10-11 有一外径为 25 mm、长为 200 mm 的水平圆管横置在风洞之中进行空气横掠的对流换热实验,管内用电加热器加热。已测得圆管外壁面的平均温度为 100 ℃,来流空气温度为 20 ℃、流速为 5 m/s,试计算圆管外壁面对流换热的表面传热系数和电加热器的功率。

$t_\infty = 20℃$, $t_w = 100℃$, $u_\infty = 5 m/s$

查空气物性表得:

$\lambda = 0.0259 W/m·℃$, $\nu = 15.06 \times 10^{-6} m^2/s$, $Pr = 0.703$, $Pr_w = 0.688$

$Re = \dfrac{u_\infty d}{\nu} = \dfrac{5 \times 25 \times 10^{-3}}{15.06 \times 10^{-6}} = 8300$

$Nu = 0.26 Re^{0.6} Pr^{0.37} \left(\dfrac{Pr}{Pr_w}\right)^{\frac{1}{4}} = 0.26 \times 8300^{0.6} \times 0.703^{0.37} \times \left(\dfrac{0.703}{0.688}\right)^{\frac{1}{4}} = 51.54$

$h = \dfrac{\lambda}{d} Nu = \dfrac{0.0259}{0.025} \times 51.54 = 53.4 \ W/m^2·K$

$P = h(t_w - t_\infty) \cdot \pi d l = 53.4 \times 80 \times \pi \times 0.025 \times 0.2 = 67.07 W$

10-13 室内有一外径为 76 mm 的水平暖气管道,壁面温度为 80 ℃,室内空气温度为 20 ℃,试求暖气管外壁面处自然对流换热的表面传热系数及单位管长的散热量。

$t_m = \dfrac{t_w + t_\infty}{2} = \dfrac{80 + 20}{2} = 50℃$

查空气物性表得:

$\lambda = 0.0283 W/m·℃$, $\nu = 17.95 \times 10^{-6} m^2/s$, $Pr = 0.698$

$\alpha = \dfrac{1}{T_m} = \dfrac{1}{273 + 50} = 3.096 \times 10^{-3} K^{-1}$

$Ra = Gr \cdot Pr = \dfrac{g\alpha \Delta t d^3}{\nu^2} \cdot Pr = \dfrac{9.8 \times 3.096 \times 10^{-3} \times 60 \times 0.076^3}{(17.95 \times 10^{-6})^2} \times 0.698 = 1.8 \times 10^6$

$C = 0.48, n = \dfrac{1}{4}$

$Nu_f = C(Gr \cdot Pr)^n = 0.48 \times (1.8 \times 10^6)^{\frac{1}{4}} = 17.58$

$h = Nu \dfrac{\lambda}{d} = 17.58 \times \dfrac{0.0283}{0.076} = 6.55 \ W/m^2·K$

$q = hA(t_w - t_f) = 6.55 \times \pi \times 0.076 \times 60 = 93.83 \ W/m$

① 垂直段

$$t_m = \frac{t_w + t_\infty}{2} = \frac{150 + 18}{2} = 84℃$$

查空气物性表得:

$$\lambda = 0.031 \ W/m\cdot℃ \ , \ \nu = 21.49 \times 10^{-6} \ m^2/s, \ Pr = 0.691$$

$$\alpha = \frac{1}{T_m} = \frac{1}{273 + 84} = 2.8 \times 10^{-3} K^{-1}$$

$$Ra = Gr \cdot Pr = \frac{g\alpha\Delta t d^3}{\nu^2} \cdot Pr = \frac{9.8 \times 2.8 \times 10^{-3} \times 132 \times 1.6^3}{(21.49 \times 10^{-6})^2} \times 0.691 = 2.2 \times 10^{10}$$

$$C = 0.1, \ n = \frac{1}{3}$$

$$Nu_f = C(Gr \cdot Pr)^n = 0.1 \times (2.2 \times 10^{10})^{\frac{1}{3}} = 280.2$$

$$h = Nu \frac{\lambda}{d} = 280.2 \times \frac{0.031}{1.6} = 5.43 \ W/m^2\cdot K$$

$$Q_1 = h(t_w - t_f)\pi d h t = 5.55 \times 60 \times \pi \times 0.15 \times 1.6 \times 3600 = 1944.5 \ kJ$$

② 水平段

$$t_m = \frac{t_w + t_\infty}{2} = \frac{100 + 18}{2} = 59℃$$

查空气物性表得:

$$\lambda = 0.029 \ W/m\cdot℃ \ , \ \nu = 18.97 \times 10^{-6} \ m^2/s, \ Pr = 0.696$$

$$\alpha = \frac{1}{T_m} = \frac{1}{273 + 59} = 3.01 \times 10^{-3} K^{-1}$$

$$Ra = Gr \cdot Pr = \frac{g\alpha\Delta t d^3}{\nu^2} \cdot Pr = \frac{9.8 \times 3.01 \times 10^{-3} \times 82 \times 0.15^3}{(18.97 \times 10^{-6})^2} \times 0.696 = 1.58 \times 10^7$$

$$C = 0.125, \ n = \frac{1}{3}$$

$$Nu_f = C(Gr \cdot Pr)^n = 0.125 \times (1.58 \times 10^7)^{\frac{1}{3}} = 31.37$$

$$h = Nu \frac{\lambda}{d} = 31.37 \times \frac{0.029}{0.15} = 6.06 \ W/m^2\cdot K$$

$$Q_2 = h(t_w - t_f)\pi d h t = 6.06 \times 82 \times \pi \times 0.15 \times 5 \times 3600 = 4212.9 \ kJ$$

$$\Rightarrow Q = Q_1 + Q_2 = 6157.4 \ kJ$$