

HW#6

8.30) Dry, compressed air @ $T_{m,i} = 55^\circ\text{C}$, $p = 15 \text{ atm}$, $\dot{m} = 0.05 \text{ kg/s}$ enters a $50 \text{ mm } \phi$, 2.5 m long tube w/ $T_s = 25^\circ\text{C}$

- a) find \bar{T} of air @ outlet, rate of heat transfer from air to tube wall, & power required to flow air through tube

Table A-4: $T \approx 320 \text{ K}$, $\mu = 1.94 \times 10^{-5} \text{ N}\cdot\text{s/m}^2$, $\rho = 15(1.095) = 16.42 \text{ kg/m}^3$
 $c_p = 1008 \text{ J/kg}\cdot\text{K}$, $k = 0.0278 \text{ W/m}\cdot\text{K}$, $Pr = 0.704$

a)

$$Re = \frac{4\dot{m}}{\pi D \mu} = \frac{4(0.05)}{\pi(0.05)(1.94 \times 10^{-5})} = 65,631 > 10^4 \therefore \text{Turbulent}$$

8.60 2.60 70% \therefore Developed & w/ $Nu = \frac{hD}{k} \Rightarrow h = \frac{Nu k}{D}$

$$h = \frac{0.023}{50 \times 10^{-3}} (6.56 \times 10^4)^{4/5} (0.704)^{1/3} \cdot 0.0278 = 82.15 \text{ W/m}^2\cdot\text{K} = h$$

Power) Eq. 8.22a,b

$$P = \Delta p \dot{V} = \frac{\dot{m}}{\rho} \left(f \frac{\rho u_m^2}{2\sigma} (Lx) \right) = \frac{\dot{m} f u_m^2 Lx}{2\sigma}$$

need f from 8.21: $f = (0.79 \ln(Re_D) - 1.64)^{-2}$

$$f = (0.79 \ln(6.56 \times 10^4) - 1.64)^{-2} = 0.0197$$

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$$\dot{m} = \dot{V} A \rho \Rightarrow v = \dot{m} / A \rho = \frac{\dot{m}}{\sigma^2 \pi \rho} = \frac{4(0.05)}{(5003)^2 \pi (16.42)} = 1.55 \text{ m/s}$$

$$P = \frac{(0.05)(0.0197)(1.55)^2(2.5)}{2(5003)} = 0.593 \text{ W} = P$$

T_o) 8.41b

$$\frac{T_s - T_{m,i}}{T_s - T_{m,i}} = \exp\left(\frac{-PL}{\dot{m} c_p} \bar{A}\right) \Rightarrow T_{m,i} = T_s + (T_{m,i} - T_s) \exp\left(\frac{-\pi \sigma \bar{A} L}{\dot{m} c_p}\right)$$

$$T_{m,i} = 25 + (55 - 25) \exp\left(\frac{-\pi (5003)(82.1)(2.5)}{(0.05)(1008)}\right) = 40.82^\circ\text{C} = T_{m,i}$$

$$q = \dot{m} c_p (T_{m,i} - T_{m,o}) = (0.05)(1008)(55 - 40.82) = 714.79 \text{ W} = q$$

$$T_{m,o} = 40.82^\circ\text{C}, \quad q = 714.79 \text{ W}$$

$$P = 0.593 \text{ W}$$

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b) 40 cm , find L & P to have same q

know m is the same, so $u/q = m c_p (T_{m,i} - T_{m,o})$ we know $T_{m,o}$ has to be the same

$$u / \text{this} \propto T_{m,o} = T_s + (T_{m,i} - T_s) \exp\left(\frac{-\pi U A L}{m c_p}\right)$$

set both equal & separate argument of exp to get

$$\frac{\pi U_1 A_1 L_1}{m c_p} = \frac{\pi U_2 A_2 L_2}{m c_p} \Rightarrow U_1 A_1 L_1 = U_2 A_2 L_2$$

$$\& h \propto \frac{Re^{1/5}}{D} \propto \left(\frac{1}{D}\right)^{4/5} \propto D^{-4/5} D^{-1} \propto D^{-1.8}$$

