Void Fraction Calculations

Take the averaging volume as V, the number density as n

$$V_g := \frac{4}{3} \cdot n \cdot \pi \cdot r^3 \cdot V$$

$$V_l := V - V_g$$

$$\alpha := \frac{V_g}{(V_g + V_l)}$$

$$\alpha = \frac{4}{3} \cdot n \cdot \pi \cdot r^3$$

$$V := A \cdot l$$

$$n_{bub} := \frac{3}{4} \cdot \frac{\alpha}{(\pi \cdot r^3)}$$

$$n_{drop} := \frac{3}{4} \cdot \frac{1 - \alpha}{(\pi \cdot r^3)}$$

Fraction of area blocked from view by droplets over length l is: $n_{drop} \cdot \pi \cdot r^2 \cdot \frac{V}{A} \rightarrow$ ▪

Distance at which this fraction goes to 1.0 is:

$$\frac{3}{4} \cdot \frac{(1 - \alpha)}{r} \cdot l = 1$$

$$\frac{1}{\left[\frac{3}{(4 \cdot r)} - \frac{3}{(4 \cdot r)} \cdot \alpha\right]}$$

$$\frac{4}{3} \cdot \frac{r}{(1 - \alpha)}$$

$$\frac{4}{3} \cdot \frac{r}{(1 - \alpha)} = l$$

The void fraction as a function of distance and droplet diameter for this relation is:

$$\frac{1}{3}\cdot\frac{(-4\cdot r + 3\cdot l)}{l}$$

$$\frac{-1}{3}\cdot\frac{(4\cdot r - 3\cdot l)}{l} \qquad 1 - \frac{4}{3}\cdot\frac{r}{l}$$

Example: a rain storm with quarter inch drops and 1000 feet visibility

$$r := \frac{1}{4}\cdot in$$

$$l := 1000\cdot ft$$

$$\alpha := 1 - \frac{4}{3}\cdot\left(\frac{r}{l}\right)$$

$$\alpha = 0.9999722222$$

Example: void fraction of bubbles just touching

$$r := 1\cdot mm$$

$$V_g := \frac{4}{3}\cdot\pi\cdot r^3$$

$$V := (2\cdot r)^3$$

$$\alpha := \frac{V_g}{V}$$

$$\alpha = 0.524$$

Example: Void Fraction when Droplets are separated at surface by one diameter

$$V := (4\cdot r)^3$$

$$V_g := V - \frac{4}{3}\cdot\pi\cdot r^3$$

$$\alpha := \frac{V_g}{V}$$

$$\alpha = 0.935$$

A void fraction of 0.75 is often taken as the beginning of the pure droplet flow regime. Separation as a multiple of the drop diameter at this void fraction can be calculated quickly as:

$$\left[\frac{\frac{4}{3}\cdot\pi}{2^3\cdot(1. - .75)}\right]^{\frac{1}{3}} = 1.279$$

This tight packing tells us that laws for interfacial drag will be quite complex. Simple relations for drag on an isolated sphere are completely inadequate.