6.3.2 Horizontal Disperse Flow

As might be expected, frictional losses in straight uniform pipe flows have been the most widely studied and so it is appropriate to begin with a discussion of that subject, focusing first on disperse or nearly disperse flows and then on separated flows.

Beginning with disperse horizontal flow, it is noted that there exists a substantial body of data relating to the frictional losses or pressure gradient, $(-dp/ds)$, in a straight pipe of circular cross-section (the coordinate s is measured along the axis of the pipe). Clearly $(-dp/ds)$ is a critical factor in the design of many systems (for example slurry pipelines). This pressure gradient is usually non-dimensionalized using the pipe diameter, d, the density of the continuous phase (ρ_C), and either the total volumetric flux, j, or the volumetric flux of the continuous fluid (j_C). Thus, commonly used friction coefficients are

$$C_f = \frac{d}{2\rho_C j_C^2}\left(-\frac{dp}{ds}\right) \quad \textbf{or} \quad C_f = \frac{d}{2\rho_C j^2}\left(-\frac{dp}{ds}\right) \tag{1}$$

and, in parallel with the traditional Moody diagram for single phase flow, these friction coefficients are usually presented as functions of a Reynolds number for various mixture ratios as characterized by the volume fraction, α, or the volume quality, β, of the disperse phase. Commonly used Reynolds numbers are based on the pipe diameter, the viscosity of the continuous phase (ν_C) and either the total volumetric flux, j, or the volumetric flux of the continuous phase, j_C. For boiling flows or for gas/liquid flows, the reader is referred to the reviews of Hsu and Graham (1976) and Collier and Thome (1994). For a review of slurry pipeline data the reader is referred to Shook and Roco (1991) and Lazarus and Neilsen (1978). For the solids/gas flows associated with the pneumatic conveying of solids, Soo (1983) provides a good summary.