$$\Rightarrow U_1^{-0.8} L_1 = U_2^{-0.8} L_2 \Rightarrow L_2 = \left(\frac{U_1}{U_2}\right)^{0.8} L_1 = \left(\frac{40}{50}\right)^{0.8} 2.5 = 2.09 \text{ m}$$

$$\boxed{L_2 = 2.09 \text{ m}}$$

$$\text{then power } P = \frac{m \dot{f} u_m \Delta T}{2U}$$

$$f = (0.79 \ln(Re) - 1.64)^{-2}, \quad Re = \frac{4m}{\pi D \mu} = 82039$$

$$f = 0.01877 \quad \& \quad v = \frac{4m}{\pi D \rho} = 2.42 \text{ m/s}$$

$$\Rightarrow \boxed{P = 0.144 \text{ W}}$$

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B.34) NaK (56%/44%), $\dot{m} = 0.8 \text{ kg/s}$, $D = 40 \text{ cm}$, $T_s = 435 \text{ K}$, $T_{m,i} = 335 \text{ K}$, $T_{m,o} = 397 \text{ K}$

Find L & convective heat flux @ exit.

Table A.7) $\bar{T}_m = \frac{335 + 397}{2} = 366 \text{ K}$, $\rho = 887 \text{ kg/m}^3$, $k = 25.6 \text{ W/m}\cdot\text{K}$
 $\nu = 6.52 \times 10^{-7} \text{ m}^2/\text{s}$, $Pr = 0.026$, $c_p = 1130 \text{ J/kg}\cdot\text{K}$

$$Re = \frac{4\dot{m}}{\pi D \nu} = \frac{4(0.8)}{\pi(0.04)(6.52 \times 10^{-7})(887)} = 49,032 > 10,000 \therefore \text{Turbulent}$$

Check $Pe_D = Re_D Pr = (49,032)(0.026) = 1144.2 \therefore \text{Eq. 8.65}$

$$Nu = 5.0 + 0.025 Pe_D^{0.8} = 11.997 \Rightarrow h = \frac{k Nu}{D} = \frac{(25.6)(11.997)}{(0.04)}$$

$$h = 7678.31 \text{ W/m}^2\cdot\text{K}$$

Eq. 8.41a $L = \frac{\dot{m} c_p \ln\left(\frac{\Delta T_i}{\Delta T_o}\right)}{\pi D h} = \frac{(0.8)(1130) \ln\left(\frac{100}{32}\right)}{\pi(0.04)(7678.31)} = 0.906 \text{ m} = L$

Answer $q'' = h(T_s - T_{m,o}) = h(435 - 397) = 291,776 \text{ W/m}^2 = q''$

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2.36) Hg , $\dot{m} = 0.25 \text{ kg/s}$ heated $325 \text{ K} \rightarrow 375 \text{ K}$, 250^{-3} m ϕ @ 400 K
Find L w/ engine metal & compare to $Pr \geq 0.7$

Table A.5) $\bar{T}_m = \frac{375 - 325}{2} = 350 \text{ K}$, $C_p = 137.7 \text{ J/kg K}$, $\mu = 0.1309 \times 10^{-2} \text{ N s/m}^2$,
 $k = 9.18 \text{ W/m K}$, $Pr = 0.0196$

$$Re = \frac{4\dot{m}}{\pi D \mu} = \frac{4(0.25)}{\pi(0.025)(0.1309 \times 10^{-2})} = 9726.81 \approx 10,000 \therefore \text{Fully developed, but use Fittus-Dotter}$$

$$Pe = Re Pr = 9726.81(0.0196) = 190.645$$

2.65

$$Nu = 5 + 0.25 Pe^{0.5} = 5 + 0.25(190.645)^{0.5} = 6.668$$

$$\frac{q}{D} = \frac{h Nu}{D} = \frac{9.18}{0.025} Nu = 2449.30 \text{ W/m}^2 \text{ K}$$

$$\text{Eq. 2.41)} L = \frac{\dot{m} C_p \ln(\frac{\Delta T_i}{\Delta T_o})}{\pi D R} = \frac{(0.25)(137.7)}{\pi(0.025)(2449)} \ln\left(\frac{400 - 325}{400 - 375}\right) = 0.1966 \text{ m} = L_1$$

