Module 3: Internal Flows

Lecture 17: Some Practical Applications

The Lecture Contains:

Previous Next

Summary of the Solutions for Various Flow and Heat Transfer Situation in Internal Flows

A marvelous compilation of different results due to various investigations are available in **Shah and London (1978) [Shah, R. K., and London, A. L., Advances in Heat Transfer, Laminar Flow Forced Convection in ducts, Academic Press, New York, 1978].** **Figure 3.12** provides the results in a comprehensive manner

$$\frac{x/D}{Re\ Pr}$$

Nu_D is plotted against the **dimensionless parameter** $\frac{x/D}{Re\ Pr}$ **or reciprocal of Graetz number**. (Graetz number $G \equiv \frac{D\ Re\ Pr}{x}$)**.** Fully developed values are independent of Prandtl number**.** Fully developed conditions are reached for $\frac{x/D}{Re\ Pr} \approx 0.05$ **.**

For the constant surface temperature condition, it is desirable to know the average convection coefficient (in the entry length) **for use with equation (3.40)** $q_{conv} = \overline{h} A_w \Delta T_{l,m}$ **.** Hausen presents the following correlation for hydrodynamically fully developed flow (laminar) in tubes at constant wall temperature

$$\overline{Nu}_D = 3.66 + \frac{0.0668(D/L)Re_D\ Pr}{1 + 0.04[(D/L)Re_D\ Pr]^{2/3}}$$

Previous Next

Because the above result is for thermally developing flow, it is not generally applicable.For simultaneously developing flow, a suitable correlation due to **Sieder and Tate (1936) is of the form:**

$$\overline{Nu}_D = 1.86\left[\frac{Re_D\,Pr}{L/D}\right]^{1/3}\left(\frac{\mu}{\mu_w}\right)^{0.14}$$

All properties are evaluated at $T_m = (T_{m,0}+T_{m,i})/2$, μ_w is the viscosity of the fluid at wall temperature.

Cross section	$\frac{b}{a}$	$Nu_D = (hDn)/k$	
		Constant q''_s	Constant T_w
(circle)	–	4.36	3.66
b, a	1.0	3.61	2.98
b, a	1.43	3.73	3.08
b, a	2.0	4.12	3.39
b, a	3.0	4.79	3.96
-	4.0	5.33	4.44
-	8.0	6.49	5.60
(parallel plate)	α	8.23	7.54
(triangle)		3.00	2.35

Table 3.1: Nusselt numbers for fully developed laminar flow intubes of differing cross section.

Previous Next

Convection correlations for non-circular tubes:

To a first approximation, many of the circular tube results may be applied by using hydraulic diameter as characteristic length which is

$$D_h = \frac{4Ac}{P}$$

Here, **A_c flow cross sectional area and P wetted perimeter**

However, in a non-circular tube, the convection coefficients vary around the periphery,
38 approaches zero in the corners.

For turbulent flow $\left[\text{ i.e., for } Re_{D_h} > 2300\right]$ often it is reasonable to use the modied ($D \rightarrow D_h$) circular tube correlations. However, for laminar flow, the use of circular tube correlations are less accurate. For such cases **Nusselt number corresponding to fully developed condition may be obtained from Shah and London's book. Some results are shown in Table 3.1.**

Previous Next

References

1. Sellars, J. R., Tribus, M., and Klein, J. S., 1956, Heat Transfer to Laminar Flow in a Round Tube or at Conduit- The Graetz Problem Extended, Trans ASME, Vol. 78, pp. 441-448.

2. Siegel, R., Sparrow, E. M., and Hallman, T. M., 1958, Steady Laminar Flow Heat Transfer in a Circular Tube with a Prescribed Wall Heat Flux, Appl. Scient. Res., A7, pp. 386-392.

3. Shah, R. K., 1975, Laminar Flow Friction and Forced Convection Heat Transfer in Ducts of Arbitrary Geometry, Int. J. Heat Mass Transfer, Vol. 18, pp. 849-862.

4. Basu, T., and Roy, D. N., 1985, Laminar Heat Transfer in a Tube with Viscous Dissipation, Int. J. Heat Mass Transfer, Vol. 28, pp. 699-701.

5. Shah, R. K., and London, A. L., 1978, Advances in Heat Transfer, Laminar Flow Forced Convection in Ducts, Academic Press, New York.

6. Sieder, E. N., and Tate, G. E., 1936, Heat Transfer and Pressure Drop of Liquids in Tubes, Ind. Eng. Chem., Vol. 28, pp. 1429-1436.

Previous Next