72 \cdot 10^6\ Sm^3/d}$$

d) Må konvertere en av dem;

$$18.72 \cdot 10^6 \frac{Sm^3}{d} \cdot 42300 \frac{kmol}{10^6\ Sm^3} \cdot 0.63 \cdot 29 \frac{kg}{kmol} \cdot \frac{1}{86400\ s/d}$$

$$= \underline{167.4\ kg/s}$$

$$\rightarrow \frac{167.4 - 120.3}{167.4} \approx -0.017 = \underline{\underline{1.7\%}}$$

Oppgave 2:

a) pwf (after the lift gas is introduced) = 2900 psia; the necessary casing pressure at well depth will be 100 psi higher; pc,v = 3000 psia

b) Surface casing pressure given by equation (17.8) assumes only hydrostatic pressure difference due to the weight of the gas itself.

$$p_{c,s} = 3000 \cdot e^{-0.01875 \cdot \frac{0.65 \cdot 10000}{0.9 \cdot (95+460)}} = \underline{\underline{2350 \text{ psi}}}$$

(The approximation leading up to equation (17.10) is obsolete, since now we do have calculators ...)

c) In simplified analysis like this one usually ignore topside pressure drops in piping:

The compressor should compress the lift gas from pwh = 1450 psia, up to pc,s = 2350 psia;

Using the equations from chp. 11, performing the calculations in metric units should be more convenient, as long as we need not worry about the pressure units:

$$R = \frac{8.314 \text{ J/mol K}}{0.65 \cdot 29 \text{ g/mol}} = 0.441 \text{ J/g} = \underline{441 \text{ J/kg K}}$$

$$95^\circ F = 95 + 460 = 555^\circ R \times \frac{1}{1.8} = \underline{308 \text{ K}}$$

$$\rightarrow w_s = \frac{1.24}{0.24} \cdot 441 \cdot 308 \cdot \left[\left(\frac{2350}{1450}\right)^{\frac{0.24}{1.24}} - 1\right] = 68747 \text{ J/kg}$$

Then convert to US Field:

$$w_s = 68747 \frac{\text{J}}{\text{kg}} \cdot 0.73766 \frac{\text{ft} \cdot \text{lbf}}{\text{J}} \cdot \frac{1}{2.205} \frac{\text{kg}}{\text{lbm}} = 22999 \frac{\text{ft lbf}}{\text{lbm}}$$

Using equation (17.24) directly will give the same result, given some round-off errors:

$$W = \frac{1.24}{0.24} \cdot \frac{53.241 \cdot 555}{0.65} \cdot \left[\left(\frac{2350}{1450}\right)^{\frac{0.24}{1.24}} - 1\right] = 23009 \frac{\text{ft lbf}}{\text{lbm}}$$