if $Pr \geq 0.7$, R given by 2.60)

$$\frac{q}{D} = \frac{h(0.0243) Re^{1/5} Pr^{0.4}}{D} = \frac{9.18}{0.025} \underbrace{(0.0243)}_{7.214} \underbrace{(Re)^{1/5}}_{10.0} \underbrace{Pr^{0.4}}_{0.0196^{0.4}} = 2715.69 \text{ W/m}^2 \text{ K}$$

$$L = \frac{\dot{m} C_p \ln(\frac{\Delta T_i}{\Delta T_o})}{\pi D R} = 0.1773 \text{ m} = L_2$$

$L_1 > L_2$ where L_2 is assuming $Pr \geq 0.7$

HW#6

gas tube
↓

8.42) HT 9R, radiant tubes $20 \times 10^{-3} \text{ m } \phi$ & $780 \times 10^{-3} \text{ m L}$, $\text{He} @ 600 \text{ K} \rightarrow 1000 \text{ K}$, $\dot{m} = 2 \times 10^{-3} \text{ kg/s}$

Table A-4) $\text{He}; \bar{T} = 800 \text{ K}, P = 1 \text{ atm}, \rho = 0.06272 \text{ kg/m}^3, C_p = 5193 \text{ J/kg} \cdot \text{K}$,

b) $k = 0.304 \text{ W/m} \cdot \text{K}, \mu = 382 \times 10^{-7} \text{ N} \cdot \text{s/m}^2, \nu = 6.39 \times 10^{-4} \text{ m}^2/\text{s}, Pr = 0.654$

$\text{Air}; \bar{T} = 800 \text{ K}, P = 1 \text{ atm}, \rho = 0.4354 \text{ kg/m}^3, C_p = 1099 \text{ J/kg} \cdot \text{K}$,

$k = 57.3 \times 10^{-3} \text{ W/m} \cdot \text{K}, \nu = 84.93 \times 10^{-6} \text{ m}^2/\text{s}, Pr = 0.709$

a) Find T_s & q

$$Re = \frac{4\dot{m}}{\pi D \mu} = \frac{4(2 \times 10^{-3})}{\pi(0.02)(382 \times 10^{-7})} = 13,332.4 > 10,000 \therefore \text{Fully developed}$$

$$2.60) Nu = 0.023 Re^{1/2} Pr^{1/4} = 38.72$$

$$h = \frac{k}{D} Nu = \frac{0.304}{0.02} (38.72) = 588.484 \text{ W/m}^2 \cdot \text{K}$$

$$8.41b) \frac{T_s - T_{m,o}}{T_s - T_{m,i}} = \exp\left(-\frac{\pi D A L}{\dot{m} C_p}\right) \approx 0.5 = \frac{T_s - 1000}{T_s - 600}$$

$$\Rightarrow 0.5 T_s - 0.5(600) = T_s - 1000 \Rightarrow 0.5 T_s = 1000 - 0.5(600)$$

$$T_s = 1400.0 \text{ K}$$

$$q = \dot{m} C_p (T_{m,o} - T_{m,i}) = (2 \times 10^{-3})(5193)(1000 - 600) = 16,617.6 \text{ W}$$

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- b) if air, find \dot{m} if q & T_s are the same. Find outlet temp of air.

$$\text{know } q = \dot{m} c_p (T_{mo} - T_{mi}) \Rightarrow \dot{m} = \frac{q}{c_p} \cdot \frac{1}{(T_{mo} - T_{mi})}$$

$$\frac{q}{A} = 0.023 Re^{4/5} Pr^{0.4} \Rightarrow h = \frac{q}{\sigma} = 0.023 Re^{4/5} Pr^{0.4}$$

$$Re = \frac{4\dot{m}}{\pi D \mu} \Rightarrow h = \frac{q}{\sigma} = 0.023 \left(\frac{4\dot{m}}{\pi D \mu} \right)^{4/5} Pr^{0.4}$$

