

6 Hindered systems and rheology

On increasing the particle concentration from the low values considered in the previous chapter, the system properties will change considerably from those of the continuous phase, usually water, and the individual particles. In settling, the presence of a large number of fine particles will *hinder* the fall of the larger particles and the very small particles will be dragged down more quickly than under free settling. There is an important question to be considered in our treatment of high concentration suspensions: are we interested in the behaviour of the particles compared to the continuous phase, such as during hindered settling, or the behaviour of the suspension as a new homogeneous phase, such as during pumping of a mixture? The latter is the concern of buoyancy, viscosity and rheology and is considered in the later sections. Initially, the settling of particles within a continuous phase will be considered. Another fundamental concern is the particle concentration at which hindered systems are appropriate, rather than the models discussed in the previous chapter. In general, hindered settling is appropriate when the particle concentration is greater than about 1% by mass. To describe concentrated suspensions we will need to use some of the definitions from Chapter 3. An illustration of porosity and solid concentration by volume fraction is reprinted in Figure 6.1.

The industrial equipment in which hindered settling is conducted is simply tanks, which may be operated batch-wise or continuously. Settling is a cheap method of concentrating solids, the driving potential for it is free (gravity), but it provides only a limited final solid concentration and the process is slow. However, it is very often used in *thickening* a suspension before a more capital intensive operation, such as filtration. The design of industrial thickeners is covered in Section 6.3.

6.1 Hindered settling and zone theory

One method to ascertain if a suspension is settling in the hindered settling regime is to mix the suspension thoroughly and to watch it settle in a laboratory measuring cylinder. If an interface between the settling suspension and clearer residual liquid is apparent, then the settling is within the hindered settling regime. It may be possible to observe the rate of descent of the interface with time, as illustrated in Figure 6.2. Below the settling interface exists a porous medium, similar to that illustrated in Figure 6.1. If it were possible to turn the measuring cylinder upside-down, without everything falling out, then the liquid velocity upwards, required to keep the settling interface stationary, would be the same as the superficial velocity illustrated in Figure 6.1. Hence, the settling velocity is the same as the superficial velocity and we can justifiably use the symbol U_o for both.

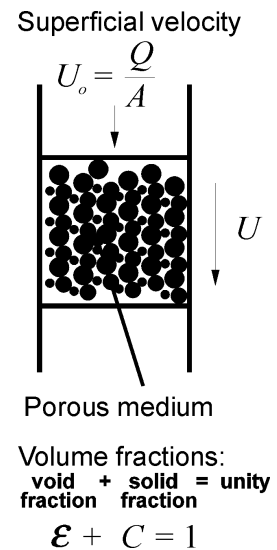


Fig. 6.1 Illustration of porous medium - including settling suspension

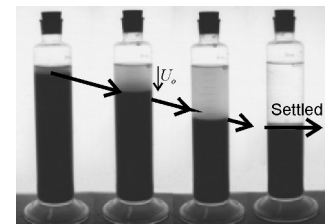


Fig. 6.2 Hindered settling in cylinders - interface fall with time