ZADATAK: Odrediti pad pritiska usled trenja pri strujanju vlažne pare stepena suvoće 0,9 u parovodu dužine 10 m, unut. prečnika 0,2m i hidraulički glatke površine unutrašnjeg zida. Brzina strujanja vlažne pare je 40 m/s. Potrebne termofizičke parametre vlažne pare odrediti za pritisak 180 bar. Koeficijent trenja odrediti Blazijusovim obrascem $f = \frac{0,079}{Re^{0,25}}$, dinamičke viskoznost vode je $^{111^{\circ}C}$ $62,17 \cdot 10^{-6}$ Pa·s
— " — pare je $^{116^{\circ}C}$ $25,05 \cdot 10^{-6}$ Pa·s.

$x = 0,9$ – stepen suvoće $u_1 = u_2 = u$ HOMOGENO STRUJANJE!
$L = 10$ m
$D = 0,2$ m
$u = 40$ m/s
$p = 180$ bar
$\mu_1 = 62,17 \cdot 10^{-6}$ Pa·s
$\mu_2 = 25,05 \cdot 10^{-6}$ Pa·s

$p = 180$ bar $\quad \rho_1 = \frac{1}{v'} = \frac{1}{0,0018395} = 543,628$ kg/m^3

$\rho_2 = \frac{1}{v''} = \frac{1}{0,0074987} = 133,357$ kg/m^3

$\Delta p_{tr} = ?$

$-\left(\frac{dp}{dz}\right)_{tr,DT} = -\left(\frac{dp}{dz}\right)_{tr,1} \cdot \Phi_1^2 = -\left(\frac{dp}{dz}\right)_{tr,2} \cdot \Phi_2^2$ ili

① pad p usled trenja u dvofaznom toku

② pad p usled trenja pri strujanju tečne faze celim popr. presekom parovoda

③ množitelj pada pritiska usled trenja u dvofaznom toku

$\Phi_1^2 = 1 + \frac{C}{X} + \frac{1}{X^2}$

$\Phi_2^2 = 1 + CX + X^2$

LOCKHART-MARTINELLI-jev parametar

$X^2 = \frac{\left(\frac{dp}{dz}\right)_{tr,1}}{\left(\frac{dp}{dz}\right)_{tr,2}}$

C – empirijska konstanta koja zavisi od režima strujanja tečne i pare/gasne faze

TAB.

Tečnost	Gas/para	C
T	T	20
L	T	12
T	L	10
L	L	5

$Re > 2300 \Rightarrow T$

$X^2 = \frac{\rho_2}{\rho_1} \left(\frac{\mu_1}{\mu_2}\right)^n \cdot \left(\frac{1-x}{x}\right)^{2-n}$

Koef. trenja ima oblik $f = \frac{k}{Re^n}$

(L) laminarno strujanje $Re \leq 2300$ $f = \frac{16}{Re}$ $n = 1$

(T) turbulentno strujanje $Re > 2300$ $f = \frac{0,079}{Re^{0,25}}$ $n = 0,25$

$$-\left(\frac{dp}{dz}\right)_{tr,1} = \frac{f_1 \cdot (1-x)^2 \cdot G^2}{2\rho_1} \cdot \frac{4}{D} \cdot a \qquad -\left(\frac{dp}{dz}\right)_{tr,2} = f_2 \frac{x^2 \cdot G^2}{2\rho_2} \cdot \frac{4}{D}$$

radimo za 1 — τ - napon trenja, a - koncentracija razdeljene površine

$G = ?$ $\boxed{G = \frac{\dot{m}}{A} = \frac{\rho u A}{A} = \rho u = 144{,}242 \cdot 40 = 5769{,}69 \frac{kg}{m^2 s}}$

$\boxed{\rho = \frac{1}{v} = \frac{1}{v' + x(v'' - v')} = \frac{1}{0{,}0018395 + 0{,}9 \cdot (0{,}0074987 - 0{,}0018395)} = 144{,}242 \frac{kg}{m}}$

gustina dvofazne mešavine

$f_1 = ?$ $f_1 = \frac{0{,}079}{Re_1^{0{,}25}}$ $Re_1 = ?$ $Re_1 = \frac{f_1 \rho_1 u_1 D}{\mu_1}$ $\boxed{n = 0{,}25}$ $Re_2 = \frac{f_2 \rho_2 u_2 D}{\mu_2}$

