8 Centrifugal separation

The basic equations for most centrifugal modelling were introduced in Chapter 5. The liquid drag force was given in equation (5.4), under streamline flow, and the centrifugal field force was provided in equation (5.18). It is a simple matter to equate these to arrive at an analogue equation to the terminal settling velocity, equation (5.5), but with one significant difference

$$\frac{dr}{dt} = \frac{x^2(\rho_s - \rho)r\omega^2}{18\mu} \tag{8.1}$$

the distance with time differential is not constant. In a centrifugal field the particle moves radially, see Figure 8.1 and equation (5.18), and the radial position is part of the field force – hence the particle accelerates during its travel in the radial direction. Thus, to determine the particle position as a function of time integration is required.

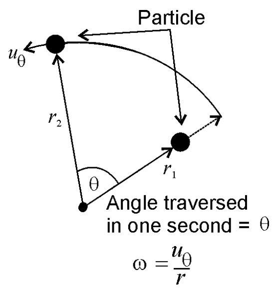

Fig. 8.1 Particle in rotation and definitions

It is well known that from a strict physical definition of forces on a particle, in circular motion, the *centripetal* force and not the centrifugal force should be considered. An unrestrained particle would leave its orbit tangentially if the centripetal force was suddenly removed. This is what happens with particles in cyclone separation from gases and this is discussed further in Chapter 14. However, this chapter is concerned with separation of particles in rotating flow within a viscous medium, usually water. The particle will not travel tangentially to one orbit, but to lots of orbits, giving the impression of radial movement outwards (provided the particle is denser than the surrounding continuous phase). Mathematically, we can use the well-known expressions, such as equations (5.18) and (8.1), to describe this travel.

Buoyancy
If a particle floats, rather than sinks, then it will move inwards in a centrifugal field. Particles denser than the fluid will move outwards. The centrifugal field acts like an enhanced gravitational field in equation (5.3) and it is usual to speak in terms of the equivalent 'g' force: i.e. centrifugal acceleration / 9.81 m s^{-2}.

As illustrated in Figure 8.1, the centrifugal acceleration is simply the product of the radial position (r) and the square of the angular velocity (ω). The SI units of angular velocity are s^{-1}, but calculated by converting from revs per minute (rpm) into radians per second – then ignoring the dimensionless radian term. In solid body rotation, such as a centrifuge, this is easily calculated from the rotational speed, usually provided in rpm. Thus, 1 rpm is 2π s^{-1} as an angular velocity. In free body rotation, such as the hydrocyclone, the angular velocity is calculated from the tangential velocity (u_θ) by

$$\omega = \frac{u_\theta}{r} \tag{8.2}$$

this is also illustrated on Figure 8.1. In the hydrocyclone the principle known as *the conservation of angular momentum* is used; in which knowledge of the tangential velocity at any radial position can be used to calculate the tangential velocity at another because

$$u_{\theta 1}r_1 = u_{\theta 2}r_2 = \text{constant} \tag{8.3}$$