Magnitude of Relative Motion

Qualitative estimates of the magnitude of the relative motion in multiphase flows can be made from the analyses of the last section. Consider a general steady fluid flow characterized by a velocity, U, and a typical dimension, ℓ; it may, for example, be useful to visualize the flow in a converging nozzle of length, ℓ, and mean axial velocity, U. A particle in this flow will experience a typical fluid acceleration (or effective g) of U^2/ℓ for a typical time given by ℓ/U and hence will develop a velocity, W, relative to the fluid. In many practical flows it is necessary to determine the maximum value of W (denoted by W_m) that could develop under these circumstances. To do so, one must first consider whether the available time, ℓ/U, is large or small compared with the typical time, t_u, required for the particle to reach its terminal velocity as given by equation (Nei2) or (Nei11). If $t_u \ll \ell/U$ then W_m is given by equation (Nei3), (Nei7) or (Nei12) for W_∞ and qualitative estimates for W_m/U would be

$$\left(1-\frac{m_p}{\rho_C v}\right)\left(\frac{UR}{\nu_C}\right)\left(\frac{R}{\ell}\right) \quad \text{and} \quad \left(1-\frac{m_p}{\rho_C v}\right)^{\frac{1}{2}}\frac{1}{C_D^{\frac{1}{2}}}\left(\frac{R}{\ell}\right)^{\frac{1}{2}} \qquad \text{(Nej1)}$$

when $WR/\nu_C \ll 1$ and $WR/\nu_C \gg 1$ respectively. We refer to this as the *quasistatic regime*. On the other hand, if $t_u \gg \ell/U$, W_m can be estimated as $W_\infty \ell/Ut_u$ so that W_m/U is of the order of

$$\frac{2(1-m_p/\rho_C v)}{(1+2m_p/\rho_C v)} \qquad \text{(Nej2)}$$

for all WR/ν_C. This is termed the *transient regime*.

In practice, WR/ν_C will not be known in advance. The most meaningful quantities that can be evaluated prior to any analysis are a Reynolds number, UR/ν_C, based on flow velocity and particle size, a size parameter

$$X = \frac{R}{\ell}|1-\frac{m_p}{\rho_C v}| \qquad \text{(Nej3)}$$

and the parameter

$$Y = \,|\,1-\frac{m_p}{\rho_C v}\,|/(1+\frac{2m_p}{\rho_C v}) \qquad \text{(Nej4)}$$

The resulting regimes of relative motion are displayed graphically in figure 1. The transient regime in the upper right-hand sector of the graph is characterized by large relative motion, as suggested by equation (Nej2). The quasistatic regimes for $WR/\nu_C \gg 1$ and $WR/\nu_C \ll 1$ are in the lower right- and left-hand sectors respectively. The shaded boundaries between these regimes are, of course, approximate and are functions of the parameter Y, that must have a value in the range $0 < Y < 1$. As one proceeds deeper into either of the quasistatic regimes, the magnitude of the relative velocity, W_m/U, becomes smaller and smaller. Thus, homogeneous flows (see section (Nl)) in which the relative motion is neglected require that *either* $X \ll Y^2$ *or* $X \ll Y/(UR/\nu_C)$. Conversely, if either of these conditions is violated, relative motion must be included in the analysis.

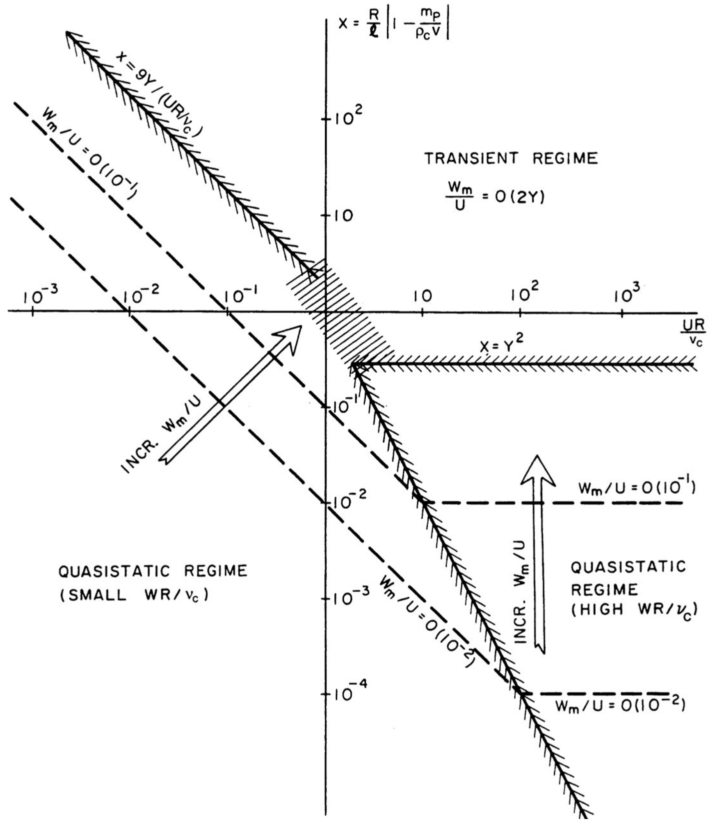

Figure 1: Schematic of the various regimes of relative motion between a particle and the surrounding flow.