HW7

Wednesday, November 1, 2023 10:08 PM

Chapter 7:

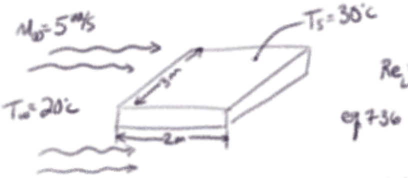
Problems: 10, 20, 41, 42,and 54

7.10 Consider a flat plate subject to parallel flow (top and bottom) characterized by $u_\infty = 5$ m/s, $T_\infty = 20°C$.

(a) Determine the average convection heat transfer coefficient, convective heat transfer rate, and drag force associated with an $L = 2$-m-long, $w = 3$-m-wide flat plate for airflow and surface temperatures of $T_s = 30°C$ and $80°C$.

$T_f = \frac{30+20}{2} = 25°C\ (298\text{K})$

TA4 → $k = 26.3\times10^{-3}$ W/mK, $\nu = 15.89\times10^{-6}$ m²/s, $Pr = 0.707$, $\rho = 1.1614$ kg/m³



$Re_L = \frac{VL}{\nu} = \frac{(5\text{ m/s})(2\text{m})}{(15.89\times10^{-6}\text{ m}^2/\text{s})} = 629327$ TURBULENT

eq 7.36 $Nu_L = 0.0296 Re_L^{4/5} Pr^{1/3} = 0.0296(629327)^{4/5}(0.707)^{1/3}$

$Nu_L = 1148.68$

$Nu_L = \frac{hL}{k} \longrightarrow h = \frac{(1148.68)(26.3\times10^{-3}\text{ W/mK})}{(2\text{m})} = 15.1$ W/m²K

$q = hA\Delta T = (15.1\text{ W/m}^2\text{K})(2\text{m}\times3\text{m})(30-20\text{ K}) = 906$ W

$C_D = 0.0592 Re_x^{-1/5} = 0.0592(629327)^{-1/5} = 0.004098$

$F_D = C_D A\rho V^2/2 = (0.004098)(2\text{m}\times3\text{m})(1.1614\text{ kg/m}^3)(5\text{ m/s})^2\frac{1}{2} = 0.357$ N

Correlation		Geometry	Conditions[c]
$\delta = 5x\, Re_x^{-1/2}$	(7.19)	Flat plate	Laminar, T_f
$C_{f,x} = 0.664\, Re_x^{-1/2}$	(7.20)	Flat plate	Laminar, local, T_f
$Nu_x = 0.332\, Re_x^{1/2}\, Pr^{1/3}$	(7.23)	Flat plate	Laminar, local, T_f, $Pr \gtrsim 0.6$
$\delta_t = \delta\, Pr^{-1/3}$	(7.24)	Flat plate	Laminar, T_f
$\overline{C}_{f,x} = 1.328\, Re_x^{-1/2}$	(7.29)	Flat plate	Laminar, average, T_f

Table 7.7 *(Continued)*

Correlation		Geometry	Conditions[c]
$\overline{Nu}_x = 0.664\, Re_x^{1/2}\, Pr^{1/3}$	(7.30)	Flat plate	Laminar, average, T_f, $Pr \gtrsim 0.6$
$Nu_x = 0.564\, Pe_x^{1/2}$	(7.32)	Flat plate	Laminar, local, T_f, $Pr \lesssim 0.05$, $Pe_x \gtrsim 100$
$C_{f,x} = 0.0592\, Re_x^{-1/5}$	(7.34)	Flat plate	Turbulent, local, T_f, $Re_x \lesssim 10^8$
$\delta = 0.37x\, Re_x^{-1/5}$	(7.35)	Flat plate	Turbulent, T_f, $Re_x \lesssim 10^8$
$Nu_x = 0.0296\, Re_x^{4/5}\, Pr^{1/3}$	(7.36)	Flat plate	Turbulent, local, T_f, $Re_x \lesssim 10^8$, $0.6 \lesssim Pr \lesssim 60$
$\overline{C}_{f,L} = 0.074\, Re_L^{-1/5} - 1742\, Re_L^{-1}$	(7.40)	Flat plate	Mixed, average, T_f, $Re_{x,c} = 5\times10^5$, $Re_L \lesssim 10^8$
$\overline{Nu}_L = (0.037\, Re_L^{4/5} - 871)\, Pr^{1/3}$	(7.38)	Flat plate	Mixed, average, T_f, $Re_{x,c} = 5\times10^5$, $Re_L \lesssim 10^8$, $0.6 \lesssim Pr \lesssim 60$

