Shell Side Pressure Drop in a Shell-and-Tube Heat Exchanger

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There are several ways to estimate the pressure drop for the flow of the shell-side fluid in a shell-and-tube heat exchanger. A ball-park estimate can be obtained by the relatively simple approach described below, which is given in a book by Peters, Timmerhaus, and West (1). This book also provides much valuable information on the design of such heat exchangers, including more sophisticated methods of estimating the pressure drop.

The pressure drop on the shell-side is calculated using

$$\Delta P_{shell} = \frac{2\, f\, G_s^2 D_s \left(N_B + 1\right)}{\rho D_e \left(\dfrac{\mu}{\mu_s}\right)^{0.14}}$$

In this equation, f is a Fanning friction factor for flow on the shell side given in Figure 14-44 of reference (1), G_s is the mass velocity on the shell side, D_s is the inside diameter of the shell, N_B is the number of baffles, ρ is the density of the shell-side fluid, and D_e is an equivalent diameter. The mass velocity $G_s = m / S_m$, where m is the mass flow rate of the fluid, and S_m is the crossflow area measured close to the central symmetry plane of the shell containing its axis. This area is defined as

$$\text{Cross flow area} = D_s\ L_B \times \frac{\text{clearance}}{\text{pitch}}$$

where L_B is the baffle spacing, and the clearance and pitch are defined in the notes on shell-and-tube heat exchangers. The equivalent diameter is defined as follows.

$$D_e = \frac{4\left(C_p S_n^2 - \dfrac{\pi D_0^2}{4}\right)}{\pi D_0}$$

Here, D_0 is the outside diameter of the tubes, and S_n is the pitch (center-to-center distance) of the tube assembly. The constant $C_p = 1$ for a square pitch, and $C_p = 0.86$ for a triangular pitch. The friction factor f is given in Figure 14-44 of the book as a function of the Reynolds number based on the equivalent diameter (Note the difference from the Reynolds number that we use for the heat transfer coefficient from Holman, which uses D_0 as the length scale). For the friction factor graph, we must use the Reynolds number Re defined as

$$\mathrm{Re} = \frac{D_e G_s}{\mu}$$

where μ is the viscosity of the shell-side fluid.

Reference

1. Peters, M.S., Timmerhaus, K.D., and West, R.E., *Plant Design and Economics for Chemical Engineers,* McGraw-Hill, New York, 2003.