Introduction to Homogeneous Flows

In this chapter we shall be concerned with the dynamics of multiphase flows in which the relative motion between the phases can be neglected. It is clear that two different streams can readily travel at different velocities, and indeed such relative motion is an implicit part of the study of separated flows. On the other hand, it is clear from the results of section (Nej) that any two phases could, in theory, be sufficiently well mixed and therefore the disperse particle size sufficiently small so as to eliminate any significant relative motion. Thus the asymptotic limit of truly homogeneous flow precludes relative motion. Indeed, the term homogeneous flow is sometimes used to denote a flow with negligible relative motion. Many bubbly or mist flows come close to this limit and can, to a first approximation, be considered to be homogeneous. In the present chapter some of the properties of homogeneous flows will be considered.

In the absence of relative motion the governing mass and momentum conservation equations for inviscid, homogeneous flow reduce to the single-phase form,

$$\frac{\partial \rho}{\partial t} + \frac{\partial}{\partial x_j}(\rho u_j) = 0 \tag{Nla1}$$

$$\rho \left[\frac{\partial u_i}{\partial t} + u_j \frac{\partial u_i}{\partial x_j} \right] = -\frac{\partial p}{\partial x_i} + \rho g_i \tag{Nla2}$$

where, as before, ρ is the mixture density given by equation (Nac8). As in single-phase flows the existence of a barotropic relation, $p = f(\rho)$, would complete the system of equations. In some multiphase flows it is possible to establish such a barotropic relation, and this allows one to anticipate (with, perhaps, some minor modification) that the entire spectrum of phenomena observed in single-phase gas dynamics can be expected in such a two-phase flow. In this chapter we shall not dwell on this established body of literature. Rather, attention will be confined to the identification of a barotropic relation (if any) and focused on some flows in which there are major departures from the conventional gas dynamic behavior.

From a thermodynamic point of view the existence of a barotropic relation, $p = f(\rho)$, and its associated sonic speed,

$$c = \left(\frac{dp}{d\rho} \right)^{\frac{1}{2}} \tag{Nla3}$$

implies that some thermodynamic property is considered to be held constant. In single-phase gas dynamics this quantity is usually the entropy or, occasionally, the temperature. In multiphase flows the alternatives are neither simple nor obvious. In single-phase gas dynamics it is commonly assumed that the gas is in thermodynamic equilibrium at all times. In multiphase flows it is usually the case that the two phases are *not* in thermodynamic equilibrium with each other. These are some of the questions that must be addressed in considering an appropriate homogeneous flow model for a multiphase flow. We begin in the next section by considering the sonic speed of a two-phase or two-component mixture.