Introduction to Kinematic Waves

The one-dimensional theory of sedimentation was introduced in a classic paper by Kynch (1952), and the methods he used have since been expanded to cover a wide range of other multiphase flows. In sections (Nq) we introduced the concept of drift flux models and showed how these can be used to analyse and understand a class of steady flows in which the relative motion between the phases is determined by external forces and the component properties. The present chapter introduces the use of the drift flux method to analyse the formation, propagation and stability of concentration (or kinematic) waves. For a survey of this material, the reader may wish to consult Wallis (1969).

The general concept of a kinematic wave was first introduced by Lighthill and Whitham (1955) and the reader is referred to Whitham (1974) for a rigorous treatment of the subject. Generically, kinematic waves occur when a functional relation connects the fluid density with the flux of some physically conserved quantity such as mass. In the present context a kinematic (or concentration) wave is a gradient or discontinuity in the volume fraction, α. We will refer to such gradients or discontinuities as local *structure* in the flow; only multiphase flows with a constant and uniform volume fraction will be devoid of such structure. Of course, in the absence of any relative motion between the phases or components, the structure will simply be convected at the common velocity in the mixture. Such flows may still be non-trivial if the changing density at some Eulerian location causes deformation of the flow boundaries and thereby creates a dynamic problem. But we shall not follow that path here. Rather this chapter will examine, the velocity of propagation of the structure when there is relative motion between the phases. Then, inevitably, the structure will propagate at a velocity that does not necessarily correspond to the velocity of either of the phases or components. Thus it is a genuinely propagating wave. When the pressure gradients associated with the wave are negligible and its velocity of propagation is governed by mass conservation alone, we call the waves *kinematic* to help distinguish them from the *dynamic* waves in which the primary gradient or discontinuity is in the pressure rather than the volume fraction.