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.

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

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

(1)

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

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

(2)

or

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

(3)

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

It is assumed that

$$v_0^p \approx v_0^f.$$  

(4)

Equation (3) then becomes

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

(5)

or

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

(6)

Figure 1. Schematic diagram of a cyclone.
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

\[
N_1 = \frac{\theta}{2\pi} = \frac{3\mu d}{2m} \int_a^b \frac{dr}{v_0 r},
\]

or

\[
N_1 = \frac{9\mu}{\pi^2 \rho^p} \int_a^b \frac{dr}{v_0 r}. \tag{7}
\]

Alternatively, the smallest particle that can be removed in \(N_1\) turns is given by

\[
d_{\min} = \left[\frac{9\mu}{\pi \rho^p N_1} \int_a^b \frac{dr}{v_0 r}\right]^{1/2}. \tag{8}
\]

In practice, an approximate expression

\[
d_{\min} \sim \left[\frac{\mu(b - a)}{\rho^p N_1 U}\right]^{1/2}, \tag{10}
\]

is used, where \(U\) is the mean inlet velocity.