$G = f_1 \rho_1 u_1 + f_2 \rho_2 u_2$

HOMOGENO STRUJANJE $x = \chi$, $\chi = \frac{\dot{m}_2}{\dot{m}} = \frac{\rho_2 u_2 f_2 A}{G A} = x \Rightarrow \rho_2 u_2 f_2 = G x$

$G = f_1 \rho_1 u_1 + G x \Rightarrow f_1 \rho_1 u_1 = G(1-x) \Rightarrow Re_1 = \frac{G(1-x) \cdot D}{\mu_1}$ $Re_2 = \frac{GxD}{\mu_2}$

$\boxed{Re_1 = \frac{5769{,}69 \cdot (1-0{,}9) \cdot 0{,}2}{62{,}17 \cdot 10^{-6}} = 1{,}856 \cdot 10^6}$ → TURBULENTNO STRUJANJE

$\boxed{f_1 = \frac{0{,}079}{(1{,}856 \cdot 10^6)^{0{,}25}} = 0{,}002114}$ Faning-ov koeficijent trenja

$\boxed{-\left(\frac{dp}{dz}\right)_{tr,1} = \frac{0{,}002114 \cdot (1-0{,}9)^2 \cdot 5769{,}69^2}{2 \cdot 543{,}628} \cdot \frac{4}{0{,}2} = 13{,}104 \frac{Pa}{m}}$

$C = ?$ $\boxed{Re_2 = \frac{G \cdot x \cdot D}{\mu_2} = \frac{5769{,}69 \cdot 0{,}1 \cdot 0{,}2}{25{,}05 \cdot 10^{-6}} = 4{,}459 \cdot 10^6}$ → TURBULENTNO STRUJANJE

Iz TAB. za T T $\Rightarrow \boxed{C = 20}$

$\boxed{X^2 = \frac{\rho_2}{\rho_1} \left(\frac{\mu_1}{\mu_2}\right)^n \left(\frac{1-x}{x}\right)^{2-n} = \frac{133{,}357}{543{,}628} \cdot \left(\frac{62{,}17 \cdot 10^{-6}}{25{,}05 \cdot 10^{-6}}\right)^{0{,}25} \left(\frac{1-0{,}9}{0{,}9}\right)^{2-0{,}25} = 6{,}58939 \cdot 10^{-3}}$

$\boxed{X = 0{,}0811411}$

$\boxed{\Phi_1^2 = 1 + \frac{C}{X} + \frac{1}{X^2} = 1 + \frac{20}{0{,}0811411} + \frac{1}{6{,}58939 \cdot 10^{-3}} = 399{,}244}$

$-\left(\frac{dp}{dz}\right)_{tr,DT} = -\left(\frac{dp}{dz}\right)_{tr,1} \cdot \Phi_1^2 = -13{,}104 \cdot 399{,}244 = -5{,}2316 \cdot 10^3 \frac{Pa}{m}$

$\boxed{\Delta p_{tr} = -\left(\frac{dp}{dz}\right)_{tr,DT} \cdot L = -5{,}2316 \cdot 10^3 \cdot 10 = -5{,}2316 \cdot 10^4 Pa = -0{,}52316 \text{ bar}}$

- caso radimo za 2

$$-\left(\frac{dp}{dz}\right)_{tr,2} = f_2 \frac{x^2 G^2}{2\rho_2} \cdot \frac{4}{D} = 1990{,}627 \frac{Pa}{m}$$

$f_2 = ?$ $\quad f_2 = \frac{0{,}079}{Re_2^{0{,}25}} = 0{,}00009845$

$$\Phi_2^2 = 1 + CX + X^2 = 2{,}6294$$

$$-\left(\frac{dp}{dz}\right)_{tr,PT} = -\left(\frac{dp}{dz}\right)_{tr,2} \cdot \Phi_2^2 = 5{,}234 \cdot 10^3 \frac{Pa}{m}$$

$$\Delta p_{tr} = -\left(\frac{dp}{dz}\right)_{tr,PT} \cdot L$$