$$\frac{T_s - T_{mo}}{T_s - T_{mi}} = \exp\left(\frac{-D\pi L h}{\dot{m} c_p}\right) \Rightarrow T_{mo} = T_s - (T_s - T_{mi}) \exp\left(\frac{-D\pi L h}{\dot{m} c_p}\right)$$

plug in values each step & get

$$T_{mo} = 890.18 \text{ K}$$

$$\dot{m} = 0.05204 \text{ kg/s}$$

converges after 6 steps
w/ error of
 10^{-10}

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1 #Constants
2 rho, cp, k, nu, Pr, D, L, Ts, q, Ti= 0.4354, 1099, 57.3e-3, 84.93e-6, 0.709, 20e-3, 780e-3, 1400, 16617.6, 600
3 mu = nu*rho
4
5 #Power Iteration
6 epsilon, error, T0, step = 1e-10, 1, 1000, 0
7
8 while error > epsilon:
9     m = q/cp/(T0-Ti)
10    Re = 4*m/np.pi/D/mu
11    h = k/D*0.023*(4*m/np.pi/D/mu)**(4/5)*Pr**(0.4)
12    T1 = Ts - (Ts-Ti)*np.exp(-D*np.pi*L*h/m/cp)
13    error = (T1-T0)**2/T0**2
14    T0 = T1
15    step += 1
16
17 print('T1 [C]:', T1)
18 print('m_dot [kg/s]:', 15.1/(T1-600))
19 print('Steps to Converge:', step)

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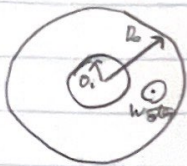
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T1 [C]: 890.1844143564228
m_dot [kg/s]: 0.052035875301880356
Steps to Converge: 6

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HW#6

8.73)



water @ $\dot{m} = 0.03 \text{ kg/s}$, $T_{m,i} = 25^\circ\text{C}$

inner heated w $q' = 3000 \text{ W/m}$, outer insulated

How long to get 85°C ? $T_{s,\text{inner}}$ @ outlet? (fully developed)

Table A.6) $\bar{T} = \frac{85-25}{2} + 25 + 273 = 328 \text{ K}$, $c_p = 4183 \text{ J/kg}\cdot\text{K}$,
 $\mu = 332 \times 10^{-6} \text{ kg/m}\cdot\text{s}$, $k = 0.673 \text{ W/m}\cdot\text{K}$, $Pr = 2.07$

8.34) $q = \dot{m} c_p (T_{m,o} - T_{m,i}) = q' L \Rightarrow L = \frac{\dot{m} c_p (T_{m,o} - T_{m,i})}{q'}$

$L = \frac{(0.03)(4183)(85-25)}{3000} = 2.51 \text{ m} = L$

T_s) 8.1) $Re = \frac{\rho u_m D}{\mu}$

8.5) $\dot{m} = \rho u_m A \Rightarrow u_m = \frac{\dot{m}}{\rho A}$

$\Rightarrow Re = \frac{\dot{m} D}{\mu A} = \frac{\dot{m} (D_o - D_i)}{\frac{\pi}{4} (D_o^2 - D_i^2) \mu} = \frac{4 \dot{m}}{\pi (D_o + D_i) \mu} = \frac{4(0.03)}{\pi(0.075)(332 \times 10^{-6})} = 1534$

$Re < 2300 \therefore \text{Laminar}$, Table 8.3) $\frac{D_i}{D_o} = 0.5 \therefore Nu_i = 6.24$

Eq 8.69) $h_i = \frac{k Nu_i}{D_i}$ u/ Eq 8.71) $D_a = D_o - D_i = 0.025 \text{ m}$

$h_i = \frac{6.24(0.673)}{0.025} = 168 \text{ W/m}^2\cdot\text{K}$ Eq 8.67) $q'_i = h_i (T_{s,i} - T_m)$

$\Rightarrow T_{s,i} = T_{m,o} + \frac{q'_i}{h_i} = T_{m,o} + \frac{q' / \pi D_i}{h_i} = 85 + \frac{3000}{\pi(0.025)(168)} = 312.36^\circ\text{C} = T_{s,i}$