6.2.5 Limits of disperse flow regimes

In order to determine the limits of a disperse phase flow regime, it is necessary to identify the dominant processes enhancing separation and those causing dispersion. By far the most common process causing phase separation is due to the difference in the densities of the phases and the mechanisms are therefore functions of the ratio of the density of the disperse phase to that of the continuous phase. Then the buoyancy forces caused either by gravity or, in a non-uniform or turbulent flow by the Lagrangian fluid accelerations will create a relative velocity between the phases that may lead to phase separation.

While the primary mechanism of phase separation in a quiescent multiphase mixture is sedimentation, in flowing mixtures the mechanisms are more complex and, in most applications, are controlled by a balance between the buoyancy/gravity forces and the hydrodynamic forces. In high Reynolds number, turbulent flows, the turbulence can cause either dispersion or segregation. Segregation may occur when, for example, solid particles suspended in a gas flow are centrifuged out of the more intense turbulent eddies and collect in the shear zones in between (see for example, Squires and Eaton 1990, Elghobashi and Truesdell 1993) or when bubbles in a liquid collect in regions of low pressure such as in the wake of a body or in the centers of vortices (see for example Pan and Banerjee 1997). Counteracting these separation processes are dispersion processes and in many engineering contexts the principal dispersion is caused by the turbulent or other unsteady motions in the continuous phase. The shear created by unsteady velocities can also cause either fission or fusion of the disperse phase bubbles or drops. Quantitative evaluation of these competing forces of segregation and dispersion can lead to criteria determining the boundary between separated and disperse flow in a flow regime map (see, for example, Brennen 2005).

As a postscript, note from the above that an evaluation of the disperse flow separation process will normally require knowledge of the bubble or droplet size and this is not usually known, *a priori*. This is a serious complication because the size of the bubbles or drops is often determined by the flow itself since the flow shear tends to cause fission of those bubbles or drops and therefore limit the maximum size of the surviving bubbles or drops. Then the flow regime may depend upon the particle size that in turn depends on the flow and this two-way interaction can be difficult to unravel. When the bubbles or drops are very small, a variety of forces may play a role in determining the effective size. However, often the bubbles or drops are sufficiently large that the dominant force resisting fission is due to surface tension while the dominant force promoting fission is the shear in the flow. Typical regions of high shear occur in boundary layers, in vortices or in turbulence. Frequently, the larger drops or bubbles are fissioned when they encounter regions of high shear and do not subsequently coalesce to any significant degree. For further analyses and criteria the reader is referred to Mandhane *et al.* (1974), Taitel and Dukler (1976), and Brennen (2005).