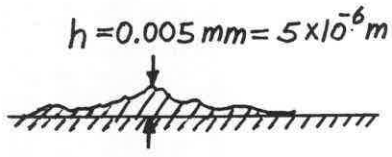
8.31

8.31 Water at 10 °C flows through a smooth 60-mm-diameter pipe with an average velocity of 8 m/s. Would a scratch of height 0.005 mm on the pipe wall protrude through the viscous sublayer? Explain.



δ_s = sublayer thickness = $\frac{5\nu}{u^*}$, where $u^* = \left(\frac{\tau_w}{\rho}\right)^{1/2}$ and $\tau_w = \frac{D\Delta p}{4\ell}$

Also, $\frac{\Delta p}{\ell} = f\frac{\ell}{D}\frac{V^2}{2g}$ so that $\tau_w = \frac{fV^2\rho}{8}$

For a smooth pipe with $Re = \frac{VD}{\nu} = \frac{(8\frac{m}{s})(0.06m)}{1.307\times10^{-6}\frac{m^2}{s}} = 3.67\times10^5$ we obtain $f = 0.0138$ (see Fig. 8.20).

Thus, $\tau_w = \frac{0.0138(8\frac{m}{s})^2(999.7\frac{kg}{m^3})}{8} = 110\frac{N}{m^2}$

or $u^* = \left(\frac{110\frac{N}{m^2}}{999.7\frac{kg}{m^3}}\right)^{1/2} = 0.332\frac{m}{s}$

and $\delta_s = \frac{5\nu}{u^*} = \frac{5(1.307\times10^{-6}\frac{m^2}{s})}{0.332\frac{m}{s}} = 1.97\times10^{-5}m > h = 5\times10^{-6}m$

Thus, the scratch does not protrude through the laminar sublayer.