

Flow Pattern Classifications

One of the most fundamental characteristics of a multiphase flow pattern is the extent to which it involves global separation of the phases or components. At the two ends of the spectrum of separation characteristics are those flow patterns that are termed *disperse* and those that are termed *separated*. A *disperse* flow pattern is one in which one phase or component is widely distributed as drops, bubbles, or particles in the other *continuous* phase. On the other hand, a *separated* flow consists of separate, parallel streams of the two (or more) phases. Even within each of these limiting states there are various degrees of component separation. The asymptotic limit of a disperse flow in which the disperse phase is distributed as an infinite number of infinitesimally small particles, bubbles, or drops is termed a *homogeneous* multiphase flow. As discussed in sections (Nej) and (Nla) this limit implies zero relative motion between the phases. However, there are many practical disperse flows, such as bubbly or mist flow in a pipe, in which the flow is quite disperse in that the particle size is much smaller than the pipe dimensions but in which the relative motion between the phases is significant.

Within separated flows there are similar gradations or degrees of phase separation. The low velocity flow of gas and liquid in a pipe that consists of two single phase streams can be designated a *fully separated* flow. On the other hand, most annular flows in a vertical pipe consist of a film of liquid on the walls and a central core of gas that contains a significant number of liquid droplets. These droplets are an important feature of annular flow and therefore the flow can only be regarded as partially separated.

To summarize: one of the basic characteristics of a flow pattern is the degree of separation of the phases into streamtubes of different concentrations. The degree of separation will, in turn, be determined by (a) some balance between the fluid mechanical processes enhancing dispersion and those causing segregation, or (b) the initial conditions or mechanism of generation of the multiphase flow, or (c) some mix of both effects. In the section (Njf) we shall discuss the fluid mechanical processes referred to in (a).

A second basic characteristic that is useful in classifying flow patterns is the level of intermittency in the volume fraction. Examples of intermittent flow patterns are slug flows in both vertical and horizontal pipe flows and the occurrence of interfacial waves in horizontal separated flow. The first separation characteristic was the degree of separation of the phases between streamtubes; this second, intermittency characteristic, can be viewed as the degree of periodic separation in the streamwise direction. The slugs or waves are kinematic or concentration waves (sometimes called continuity waves) and a general discussion of the structure and characteristics of such waves is contained in section (Nrg). Intermittency is the result of an instability in which kinematic waves grow in an otherwise nominally steady flow to create significant streamwise separation of the phases.

In the rest of this chapter we describe how these ideas of cross-streamline separation and intermittency can lead to an understanding of the limits of specific multiphase flow regimes. The mechanics of limits on disperse flow regimes are discussed first in sections (Njf), (Nfg), (Njj) and (Njk). Limits on separated flow regimes are outlined in sections (Njo), (Njp) and (Njq).