Cyclone Separator

Cyclones are used for removal of particles with diameter more than a few microns from gases. Gas enters from the side and acquires a rotational speed. Particles are moved towards the wall due to centrifugal forces.

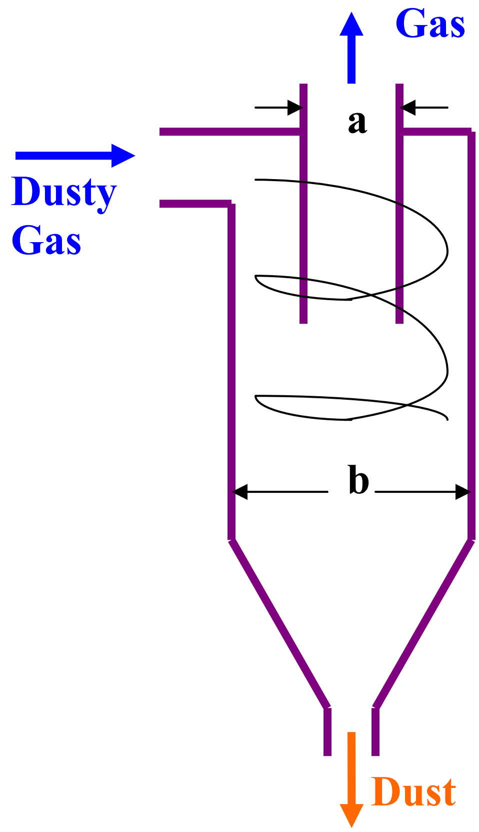

Figure 1. Schematic diagram of a cyclone.

Radial force balance for a particle in the rotating flow in a cyclone is given as

$$m\left[\frac{d^2r}{dt^2} - r\left(\frac{d\theta}{dt}\right)^2\right] = F_r = -3\pi\mu d(v_r^p - v_r^f) \tag{1}$$

For small particles, $\frac{d^2r}{dt^2}$ is small and may be neglected. Neglecting also v_r^f, it follows that

$$v_r^p = \frac{dr}{dt} = \frac{mr}{3\pi\mu d}\left(\frac{d\theta}{dt}\right)^2 \tag{2}$$

or

$$\frac{dr}{d\theta} = \frac{m}{3\pi\mu d}\left(r\frac{d\theta}{dt}\right) = \frac{mv_\theta^p}{3\pi\mu d}, \tag{3}$$

where $\frac{dr}{dt} = \frac{dr}{d\theta}\frac{d\theta}{dt}$ is used.

It is assumed that

$$v_\theta^p \approx v_\theta^f. \tag{4}$$

Equation (3) then becomes

$$\frac{3\pi\mu d}{m}\frac{dr}{v_\theta^f} = d\theta, \tag{5}$$

or

$$\theta = \frac{3\pi\mu d}{m}\int\frac{dr}{v_\theta^f}. \tag{6}$$

The number of turns needed to deposit the particles of size d (that is, moving the particles from the radius a to the side wall at r=b) is given by

$$N_t = \frac{\theta}{2\pi} = \frac{3\mu d}{2m}\int_a^b \frac{dr}{v_\theta^f}, \tag{7}$$

or

$$N_t = \frac{9\mu}{\pi d^2 \rho^p}\int_a^b \frac{dr}{v_\theta^f}. \tag{8}$$

Alternatively, the smallest particle that can be removed in N_t turns is given by

$$d_{min} = [\frac{9\mu}{\pi \rho^p N_t}\int_a^b \frac{dr}{v_\theta^f}]^{1/2}. \tag{9}$$

In practice, an approximate expression

$$d_{min} \sim [\frac{\mu(b-a)}{\rho^p N_t U}]^{1/2}, \tag{10}$$

is used, where U is the mean inlet velocity.