3 Fluid flow in porous media

In Chapter 2 we considered how to represent a particle size distribution by, where possible, a single term that is representative of all the particle sizes. This term may then be used for modelling, design or simply to understand a process within Particle Technology. One such example is in the fluid flow through a porous medium, or porous media (plural). There are a number of practical applications of fluid flow, including filtration, flow in a packed column, permeation of water, or oil, within the matrix of a porous rock, etc. Before discussing the consequences of our choice of a single value to represent the distribution, and the appropriate modelling equations, we must define the commonly used terms.

3.1 Definitions

By definition, a porous medium consists of pores between some particulate phase, contained within a vessel, or some control volume, as illustrated in Figure 3.1. The fluid flow rate through the bed is Q ($\mathrm{m^3\,s^{-1}}$) and the bed cross sectional area is A ($\mathrm{m^2}$). Thus the superficial (or empty tube) velocity U_0 is the total flow rate divided by the cross sectional area. The existence of the particles within the bed will reduce the area available for fluid flow; i.e. to preserve fluid continuity with the entering superficial flow the fluid will have to squeeze through a smaller area; hence the velocity *within* the bed (U – interstitial velocity) will be greater than the superficial. In Particle Technology calculations it is the volume fraction that is most important, and not the mass fraction. The volume fraction of solids present (i.e. volume solids in bed divided by total bed volume) is usually referred to simply as the *volume concentration*, or solids fraction, and the remaining fraction is that of the voids. The void fraction is also called the *voidage* and the bed *porosity*. It is important to realise that, in liquid systems, the voids are usually filled with liquid and not to assume that the bed consists of just solids and air. The porosity is usually an isotropic property (i.e. the same in all directions); hence, the interstitial velocity is simply related to the superficial velocity by the following expression, which comes from a consideration of fluid continuity.

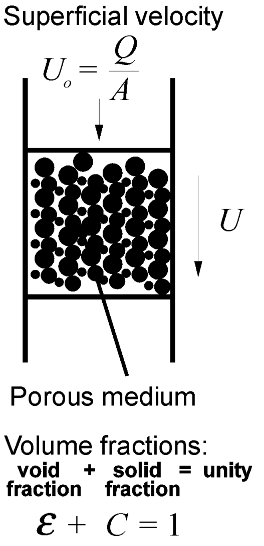

Fig. 3.1 Illustration of fluid flow through a porous medium and consideration of the volume fractions present

$$U = \frac{U_0}{\varepsilon} \tag{3.1}$$

Clearly, the resistance to fluid flow through the porous medium is related to the amount of particles present, or volume concentration, but it is conventional to work in terms of bed porosity. At one extreme, when the bed is full of solids (porosity is zero – possible with cubic particles placed carefully within the bed) the resistance is infinite. At the other, when no solids are present and the porosity is unity, the interstitial velocity will be the same as the superficial velocity. The resistance to fluid flow gives rise to a pressure drop in

exercise 3.1
Using continuity:
i.e. Q = constant,
deduce equation (3.1)