Solution to Problem 280C

FORM DRAG:

If $u = 2U\sin\theta$ over the cylindrical nose it follows from Bernoulli's equation that the pressure coefficient, C_{P1}, over the nose is given by

$$C_{P1} = \frac{p - p_\infty}{\frac{1}{2}\rho U^2} = 1 - 4\sin^2\theta$$

and if C_{P2} denotes the base pressure coefficient in the wake then it follows by integration of the differences in the pressure acting on the nose and on the base of the cylinder that the form drag coefficient, $(C_D)_{form}$, is given by

$$(C_D)_{form} = \frac{1}{H}\int_{-\frac{H}{2}}^{\frac{H}{2}} (C_{P1} - C_{P2})dy$$

Then since $y = h\sin\theta/2$, $dy = h\cos\theta d\theta/2$ and

$$C_{P2} = -\frac{1}{3} - \frac{3H}{2L}$$

it follows that

$$(C_D)_{form} = \int_0^{\frac{\pi}{2}} \cos\theta\left(1 - 4\sin^2\theta + \frac{1}{3} + \frac{3H}{2L}\right)d\theta$$

and hence

$$(C_D)_{form} = \frac{3H}{2L}$$

SKIN FRICTION DRAG ESTIMATE:

Using the results for the laminar skin friction on a flat plate (use because L/H is large) we could estimate the skin friction drag on one side of the strut as

$$\frac{\text{Skin Friction Drag}}{\frac{1}{2}\rho U^2 L} = \frac{1.328}{(Re)^{\frac{1}{2}}}$$

and therefore for the two sides the skin friction drag coefficient (based on H) is

$$(C_D)_{skinfriction} = 2\frac{L}{H}\frac{1.328}{(Re)^{\frac{1}{2}}}$$

Therefore at a Reynolds number of $Re = 10^3$ the drag will be composed of equal parts of form drag and skin friction drag when

$$\left(\frac{L}{H}\right)^2 = \frac{3\times 1000^{\frac{1}{2}}}{4\times 1.328}$$

or

$$\left(\frac{L}{H}\right) = 4.23$$