Particle Size and Particle Fission

In the preceding sections, the transition criteria determining the limits of the disperse flow regime included the particle, bubble or drop size or, more specifically, the dimensionless parameter $2R/d$ as illustrated by the criteria of equations (Njg3), (Njg4), and (Njg7). However, these criteria require knowledge of the size of the particles, $2R$, and this is not always accessible particularly in bubbly flow. Even when there may be some knowledge of the particle or bubble size in one region or at one time, the various processes of fission and fusion need to be considered in determining the appropriate $2R$ for use in these criteria. One of the serious complications is that the size of the particles, bubbles or drops is often determined by the flow itself since the flow shear tends to cause fission and therefore limit the maximum size of the surviving particles. Then the flow regime may depend upon the particle size that in turn depends on the flow and this two-way interaction can be difficult to unravel. Figure 1, section (Njf) illustrates this problem since one can observe many smaller bubbles in the flow near the suction surface and in the wake that clearly result from fission in the highly sheared flow near the suction surface. Another example from the flow in pumps is described in the next section.

When the particles are very small, a variety of forces may play a role in determining the effective particle size and some comments on these are included later in section (Njl). But often the bubbles or drops are sufficiently large that the dominant force resisting fission is due to surface tension while the dominant force promoting fission is the shear in the flow. We will confine the present discussion to these circumstances. Typical regions of high shear occur in boundary layers, in vortices or in turbulence. Frequently, the larger drops or bubbles are fissioned when they encounter regions of high shear and do not subsequently coalesce to any significant degree. Then, the characteristic force resisting fission would be given by SR while the typical shear force causing fission might be estimated in several ways. For example, in the case of pipe flow the typical shear force could be characterized by $\tau_w R^2$. Then, assuming that the flow is initiated with larger particles that are then fissioned by the flow, we would estimate that $R = S/\tau_w$. This will be used in the next section to estimate the limits of the bubbly or mist flow regime in pipe flows.

In other circumstances, the shearing force in the flow might be described by $\rho_C(\dot{\gamma}R)^2R^2$ where $\dot{\gamma}$ is the typical shear rate and ρ_C is the density of the continuous phase. This expression for the fission force assumes a high Reynolds number in the flow around the particle or explicitly that $\rho_C\dot{\gamma}R^2/\mu_C \gg 1$ where μ_C is the dynamic viscosity of the continuous phase. If, on the other hand, $\rho_C\dot{\gamma}R^2/\mu_C \ll 1$ then a more appropriate estimate of the fission force would be $\mu_C\dot{\gamma}R^2$. Consequently, the maximum particle size, R_m, one would expect to see in the flow in these two regimes would be

$$R_m = \left\{\frac{S}{\mu_C\dot{\gamma}}\right\} \quad \text{for} \quad \rho_C\dot{\gamma}R^2/\mu_C \ll 1$$

$$\underline{\text{or}} \quad \left\{\frac{S}{\rho_C\dot{\gamma}^2}\right\}^{\frac{1}{3}} \quad \text{for} \quad \rho_C\dot{\gamma}R^2/\mu_C \gg 1 \qquad \text{(Njh1)}$$

respectively. Note that in both instances the maximum size decreases with increasing shear rate.