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Cankaya University
Faculty of Engineering
Mechanical Engineering Department
ME 313 Heat Transfer
Midterm Exam II
Closed Notes Open Book
Fall 2015

1) Atmospheric nitrogen at 150 ^{0}C flows across a long 5-cm diameter circular cylinder at a velocity of 20 m/s . The surface temperature of the cylinder is 500 ^{0}C .On a per unit length basis, determine the convective heat transfer from the cylinder.

$T_\infty = 150°C$
$V = 20\ m/s$
$T_s = 500°C$

$T_f = \frac{1}{2}(500+150) = 325°C = 598K \approx 600K$

$\rho = 0.5615\ kg/m^3,\quad \mu = 290.5\times10^{-7}\ \frac{N.s}{m^2}$

$k = 44.6\times10^{-3}\ W/mK \quad Pr = 0.701$

$\overline{Nu}_D = C\,Re_D^n\,Pr^{1/3}$

$Re_D = \frac{\rho V D}{\mu} = 1.94\times10^{4}$ so $C = 0.193,\ n = 0.618$

$\overline{h} = \frac{k}{D}\overline{Nu}_D = 682\ W/m^2K \qquad \overline{Nu}_D = 76.6$

$\frac{q}{L} = \overline{h}\pi D(T_s - T_\infty) = 3750\ W/m$

2) Water flows at 7.55 kg/s through a 12-cm –diameter ,110-m-long plastic drainage pipe. The water temperature at the pipe inlet is 25 ^{0}C,and the ground in which the pipe is buried maintains the temperature of the inside pipe surface at 15 ^{0}C.
   (a) find heat transfer coefficient
   (b) water temperature at the pipe outlet
   (c) total convective heat transfer

Evaluate properties at $T_{mi} = 25°C$ We do not know outlet temperature.

$\rho = 997\ kg/m^3$ $c_p = 4183\ J/kg\,K$ $\mu = 890.5 \times 10^{-6}\ kg/ms$

$\nu = 89.32 \times 10^{-8}\ m^2/s$ $k = 0.6071\ W/mK$ $Pr = 6.14$

$\dot{m} = 7.55\ kg/s = \rho V A_c$ $A_c = \frac{\pi D^2}{4}$

$V = \frac{4\dot{m}}{\rho \pi D^2} = 0.669\ m/s$

$Re_D = \frac{\rho V D}{\mu} = 8.99 \times 10^4$ turbulent flow

$$\overline{Nu_D} = \frac{(f/8)[Re_D - 1000]Pr}{1 + 12.7[\sqrt{f/8}][Pr^{2/3} - 1]}$$

$$f = \frac{0.25}{\left[\log\left(\frac{5.74}{Re_D^{0.9}}\right)\right]^2} = 0.0183 \leftarrow \text{smooth pipe}$$

$\overline{Nu_D} = 514$

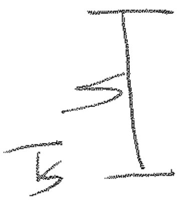
$\bar{h} = \frac{k}{D}\overline{Nu_D} = 2600\ W/m^2K$

$$T_{mo} = T_s - (T_s - T_{mi}) \exp\left[-\frac{PL\bar{h}}{\dot{m} c_p}\right] = 15.3°C$$

c) $q = \dot{m} c_p (T_{mo} - T_{mi}) = 3.06 \times 10^5 \ W$

Since outlet temperature does not differ much from inlet temperature no need to evaluate fluid properties again.

3) A flat plate with uniform temperature of 150 ^{0}C and insulated on one side is suspended vertically in 25 ^{0}C stagnant atmospheric air .If the plate height and width 40 cm and 1 m, respectively, find the convective heat transfer.



$T_s = 150\,^\circ C \qquad T_\infty = 25\,^\circ C$

$L = 40\,cm \qquad W = 1\,m$

$$T_f = \frac{1}{2}(T_s + T_\infty) = \frac{25+150}{2} = 87.5\,^\circ C = 361\,K$$

$$\beta = \frac{1}{T_f} = 2{,}77 \times 10^{-3}\ 1/K \qquad \nu = 22{,}13 \times 10^{-6}\ m^2/s$$

$$k = 0.0308\ W/m\,^\circ C \qquad Pr = 0.696$$

$$Gr_L = \frac{g\beta(T_s - T_\infty)L^3}{\nu^2} = 4{,}439 \times 10^8$$

$$Ra_L = Gr_L\,Pr = 3{,}098 \times 10^8 < 10^9 \text{ flow is laminar}$$

$$\overline{Nu_L} = 0{,}68 + \frac{0{,}67\,Ra_L^{1/4}}{\left[1 + \left(\frac{0{,}492}{Pr}\right)^{9/16}\right]^{4/9}} = 68{,}8$$

$$\bar{h} = \frac{k}{L}\overline{Nu_L} = 5{,}30\ W/m^2K$$

$$q = \bar{h}A(T_s - T_\infty) = 265\ W$$