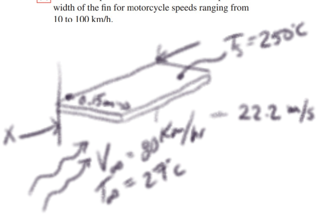
7.20 Consider a rectangular fin that is used to cool a motorcycle engine. The fin is 0.15 m long and at a temperature of 250°C, while the motorcycle is moving at 80 km/h in air at 27°C. The air is in parallel flow over both surfaces of the fin, and turbulent flow conditions may be assumed to exist throughout.

(a) What is the rate of heat removal per unit width of the fin?

(b) Generate a plot of the heat removal rate per unit width of the fin for motorcycle speeds ranging from 10 to 100 km/h.

$T_f = \frac{250+27}{2} = 138.5°C\ (411.5\text{K})$

TA4 → $k \approx 35\times10^{-3}$ W/mK, $Pr \approx 0.689$, $\nu \approx 27.5\times10^{-6}$ m²/s



$q = hA\Delta T$

$Nu = \frac{hL}{k} \longrightarrow h = \frac{Nu\,k}{L}$

eq 7.36 $Nu = 0.0296 Re^{4/5} Pr^{1/3}$

$Nu = 0.0296(121090)^{4/5}(0.689)^{1/3}$

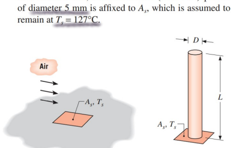
$Nu = 304.7$

$Re = \frac{VL}{\nu} = \frac{(22.2\text{ m/s})(0.15\text{m})}{(29.5\times10^{-6}\text{ m}^2/\text{s})} = 121090$

$h = \frac{(304.7)(35\times10^{-3}\text{ W/mK})}{(0.15\text{m})} = 71.09$ W/m²K

$q/m = 2\times(0.1127\text{ W/m}^2\text{K})(0.15\text{m})(250-27) = 4756$ W/m

7.41 Air at 27°C and a velocity of 5 m/s passes over the small region A_s (20 mm × 20 mm) on a large surface, which is maintained at $T_s = 127°C$. For these conditions, 0.5 W is removed from the surface A_s. To increase the heat removal rate, a stainless steel (AISI 304) pin fin of diameter 5 mm is affixed to A_s, which is assumed to remain at $T_s = 127°C$.



(a) Determine the maximum possible heat removal rate through the fin.

(b) What fin length would provide a close approximation to the heat rate found in part (a)? *Hint:* Refer to Example 3.9.

(c) Determine the fin effectiveness, ε_f.

(d) What is the percentage increase in the heat rate from A_s due to installation of the fin?

$V_\infty = 5$ m/s
$T_\infty = 27°C$
$T_s = 127°C$
$A_s = 0.0004$ m²
$D = 0.005$ m

$T_f = \frac{127+27}{2} = 77°C\ (350\text{K})$ TA4 → $\nu = 20.92\times10^{-6}$ m²/s, $k = 30\times10^{-3}$ W/mK, $Pr = 0.700$

AISI 304 $k_{300} = 15.8$ W/mK

$Re_D = \frac{VD}{\nu} = \frac{(5\text{ m/s})(0.005\text{ m})}{(20.9\times10^{-6}\text{ m}^2/\text{s})} = 1196.2$

eq 7.52 $Nu_D = \frac{\bar{h}D}{k} = C Re_D^m Pr^{1/3}$

$\bar{h} = \frac{k}{D} C Re_D^m Pr^{1/3} = \frac{(30\times10^{-3}\text{ W/mK})}{(0.005\text{m})}(0.683)(1196.2)^{(0.466)}(0.700)^{1/3}$

$\bar{h} = 98.90$

$q = hA\Delta T$

Table 7.2 Constants of Equation 7.52 for the circular cylinder in cross flow [12, 13]

Re_D	C	m
0.4–4	0.989	0.330
4–40	0.911	0.385
40–4000	0.683	0.466
4000–40,000	0.193	0.618
40,000–400,000	0.027	0.805